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# Start here for answers to your immediate triticale crop management issues



What is triticale used for?



Are best management practices for weed control in triticale similar to those for wheat?



Which nematodes are triticale susceptible to?



Is triticale susceptible to frost damage?



How can I best store triticale grain?





**TRITICALE** 





# Tips for triticale cropping

Triticale is a cross that combines the productivity of wheat with the hardiness of cereal rye

#### Frost susceptible

Sow at a similar time to wheat, however, triticale is prone to frost damage adjust sowing according to local conditions.

#### BREAK

Use as a break crop for paddocks with disease or nematode problem Can out-yield wheat on acid soils, in cool high-rainfall areas, in waterlogged paddocks and on low-nutrient soils

**SOUTHERN** 

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Set seeders
25-40% above the
setting for wheat
as triticale grain is
larger than wheat
and because
plants tiller less
than wheat

Take care at harvest – triticale can be prone to SHATTERING





Be aware that marketing triticale can be difficult



Triticale has soft grain – makes sure storage is free from insect pests





TABLE OF CONTENTS



# **Contents**

#### Introduction

<b>A</b> .1	Cro	p overview	xx
	A.1.1	Triticale for human consumption	xxi
	A.1.2	Triticale for animal consumption	xxiv
	A.1.3	Triticale for biofuel	XX\
Α.:	2 Gro	owing regions	xxv
Α.:	3 Bri	ef history	xxvi
	A.3.1	Triticale in Australia	xxvi
4			
1	Pič	anning/Paddock preparation  Key messages	
4.4	D		
1.1		ddock selection	
	1.1.1	Topography	
	1.1.2	Soil	2
		The impact of different soil moisture and soil compaction on the growth of triticale root systems	3
		Soil pH	
	1.1.3	Sampling soil quality	
	0	Sampling strategy	
		Sampling equipment	
		Sampling depth	8
		Sample handling	8
	1.1.4	Biological inputs	8
		Yield constraints in the Southern Region	8
	1.1.5	Paddock selection for forage cereals	8
	1.1.6	Weed burden and herbicide history	S
	1.1.7	Fallow moisture and management	S
1.2	Pac	dock rotation and history	9
	1.2.1	Triticale as a rotation crop	10
		Benefits of cereals as a rotation crop	1
		Disadvantages of cereals as a rotation crop	1
	1.2.2	Break cropping	12
	1.2.3	Long-fallow disorder	13
1.3	Fal	low weed control	13
		Summer fallow weed control and residue management impacts on	
		winter crop yield through soil water and N accumulation in a winter-	
	46:	dominant low rainfall region of southern Australia	
	1.3.1	The green bridge	
	1.3.2	Management strategies	
	1.3.3	Stubble retention	
		Reducina erosion risk	17











		Increasing soil water content	1/
		Increasing soil carbon	18
		Other benefits of stubble retention	18
		Management practices affecting stubble cover	18
1.4	Fal	low chemical plant-back effects	19
		Plant-back periods for fallowing herbicides	20
	1.4.1	Herbicide residues in soil: an Australia-wide study	22
1.5	See	edbed requirements	23
	1.5.1	Structural decline of seedbed soil	25
		Background	25
		Management to improve seedbed soil structure	25
	1.5.2	Tillage	26
		Tillage, microbial biomass and soil biological fertility	27
1.6	Soi	l moisture	30
	1.6.1	Dryland	30
		Soil-water extraction by dryland crops, annual pastures and lucerne	
		in south-eastern Australia	
		Monitoring soil moisture in dryland areas	31
	1.6.2	Irrigation	32
		Genetic improvement of triticale for irrigation in south-eastern Australia	33
		The future of irrigation	34
1.7	Yie	ld and targets	34
		Triticale v. durum wheat: a yield comparison in Mediterranean-type environm	
		Estimating crop yields	
		Yield Prophet®	
	1.7.1	Seasonal outlook	
		CliMate	
		Climate Analogues	
	1.7.2	Fallow moisture	
		HowWet/N?	
	1.7.3	Water Use Efficiency	
		Triticale grain yield and physiological response to water stress	40
	1.7.4	Nitrogen-use efficiency	42
		Optimising nitrogen-use efficiency	42
	1.7.5	Double-crop options	
		Crop sequencing for irrigated double cropping in the Murrumbidgee Valley	43
1.8	Dis	ease status of paddock	44
	1.8.1	Testing soil for disease	44
		PreDicta B	44
	1.8.2	Effects of cropping history	45
1.9	Ne	matode status of paddock	46
	1.9.1	Testing soil for nematodes	47
		PreDicta B	47
	1.9.2	Effects of cropping history	47











1.10	) Inse	ect status of paddock	47
	1.10.1	Testing soil for insects	48
		Using a sweep net	49
		Soil sampling by spade	49
		Germinating-seed bait technique	49
		Identifying insects	49
	1.10.2	Effects of cropping history	50
2	Pre	e-planting	
		Key messages	
2.1	Triti	icale as a dual-purpose crop	2
	2.1.1	Benefits of growing dual-purpose or winter-forage crops	2
		1. Minimises risks	
		2. Capitalises on early rainfall	2
		3. Flexibility in enterprise mix	
		4. Improved cash-flow	3
	2.1.2	When to graze	3
		Evaluation of triticale as dual-purpose forage and grain crops	
	2.1.3	Breeding dual-purpose triticale	
	2.1.3	Triticale grain for livestock	
	2.1.5	Triticale as a cover crop	
		Under-sowing lucerne	
2.2	. Var	ietal performance and ratings yield	
	2.2.1	Varieties	
		New: Astute()	10
		Berkshire()	
		New: Bison(b	
		Bogong():	
		Canobolas()	
		Chopper(b	
		Fusion():	
		Goanna	
		KM10	
		Tahara	
		Yowie	
		Hawkeye()	
		Jaywick()	
	2.2.2	Dual-purpose triticales	
		Endeavour(b	
		Rufus	
		Tobruk(b	
		Tuckerbox	
		Yukuri	
2.3	Pla	nting-seed quality	14
	2.3.1	Seed size	15











	2.3.2	Seed germination and vigour	18
	2.3.3	Seed storage	20
	2.3.4	Safe rates of fertiliser to sow with seed	21
3	Pla	inting	
		Key messages:	1
3.1	Inn	oculation	
3.2		ed treatments	
J		Emergence problems	
		Fertiliser at seeding	
2 2		re of sowing	
3.3	HIM	Lodging	
3.4	Tar	geted plant population	
3.5		culating seed requirements	
3.6		ving depth	
3.7	Sov	ving equipment	11
4	Pla	nt growth and physiology	
		Key Messages:	1
4.1	lde	ntifying triticale	1
4.2	Ger	mination and emergence	3
		Phase 1: Water absorption	3
		Phase 2: Activation	
		Phase 3: Visible germination	
		Conditions of germination	
	4.2.1	Soil moisture	8
4.3		ect of temperature, photoperiod and climate on plant growth and raiology	a
	4.3.1	Temperature	
		·	
		Photoperiod	
	4.3.3	Salinity	
		The affect of salt stress on photosynthetic characteristics and growth of triticale.	
	4.3.4	Drought  The role of stomatal conductance for water and radiation use	10
		efficiency of durum wheat and triticale in a Mediterranean environment	11
		Water stress	
		Triticale grain yield and physiological response to water stress	12
4.4	Pla	nt growth stages	12
	4.4.1	Zadoks scale of cereal growth stages	12
		Zadoks growth key	14
	4.4.2	Germination and early seedling growth	15
	4.4.3	Tillering and vegetative growth	15
	4.4.4	Stem elongation and heading	16
		Flowering and grainfilling	











		Variation in temperate cereals in rain-fed environments	2
5	Nu	trition and fertiliser	
		Key messages	
	5.1.1	Declining soil fertility	2
		Balancing sources of nutrition	
	5.1.2	Fertilisers	
	·	Application	
	5.1.3	Fungi and soil health	
	5.1.5	Management to optimise mycorrhizae	
5.2	Cro	p removal rates	
5.3		testing	
J.J			
	5.3.1	Why test soil?	
		Basic requirements	
		Types of test	
5.4	Pla	nt-tissue testing for nutrition levels	9
	5.4.1	Plant tissue analysis	S
5.5	Nitr	ogen	10
		Responses of triticale, wheat, rye and barley to nitrogen fertiliser	12
	5.5.1	Symptoms of deficiency	14
		What to look for in the paddock	14
		What to look for in the plant	14
		What else it could be	16
	5.5.2	Managing nitrogen	16
		Timing of application	16
		Budgeting	17
5.6	Pho	osphorus	17
		Cereal types and phosphorus use in Waikerie, Murray Mallee	18
	5.6.1	Symptoms of deficiency	20
		What to look for in the paddock	20
		What to look for in the plant	20
		What else it could be	
		Soil testing	
	5.6.2	Managing phosphorus	23
5.7	Sul	fur	24
	5.7.1	Symptoms of deficiency	25
		What to look for in the paddock	25
		What to look for in the plant	
		What else it could be	27
	5.7.2	Managing sulfur	27
		Supplies of sulfur (elemental or sulphate)	27
5.8	Pot	assium	28
	5.8.1	Symptoms of deficiency	29



SOUTHERN JANUARY 2018









		What to look for in the paddock	29
		What to look for in the plant	29
		What else it could be	30
5.8	8.2	Managing potassium	31
		Fertiliser types	31
		Fertiliser placement and timing	31
5.9	Mic	ronutrients	32
5.9	9.1	Manganese	33
		Symptoms of deficiency	
		Managing manganese deficiency	36
5.9	9.2	Copper	36
		Tolerance of triticale, wheat and rye to copper deficiency in low and high so	
		Symptoms of deficiency	37
		Managing copper deficiency	39
5.9	9.3	Zinc	40
		Symptoms of deficiency	40
		Managing zinc deficiency	42
5.9	9.4	Iron	43
		Symptoms of deficiency	43
		Managing iron deficiency	45
5.10	Nut	ritional deficiencies	45
5.1	10.1	Making use of the crop-nutrition information available to you	45
		Useful resources	45
6 1	Ma		45
6 1	We	ed control	
		ed control  Key messages	1
6.1	Wee	ed control  Key messages  ed competitiveness of triticale	1
<b>6.1</b> 6.1	<b>W</b> ee	ed control  Key messages ed competitiveness of triticale  Best management practices for weed control in triticale	1 1
<b>6.1</b> 6.1	<b>W</b> ee	ed control  Key messages  ed competitiveness of triticale	1 1
<b>6.1</b> 6.1 <b>6.2</b>	Wee 1.1 Inte	ed control  Key messages ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management	123
<b>6.1</b> 6.1 <b>6.2</b>	Wee 1.1 Inte	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management	123
<b>6.1</b> 6.1 <b>6.2</b> 6.2	<b>W</b> ee 1.1 <b>Inte</b> 2.1	ed control  Key messages ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management	
<b>6.1</b> 6.1 <b>6.2</b> 6.2	<b>W</b> ee 1.1 <b>Inte</b> 2.1	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.	12333
<b>6.1</b> 6.1 <b>6.2</b> 6.2	<b>W</b> ee 1.1 <b>Inte</b> 2.1	ed control  Key messages	
<b>6.1</b> 6.1 <b>6.2</b> 6.2	<b>W</b> ee 1.1 <b>Inte</b> 2.1	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics.  Review past actions  Assess the current weed status  Identify weed management opportunities.	
<b>6.1</b> 6.1 <b>6.2</b> 6.2	<b>W</b> ee 1.1 <b>Inte</b> 2.1	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics  Review past actions  Assess the current weed status  Identify weed management opportunities.  Fine-tune your list of options	13333
<b>6.1</b> 6.1 <b>6.2</b> 6.2	<b>W</b> ee 1.1 <b>Inte</b> 2.1	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics.  Review past actions  Assess the current weed status  Identify weed management opportunities.	13333
6.1 6.1 6.2 6.3 6.3	Wee 1.1 Inte 2.1 2.2	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics  Review past actions  Assess the current weed status  Identify weed management opportunities.  Fine-tune your list of options	1333456666
6.1 6.1 6.2 6 6 6 6	Wee I.1 Inte 2.1 2.2	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics.  Review past actions  Assess the current weed status  Identify weed management opportunities  Fine-tune your list of options  Combine and test ideas.	13346666
6.1 6.1 6.2 6 6 6 6	Wee I.1 Inte 2.1 2.2	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics  Review past actions  Assess the current weed status  Identify weed management opportunities  Fine-tune your list of options  Combine and test ideas.  IWM in the southern region	1333466666
6.1 6.1 6.2 6 6 6 6	Wee 1.1 Inte 2.1 2.2 Key	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics  Review past actions  Assess the current weed status  Identify weed management opportunities  Fine-tune your list of options  Combine and test ideas.  IWM in the southern region  weeds of Australia's cropping systems	1334566678
6.1 6.2 6.3 6.3	Wee 1.1 Inte 2.1 2.2 Key	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics  Review past actions  Assess the current weed status  Identify weed management opportunities  Fine-tune your list of options  Combine and test ideas.  IWM in the southern region  weeds of Australia's cropping systems  RIM (Ryegrass Integrated Management)	13345666
6.1 6.2 6.3 6.3	Wee 1.1 Inte 2.1 2.2 Key	ed control  Key messages  ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics  Review past actions  Assess the current weed status  Identify weed management opportunities  Fine-tune your list of options  Combine and test ideas.  IWM in the southern region  weeds of Australia's cropping systems  RIM (Ryegrass Integrated Management)  Ryegrass management in the southern region.	
6.1 6.2 6.3 6.3	Wee 1.1 Inte 2.1 2.2 Key	ed control  Key messages ed competitiveness of triticale  Best management practices for weed control in triticale  grated weed management  IWM for triticale  The effect of cultivation and row spacing on the competitiveness of triticale.  General IWM principles and tactics  Review past actions  Assess the current weed status  Identify weed management opportunities  Fine-tune your list of options  Combine and test ideas  IWM in the southern region  weeds of Australia's cropping systems  RIM (Ryegrass Integrated Management)  Ryegrass management in the southern region.  Mouldboard ploughing.	1334666











		Managing brome grass and bariey grass	<i>I</i> 3
	6.3.3	Emerging threat of flaxleaf fleabane	14
		Control strategy	14
	6.3.4	Feathertop Rhodes grass heads south	15
		Fallow control	
		In-crop control	16
	6.3.5	Wild radish resistance	16
6.4	Her	bicides	18
	6.4.1	Herbicides explained	18
		Residual and non-residual herbicides	
		Pre-emergent and post-emergent herbicides	
		Herbicide groups	
6.5	Pre-	emergent herbicides	19
	6.5.1	Benefits and concerns	19
	6.5.2	Understanding pre-emergent herbicides	. 20
		Behaviour of pre-emergent herbicides in the soil	20
	6.5.3	Top tips for using pre-emergent herbicides	21
6.6	Pos	t-planting pre-emergent herbicides	.22
	6.6.1	Incorporation by sowing	. 22
6.7	In-c	rop herbicides: knockdowns and residuals	.24
	6.7.1	Applying in-crop herbicides	. 24
		How to get the most out of post-emergent herbicides	25
	6.7.2	Agricultural Chemical Control Areas	. 25
6.8	Cor	ditions for spraying	. 27
	6.8.1	Minimising spray drift	. 28
	6.8.2	Types of drift	. 29
		Factors in the risk of spray drift	
		Volatility	
	6.8.4	Minimising drift	31
		Spray release height	
		Size of area treated	
		Capture surface	
		Weather conditions to avoid	
6.9		ting for herbicide tolerance	
6.10		ential herbicide damage of triticale	
	6.10.1	Avoiding crop damage from residual herbicides	
		What are the issues?	
		How can I avoid damage from residual herbicides?	
	610.2	Plant-back intervals	
	0.10.2	How does resistance start?	
	610.2	General principles to avoid resistance	
	0.10.3	Octional principles to avoid resistance	+1



SOUTHERN JANUARY 2018









		Giypriosate-resistant weeds in Australia	45
	6.10.4	Ten-point plan to weed out herbicide resistance	44
		1. Act now to stop weed seedset	44
		2. Capture weed seeds at harvest	44
		3. Rotate crops and herbicide modes of action	45
		4. Test for resistance to establish a clear picture of paddock-by-paddock status .	45
		5. Never cut the rate	46
		6. Don't automatically reach for glyphosate	46
		7. Carefully manage spray events	
		8. Plant clean seed into clean paddocks with clean borders	
		9. Use the double-knock technique	
		10. Employ crop competitiveness to combat weeds	
	6.10.5	If you think you have resistant weeds	
		Testing services	48
	6.10.6	Monitoring weeds	48
		Tips for monitoring	49
7	Ins	ect control	
		Key messages	
7.1	Pote	ential insect pests	2
7.2	Inte	grated pest management	5
	7.2.1	Key IPM strategies	
	7.2.2	Insecticide choices	
	7.2.3	Insecticide resistance	
	7.2.4	Insect sampling methods	
		Factors that contribute to quality monitoring	
		Sampling methods	
		Identifying insects	
7.3	Pus	sian wheat aphid	
	7.3.1	Damage caused by RWA	
	7.3.2	Where to look and what to look for	
	700		
		Thresholds for control	
	7.3.4	Management of RWA	
		Control options	
7.4	Aph	ids	17
	7.4.1	Oat or wheat aphid	17
	7.4.2	Corn aphid	. 18
	7.4.3	Rose-grain aphid	18
	7.4.4	Conditions favouring aphid development	. 19
	7.4.5	Thresholds for control	. 20
	7.4.6	Managing aphids	. 20
		Biological control	









	Cultural control	20
	Chemical control	
	Monitoring	21
7.5 Cu	tworm	21
7.5.1	Damage caused by cutworms	23
7.5.2	Thresholds for control	24
7.5.3	Managing cutworm	24
	Biological control	24
	Cultural control	25
	Chemical control	25
7.6 Mit	tes	25
7.6.1	Redlegged earth mite	25
	Damage caused by RLEM	27
	Managing RLEM	27
7.6.2	Balaustium mite	30
	Damage caused by Balaustium mite	31
	Management	31
7.6.3	Blue oat mite	32
	Damage caused by BOM	34
	Managing BOM	35
7.6.4	Bryobia mite	37
	Damage cause by Bryobia mites	39
	Managing Bryobia mites	39
7.7 Luc	cerne flea	39
7.7.1	Damage caused by the lucerne flea	41
7.7.2	Managing the lucerne flea	41
	Biological control	42
	Cultural control	42
	Chemical control	43
7.8 Arr	myworm	43
7.8.1	Damage caused by armyworms	45
7.8.2	Thresholds for control	46
7.8.3	Managing armyworms	46
	Sampling and detection	46
	Biological control	47

 7.9.2 Managing slugs and snails
 50

 Biological control
 50

 Cultural control
 51

 Chemical control
 51

 Monitoring snails
 51



SOUTHERN







EDBACK	
	Monitorina sluas

		Monitoring slugs	52
7.10	) Wir	eworms and false wireworms	53
	7.10.1	False wireworms	53
		Biology	55
		Damage caused by false wireworms	56
	7.10.2	True wireworm	57
		Biology	57
		Damage	58
	7.10.3	Sampling and detection of wireworms	58
		Sampling	58
		Detection	58
	7.10.4	Control	58
7.11	Plag	gue locusts	59
8	Ne	matode management	
		Key messages	1
		Cereal root disease management in Victoria and southern Australia	2
8.1	Roc	ot-lesion nematodes (RLN)	3
	8.1.1	Symptoms	5
		Soil testing	7
	8.1.2	Varietal resistance or tolerance	7
	8.1.3	Damage caused by RLN	7
	8.1.4	Conditions favouring development	8
		How long does it take to reduce P. thornei in soils?	8
	8.1.5	Thresholds for control	9
	8.1.6	Management of RLN	9
8.2	2 Cer	eal cyst nematodes	11
	8.2.1	Symptoms and detection	
	8.2.2	Varietal resistance or tolerance	
		Damage caused by CCN	
		Management	
8.3			
0.5		natodes and crown rot	
	8.3.1	Management	
	022		
		Varietal choice	17
9	Dis	seases	
		Key messages	1
9.1	Ger	neral disease-management strategies	
		Cereal root disease management in the Southern region	2
	9.1.1	Tools for diagnosing cereal diseases	3
		Crop Disease Au app	3
		The app Crop Disease Au, developed by the National Variety Trials, allows the user to quickly:	3



SOUTHERN JANUARY 2018







SOUTHERN JANUARY 2018

<b>9.</b> Z	Rus		
	9.2.1	Varietal resistance or tolerance	5
	9.2.2	Symptoms	6
	9.2.3	Stripe rust	7
		Stripe rust in southern Australia	8
		Managing stripe rust	9
	9.2.4	Stem rust (black rust)	10
		Stem rust in southern Australia	11
	9.2.5	Leaf rust (brown rust)	11
	9.2.6	Managing cereal rust	12
		Breeding cereals for rust resistance in Australia	13
9.3	Yell	ow leaf spot (tan spot)	13
	9.3.1	Varietal resistance	15
	9.3.2	Damage caused by yellow leaf spot	15
	9.3.3	Symptoms	15
		Conditions favouring development	
		Management of disease	
		Minimising the risk of yellow leaf spot	
		In-crop fungicides and timing	17
	9.3.6	Integrated disease management of rusts and yellow leaf spot	18
9.4	Tak	e-all	18
	9.4.1	Symptoms	19
		What to look for in the paddock	19
		What to look for in the plant	20
	9.4.2	Conditions favouring development	21
		Hosts	21
	9.4.3	Managing take-all	22
9.5	Cro	wn rot	22
	9.5.1	Update on the latest research	23
	9.5.2	Damage caused by crown rot	24
	9.5.3	Symptoms of crown rot	25
	9.5.4	Symptoms of Fusarium head blight	27
	9.5.5	Conditions favouring development	28
		Crown rot	28
		FHB	29
	9.5.6	Management	29
		Crop rotation	30
		Variety selection	
		Crop management	
		Cultivation	
		Stubble burning	32







TABLE OF CONTENTS



	Grass-weed management	32
	Sowing time	32
	Row placement	33
	Soil type	33
	Soil testing	33
9.6	Common root rot	34
9.6	.1 Damage caused by disease	34
9.6	.2 Symptoms	34
	What to look for in the paddock	34
	What to look for in the plant	34
9.6	.3 Conditions favouring development	35
9.6	.4 Management	35
9.7	Smut and bunt	35
9.7	1 Bunt or stinking smut	35
	Managing bunt	36
9.7	2 Loose smut	36
	Managing smut	37
9.8 F	Rhizoctonia barepatch	37
9.8	.1 Symptoms	38
	What to look for in the paddock	38
	What to look for in the plant	
	What to look for in the plant	39
9.8	.2 Conditions favouring development	
9.8		41
	.2 Conditions favouring development	41
9.8	.2 Conditions favouring development  Factors affecting Rhizoctonia	41 41 42
9.8	.2 Conditions favouring development	414242
9.8 <b>9.9</b> E	.2 Conditions favouring development	414243
9.8 <b>9.9</b> E	.2 Conditions favouring development	41424243
9.8 <b>9.9 E</b> 9.9	.2 Conditions favouring development	41424343
9.8 <b>9.9 E</b> 9.9	.2 Conditions favouring development	4142434343
9.8 <b>9.9 E</b> 9.9	.2 Conditions favouring development	414243434343
9.8 <b>9.9 E</b> 9.9	.2 Conditions favouring development	41424343434343
9.8 <b>9.9 E</b> 9.9	.2 Conditions favouring development	414243434343434343
9.8 <b>9.9 E</b> 9.9	.2 Conditions favouring development	414243434343434445
9.8 <b>9.9 E</b> 9.9 9.9	.2 Conditions favouring development	41424343434343444545

Reducing water loss.....



SOUTHERN JANUARY 2018









		Fungicides	50
9.1	l Cer	eal fungicides	51
	9.11.1	Fungicide stewardship	52
9.1	2 Bar	ley yellow dwarf virus	53
		Economic importance	53
	9.12.1	Symptoms	53
	9.12.2	Conditions favouring development	55
	9.12.3	Management	55
		Chemical treatments	56
9.1	3 Dis	ease following extreme weather	56
	9.13.1	Cereal disease after drought	56
	9.13.2	Cereal disease after flood	56
10	Pla	int growth regulators and canopy management	
		Key messages	
10.	1 Plai	nt growth regulators	1
	10.1.1		
	10.1.2	PGRs in Australia	
		Considering mixed results	
	10.1.5	Conclusions: The value of PGRs	
	10.1.4	Case study: Moddus® Evo	4
		Methods	
		Results	4
10.	2 Car	nopy management	5
		What is canopy management?	5
		Canopy management—Inverleigh	7
10.	3 Cer	eal canopy management in a nutshell	9
	10.3.1	Setting up the canopy	10
	10.3.2	Soil moisture status	10
	10.3.3	Soil nitrogen	10
	10.3.4	Seeding rate and date	11
		Row spacing	12
		Yield	
		Plant spacing	
		Dry matter  Grain quality	
		Nitrogen management	
	10 3 5	In-crop nitrogen	
		Limitations of tactical nitrogen application	
			14
11	Cro	op desiccation/spray out	
12	Ha	rvest	
		Key messages	1



SOUTHERN JANUARY 2018







EEDBACK		
	12.1	Harvesting issues

12.1	Har	vesting issues	1
12.2	2 Wir	drowing	. 2
	12.2.1	Timing	3
	12.2.2	Cutting	3
	12.2.3	Harvesting the windrow	4
12.3	3 Har	vest timing	. 4
	12.3.1	Lodging	5
	12.3.2	Harvesting triticale for silage	5
12.4	1 Har	vest equipment	. 6
12.5	5 F	Fire prevention	7
		Harvester fire reduction checklist	
		Harvesting in low-risk conditions	
		eival standards	
		vest weed seed management	
		Harvest weed seed control strategies	
		Narrow windrow burning	
		Chaff Carts	. 12
		Bale direct systems	. 12
		Harrington Seed Destructor	. 12
13	Sto	orage	
		Key messages	1
		GRDC Stored grain information hub	2
13.1	Hov	v to store product on-farm	. 2
	13.1.1	On-farm storage in Tasmania	3
	13.1.2	Silos	5
		Pressure testing	6
		The importance of a gas-tight silo	6
	13.1.3	Grain bags	7
	13.1.4	Hygiene	8
	13.1.5	Insecticide treatment	8
	13.1.6	Monitoring stored grain	8
	13.1.7	Grain storage: get the economics right	9
		Comparing on-farm grain storages	9
13.2	2 Sto	red grain pests	.11
	13.2.1	Prevention is better than cure	12
	13.2.2	Common species	12
		Why identify insect pests of stored grain pests?	. 13
	13.2.3	Monitoring grain for pests	.13
	13.2.4	Hygiene	.14
		Where to clean	. 14
		When to clean	
		How to cloan	15



SOUTHERN JANUARY 2018









13.2.5	Aeration cooling for pest control	17
13.2.6	Structural treatments	17
13.2.7	Application	18
	Silo application	19
13.2.8	Fumigation	19
	Maximum residue limits	
	Phosphine application	21
	Non-chemical treatment options	22
13.3 Gra	in protectants for storage	22
	K-Obiol® EC Combi	22
	Conserve™ On-farm	23
13.4 Aei	ration during storage	23
13.4.1	Dealing with moist grain	23
13.4.2	Aeration cooling	24
	Blending	24
13.4.3	Aeration drying	25
	High airflow for drying	25
	Ducting for drying	26
	Venting for drying	26
	Weather conditions for drying	26
	Phase one of drying	27
	Phase two of drying	
	Supplementary heating	
	Cooling after drying	27
13.4.4	Aeration controllers	27
14 En	vironmental issues	
	Key messages	1
14.1 Fro	st issues for triticale	2
14.1.1	Triticale and frost	4
	Frost tolerance in triticale and other winter cereals at flowering	5
14.1.2	Conditions that lead to frost	
	Diagnosing stem and head frost damage in cereals	
	What to look for in the paddock	
	What to look for in the plant	
14.1.4	Managing frost risk	
	Farm management planning tactics	
	Frost zone management tactics	
	Diversity the key to balancing frost and heat risks	15
14.1.5	New insight into frost events and management	16
	Guidelines to reduce frost risk and assess frost damage	
•	Matching variety to planting opportunity	
	Measuring crop temperature	
14.1.7	What to do with a frosted crop	
	Option 1: Take through to harvest	
	•	











	Option 2: Cut and bale	21
	Option 3: Grazing, manuring and crop-topping	22
	Useful tools	23
14.1.8	National Frost Initiative	23
14.2 Wat	terlogging and flooding issues for triticale	23
14.2.1	Where waterlogging occurs	25
	Constraints and opportunities for crop production in the high-rainfall	
	zone of southern Australia	25
	Identifying problem areas	26
14.2.2	Symptoms and causes	26
	What to look for in the paddock	27
	What to look for in the plant	27
	How waterlogging can be monitored	28
	Other impacts of waterlogging and flood events	28
14.2.3	Managing waterlogging	29
	Draining	29
	Choice of crop species	30
	Seeding rates	30
	Nitrogen fertiliser	30
	Weeds	30
14.3 Oth	er environmental issues	30
14.3.1	Drought and heat stress	31
	Managing drought stress	32
	Managing heat stress	33
14.3.2	Aluminium toxicity	34
15 Ma	rketing	
	Ithern feed grains: market dynamics and execution	4
	Price determinants for feed grains in southern markets	
15.1.2	Converting tonnes into cash	
	How to sell for cash	2
	Counterparty risk	
	Read market signals	
	Know the specifications of your grain	5
15.1.3	Ensuring access to markets	6
	Storage and logistics	6
	Separate delivery and pricing	7
	Cost of carrying grain	7
15.2 Ref	erences	8
16 Cu	rrent and past research	

#### 17 References







## Introduction

#### A.1 Crop overview

Triticale is an established small cereal crop that combines the productivity of wheat with the hardiness of rye. Triticale (genus X *Triticosecale*) was developed by human intervention from crosses between wheat (genus *Triticum*) and rye (genus *Secale*). The grains are longer than wheat seeds and plumper than rye, and colour can range from the tan of wheat to the grey-brown of rye (Photo 1). Triticale has several advantages in Australian conditions: this relatively low input cereal crop has good disease resistance, particularly to rusts. It is a hardy plant, which produces a feed grain as high quality as wheat.

Triticale makes good use of land that is marginal for other cereals. It has been developed to combine the high yield potential and quality of wheat with the adaptability of rye, and it is adapted to a wide range of soil types and environments. Triticale has an aggressive root system that binds light soils better than wheat, barley or oats. Under ideal conditions, researchers have found that triticale can out-yield wheat, barley and sometimes oats. It can out-yield wheat in several situations: on acid soils, in cool high-rainfall areas, and on low-nutrient soils, such as those with low levels of manganese and copper. Triticale is well established as an ingredient in livestock rations.



**Photo 1:** Grains of wheat (left), rye (middle) and triticale (right). Note that triticale grain is significantly larger than wheat grain.

Source: <u>USDA</u>

It is a tall crop bred for strong straw strength, which can be useful in rocky paddocks or circumstances where crops have been known to lodge. Triticale can out-yield barley under good conditions, and its dual purpose use as grain or forage makes it a useful crop for mixed enterprise farms.

Triticale in Australia has a spring growth habit, which means it behaves similarly to most cereal crops, maturing in late spring to early summer. Breeding and selection programs have ensured varieties possess a range of disease and pest characteristics, which can complement disease management for other cereals. It can also carry diseases that may affect other cereal species.

Triticale and wheat are similar crops, but triticale represents a valuable alternative to wheat, due to its greater biomass production and grain yield in Mediterranean-type growing conditions, such as those in parts of southern Australia. 1

Triticale can be less susceptible to the common fungal diseases of cereals, which make it suitable for use in rotations where stubble is retained. Some varieties have



SOUTHERN

<sup>1</sup> S Bassu, S Asseng, F Giunta, R Motzo (2013) Optimizing triticale sowing densities across the Mediterranean Basin. Field Crops Research 144, 167–178.



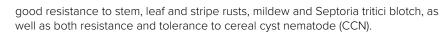






A review of triticale uses and the effect of growth environment on grain quality

Triticale agronomy



SOUTHERN

Triticale has poor tillering capacity and good tolerance to shattering. This makes it a useful cereal as a cover crop to establish undersown lucerne or medic. Seeding rates may need to be reduced, however. <sup>2</sup>

Besides its use as a feed grain, triticale can be used as a forage crop for ruminants and as a cover crop.

When added to a rotation, triticale may increase yields of other crops in the rotation, reduce costs, improve distribution of labour and equipment use, provide better cash flow, and reduce weather risk. Additionally, production of triticale may provide environmental benefits, such as erosion control and improved nutrient cycling. <sup>3</sup>

Triticale yields more than its ancestors in two types of marginal conditions: in the highlands, where acid soils, phosphorus deficiency and foliar diseases are dominant; and in the arid and semi-arid zones, where drought affects crops production. <sup>4</sup>

Triticale is a mainstream crop in Australia, mostly as spring types grown for grain production, but also as longer-season, dual-purpose types grown for fodder as hay, silage or grazing, followed by grain production.

The grain is primarily used as stock feed, with a low level of triticale use in food products. Most of the grain is used domestically although small amounts are exported.  $^{\rm 5}$ 

Triticale usually commands a lower price per tonne at the farm gate. An exception to this can be where there is strong local demand for feed grain, where a better cash return with low transport costs could be expected. <sup>6</sup>

The market for triticale is small compared to other cereals because it must compete with barley as the preferred winter feed grain. To combat this, breeders have released improved and better adapted varieties that have good yield and grain quality characteristics, with many of the factors identified as the cause of inferior performance having been eliminated. <sup>7</sup>

#### A.1.1 Triticale for human consumption

Small amounts of triticale are marketed as niche products for human food consumption. Uses include as a flour supplement to wheaten flour for bread, biscuits and cakes, as rolled whole grains for breakfast cereals, triticale noodles and in the brewing and distilling industries (Photo 2). Triticale has a distinctive nutty, aromatic and naturally sweet flavour. <sup>8</sup> Triticale as a main cereal for breadmaking is constrained by variations in breadmaking quality, low and inferior gluten content and lower flour yield. Further, with wheat and rye already established as the traditional bread cereals, it may take some time to influence consumers' preferences towards triticale.



<sup>2</sup> Agriculture Victoria (2012) Growing triticale. <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

<sup>3</sup> LR Gibson, C Nance, DL Karlen (2005) Nitrogen management of winter triticale. lowa State University. <a href="http://farms.ag.iastate.edu/sites/default/files/NitrogenManagement.pdf">http://farms.ag.iastate.edu/sites/default/files/NitrogenManagement.pdf</a>

<sup>4</sup> Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="https://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

KV Cooper, RS Jessop, NL Darvey 'Triticale in Australia' in M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="http://www.fao.org/3/a-v5553e/v5553e/v5553e0.pdf">http://www.fao.org/3/a-v5553e/v5553e0.pdf</a>

<sup>6</sup> P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries. <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf. file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

Birchip Cropping Group (2004) Triticale agronomy—2004. http://www.farmtrials.com.au/trial/13801

<sup>8</sup> Agriculture Victoria (2012) Growing triticale. <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>



**TABLE OF CONTENTS** 

FEEDBACK



SOUTHERN

**Photo 2:** Wholegrain triticale flour (left) and kibbled triticale (right) milled for human consumption.

Source: Blue Lake Milling

As consumers in general become more health conscious, however, there is a growing awareness of the health benefits of including a range of cereal grains in a balanced diet. This increased consumption of grains, together with the current consumer trend of trying new products, is leading to an increase in consumer interest in seeking baked products, such as breads baked using cereal grains other than wheat. Thus, given the nutritional and agronomic advantages of triticale, the improvements taking place in terms of baking potential, and an increasing level of consumer interest in products made from alternative grain cereals, triticale is believed to have the necessary attributes to become an important food cereal for humans in the future. <sup>9</sup>

Main culinary uses of triticale:

- Triticale flour: can be used to make biscuits, rye-type crispbreads, cakes and muffins. The flavour and texture of breads made from triticale are similar to that of light rye bread.
- Triticale flakes: Wholegrain triticale is pressed and rolled, and then may be used like rolled oats to make a hot breakfast cereal, or substituted for rolled oats in recipes (such as cookies and muffins).

Nutritional credentials of whole grain triticale:

- similar to wheat, with 13% protein, but lower in lysine and niacin
- lower in the protein complex that forms gluten
- a good source of phosphorus and magnesium, and a very good source of manganese
- contains B-group vitamins, most notably thiamin and folate <sup>10</sup>
- One study suggested triticale could be a food source that reduces obesity and diabetes problems <sup>11</sup>



Food uses of Triticale



<sup>9</sup> CM McGoverin, F Snyders, N Muller, W Botes, G Fox, M Manley (2011) A review of triticale uses and the effect of growth environment on grain quality. Journal of the Science of Food and Agriculture 917) 1155–1165

<sup>10</sup> Grain and legumes nutrition council (2016) Triticale. <a href="http://www.glnc.org.au/grains/types-of-grains/triticale/">http://www.glnc.org.au/grains/types-of-grains/triticale/</a>

<sup>11</sup> Cooper (1985) in S Tshewang (2011) Frost tolerance in Triticale and other winter cereals at flowering. Environmental and Rural Science. University of New England. <a href="https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C9IFFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22">https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C9IFFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22</a>







#### A.1.2 Triticale for animal consumption

The major uses for triticale grain are as a feed supplement in the dairy industry, as a component ingredient in beef feedlots, and as a constituent of compound rations for intensive livestock (pigs and poultry) rations. In livestock diets, triticale has a similar role to other cereals. Triticale is higher in energy than barley, and has many desirable nutritional characteristics for all classes of livestock. It is primarily an energy source, having moderate protein content with high starch and other carbohydrates, giving it high energy content.

SOUTHERN



**Photo 3:** Triticale is often chosen by farmers for stock feed due its high nutritional qualities.

Source: The Australian Dairy Farmer

Triticale is a direct substitute for barley or wheat in animal feed rations. In pig and poultry diets, triticale is equal to or better than wheat or maize in terms of energy value, and superior in terms of protein content and quality (essential amino acid content and availability). In dairy rations, triticale has an advantage over barley due to its high, easily metabolised energy, palatability and ease of milling. <sup>12</sup>

A key physical feature of triticale is that it has a hardness index almost half that observed for wheat and barley. This soft grain requires less mechanical energy to mill it before being added to livestock diets than does either wheat or barley.

On farm, triticale can be fed to livestock in the same way wheat or barley would be.  $^{\rm 13}$ 

Triticale growing regions correspond with the bulk of Australia's intensive livestock production, making triticale grain readily accessible by most feed mills.

There is a high demand for feed grain in the Wimmera region, especially for triticale, from the dairy and pig industries. The reduced transport costs and the slightly higher price for triticale compared to other feed grains makes triticale an attractive proposition. <sup>14</sup>



Triticale: stock feed guide

A guide to the use of Triticale in livestock feeds



Birchip Cropping Group (2004) Triticale agronomy—2004. http://www.farmtrials.com.au/trial/13801

Agriculture Victoria (2012) Growing triticale. <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

<sup>14</sup> University of Sydney (2012) Triticale. http://sydney.edu.au/agriculture/plant\_breeding\_institute/key\_work\_results/triticale.shtml









<u>Triticale offer benefits over wheat for biofuel</u>

#### A.1.3 Triticale for biofuel

Alternative fuels are required owing to the impending shortage and soaring prices of fossil fuels, and increasing global concern about the welfare of the environment. Biofuels are produced from organic matter and are a possible alternative fuel. Modern cultivars of triticale are a competitive feedstock for ethanol production. Advantageously, triticale possesses an autoamylolytic enzyme system that aids in converting large quantities of starch into fermentable sugars. Triticale is better suited to the production of biofuel than wheat. The use of triticale for biofuels has been explored in Europe, and could have potential elsewhere in the world.

SOUTHERN

#### A.2 Growing regions

The southern grains region stretches from Victoria, through to Tasmania and South Australia. The rainfall pattern ranges from uniform in central New South Wales through to winter-dominant in Victoria, Tasmania and South Australia.

This is a vast region of the country with a typically Mediterranean climate of dry summers and comparatively reliable winter rainfall, lending itself to winter crop production.

Planting of the winter crop depends on 'opening rains'; it usually begins in May, and can continue through until late July. The winter crop harvest can begin in late October and continue through until January in the higher rainfall areas. <sup>15</sup>

The South Australia–Victoria Mallee region comprises 7 million hectares of land, of which three quarters are allocated to dryland agriculture. It stretches from Penong in South Australia to Kerang in Victoria (Figure 1).

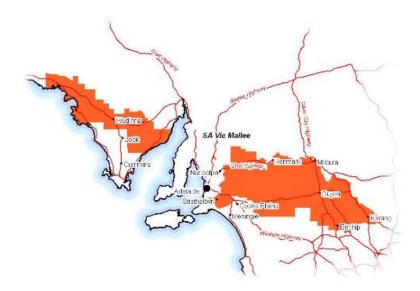


Figure 1: South Australia-Victoria Mallee Agroecological Zone.

Source: <u>GRDC</u>

Crops suitable for growing in the Mallee region during the winter are triticale, cereal rye, wheat, barley, oats, lupins, vetch, canola, field peas, chickpeas, faba beans, lentils and safflower. <sup>16</sup>



<sup>15</sup> AEGIC (2016) Australian grain production—a snapshot. Australian Export Grains Innovation Centre, 22/08/2016. http://aegic.org.au/australian-grain-production-a-snapshot/

<sup>16</sup> A Greijdanus, M Kragt (2014) The Grains Industry: An overview of the Australian broad-acre cropping. University of Western Australia. http://ageconsearch.umn.edu/bitstream/164256/2/WP1400002.pdf



TABLE OF CONTENTS

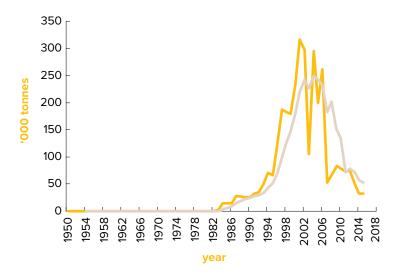


Source: PIRSA

The area sown to triticale has declined substantially in recent years, with growers favouring wheat or barley (Table 1 and Figures 2-4). <sup>17</sup>

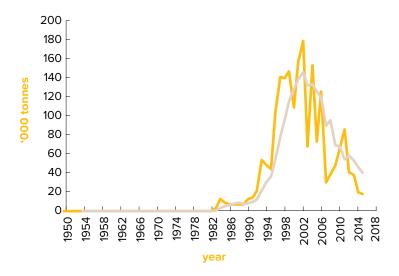
**Table 1:** Triticale production estimates in South Australia compared with a 5 year average.

	2010–11	2011–12	2012–13	2013–14	2014–15	5 year average	2015–16
Ha	85,700	80,200	69,200	49,300	27,100	62,300	21,800
Tonnes	167,100	117,500	95,920	86,500	44,300	102,300	32,700



**Figure 2:** Triticale production in Victoria. Grey line = five-year moving average.

Source: Ag Data



**Figure 3:** Triticale production in South Australia. Grey line = five-year moving average.

Source: Ag Data

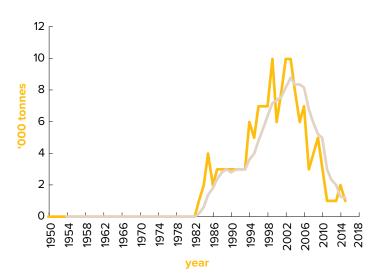


<sup>17</sup> Victorian Winter Crop Summary (2016) Agriculture Victoria. <a href="https://www.agriculture.vic.gov.au/">www.agriculture.vic.gov.au/</a> data/assets/word\_doc/0004/318883/ Triticale-2016.docx



**TABLE OF CONTENTS** 

FEEDBACK



SOUTHERN

**Figure 4:** Triticale production in Tasmania. Grey line = five-year moving average. Source: Ag Data

#### A.3 Brief history

The first wheat/rye cross-breeding occurred in Scotland in 1875, but this crossing was sterile; in 1888, German botanists first discovered how to produce a fertile hybrid of the two grains. The name triticale first seems to have been used in Germany about 1935.  $^{18}$ 

In the 1950s, plant geneticists hoped that a cross fertilisation of wheat and rye would produce a cereal with superior yield. The hardiness and disease resistance of rye was combined with the milling and baking qualities of wheat.

In 1970, the first commercial variety of triticale went on sale, and triticale bread, flour and breakfast cereals became available. Triticale was promoted as a 'miracle crop' during this time, but initial interest faded when crops were inconsistent and acceptance was slow. As such, triticale has not achieved its objectives to dominate as a grain for food production. Today in Australia, triticale is found in a range of grain foods. <sup>19</sup>

#### A.3.1 Triticale in Australia

Triticale was introduced into Australia in the early 1970s as experimental lines for evaluation. Breeding and selection programs were initiated at several universities and state government departments of agriculture, and a number of varieties were released, which were mostly spring-grain lines introduced by CIMMYT (International Maize and Wheat Improvement Centre). Triticale was quickly taken up as a useful crop for grain and fodder production on acid and waterlogged soils, and for producing an economic and soil-conserving crop on lower rainfall, nutrient-impoverished soils. Initially, triticale was mostly used on-farm or traded locally as stock feed. It was often sought as a more easily-traded feed grain than wheat, which had to be marketed through the Australian Wheat Board. On the other hand, as triticale was not a well-known grain, and as the quantity available was limited, in some areas triticale could prove difficult to sell for a good price, which tended to limit its adoption.



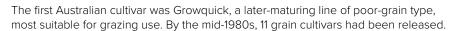
<sup>18</sup> Oldways Whole Grains Council. Rye and triticale: August grains of the month. <a href="http://wholegrainscouncil.org/whole-grains-101/easy-ways-enjoy-whole-grains/grain-month-calendar/rye-triticale-august-grains-month">http://wholegrainscouncil.org/whole-grains-101/easy-ways-enjoy-whole-grains/grain-month-calendar/rye-triticale-august-grains-month</a>

<sup>19</sup> Grain and legumes nutrition council (2016) Triticale. <a href="http://www.glnc.org.au/grains/types-of-grains/triticale/">http://www.glnc.org.au/grains/types-of-grains/triticale/</a>



**TABLE OF CONTENTS** 





**SOUTHERN** 

In the early 1980s, wheat stem rust races evolved in Queensland, and were virulent on these cultivars. In order to reduce the likelihood of rust epidemics and further evolution of virulent races, the rust-susceptible cultivars were no longer recommended, and breeders sought to produce cultivars with full rust resistance. Once this was achieved, an increasing amount of triticale was produced and after many years of good results, users gained confidence in this grain, driving an increasing demand for triticale and improved prices. Triticale gained popularity in the Mallee region during the early 2000s to a point where it was treated as an economic crop. More recently, the area of production has declined. <sup>20</sup>



<sup>20</sup> KV Cooper, RS Jessop, NL Darvey 'Triticale in Australia' in M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>



SECTION 1 TRITICALE

**TABLE OF CONTENTS** 





# Planning/Paddock preparation

#### Key messages

- Triticale is suited to all soil types but has a significant yield advantage over wheat and barley when grown in a number of problem-soil situations.
- Of all the cereals available to farmers, triticale has the best adaptation to waterlogged soils and those with high pH (alkaline).
- Triticale is also tolerant of low pH (acid) soils, grows well on sodic soils, and tolerates soils high in boron.
- Triticale can out-produce other winter cereals on lighter soils with lower fertility.
   It has a more vigorous root system than wheat, barley or oats, binding light soils and extracting more nutrients from the soil.
- Incorporate crop rotation in farming systems: triticale can provide valuable benefits to a sequence.
- Ensure that paddocks are weed free before planting seed.
- Before planting, test soils for diseases and nematodes, and sample paddock soil for insects.

#### 1.1 Paddock selection

The choice of paddock to sow cereals is based on a range of issues. Economics, production risk from disease or weed pressure, herbicide residues, seasonal forecasts, stored soil water, and achieving a balance of risk with other crop types are some of the considerations. <sup>1</sup>

#### 1.1.1 Topography

Topographical characteristics can determine crop and pasture options. Crops and varieties prone to lodging should be avoided in uneven paddocks. Waterlogged conditions also reduce root growth and can predispose plants to root rots. Triticale is less prone to waterlogging than other cereals, and can be a good option for areas where water may sit.

The topographical variations typical of large agricultural paddocks can have a substantial impact on dynamics of soil mineral nitrogen (N) as well as on the performance of crops. Variations in soil organic matter, soil microbial biomass, natural drainage, plant growth, and water and nutrient redistribution caused by topography are the main factors controlling the dynamics of soil mineral N. Along with weather, landscape topographic patterns accounted for most of the variations in plant available N.

There are potential environmental and economic benefits of site-specific topography-driven management of cover crops. Decisions regarding where to plant crops can vary depending on the management goals and complexity of the terrain. For example, cover crops seem to be particularly advantageous on eroded, unfertile slopes where legumes bring the needed N inputs, while all cover crops contribute to erosion control and carbon (C) sequestration there. <sup>2</sup> For example, on a farm in Victoria (Figure 1), the farmer manages crops and grazing based on topography and soil characteristics. Between the rising country and the river flats is the intermediate country, which covers 33% of the farm. This is used mainly for grazing with a carrying capacity of 15–18 dry-sheep equivalents (DSE) per hectare. Also, some 60–70



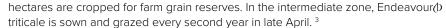
<sup>1</sup> Agriculture Victoria (2012) Growing wheat. Note AG0458. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-wheat">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-wheat</a>

<sup>2</sup> M Ladoni, AN Kravchenko, GP Robertson (2015) Topography mediates the influence of cover crops on soil nitrate levels in row crop agricultural systems. PLOS ONE, 10 (11), DOI doi:10.1371/journal.pone.0143358.

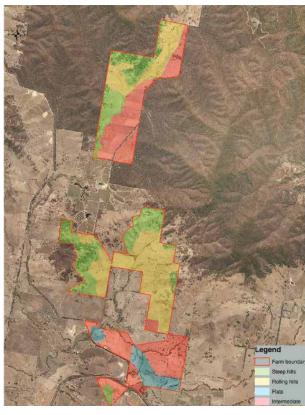
MORE INFORMATION

Dividing up the farm for flexibility and

profit



SOUTHERN



**Figure 1:** Production zones in a farm facing the challenges of highly variable topography.

Source: EverGraze

#### 1.1.2 Soil

Surface and subsurface soil characteristics such as soil pH, sodicity, salinity, acidity, texture, drainage characteristics and compaction will affect variety selection.

Of all the cereals available to farmers, triticale has the best adaptation to waterlogged soils and those of high pH (alkaline soils). Triticale is also tolerant of low pH (acid) soils, grows well on sodic soils and tolerates soils high in boron. In nutrient-deficient soils, triticale appears to respond better to applied fertilisers than other cereals do. Triticale has the capacity to survive utilising trace elements in soils which would be considered nutrient-deficient for any other type of crop. <sup>4</sup>

Triticale is suited to all soil types, but has a significant yield advantage over wheat and barley when grown in a number of problem-soil situations including:

- Acidic soils (pH less than 4.5 CaCl<sub>2</sub>) which are high in aluminium (greater than 10% of the total cations) e.g. in southern NSW, north-eastern Vic and WA.
- Alkaline soils, e.g. in SA.
- Waterlogged conditions. 5

National Variety Trials (NVT) experiments in South Australia on alkaline soils at Pinaroo, Streaky Bay and Minnipa have indicated good yields compared with other



<sup>3</sup> G Saul (n.d.) Dividing up the farm for flexibility and profit. Ever Graze, <a href="http://www.evergraze.com.au/wp-content/uploads/2014/08/">http://www.evergraze.com.au/wp-content/uploads/2014/08/</a>
CS\_Elmburgt Groop pdf

<sup>4</sup> Agriculture Victoria (2012) Growing triticale. Note AG0497. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

Waratah Seed Co. (2010) Triticale: planting guide. Waratah Seed Co., <a href="http://www.porkcrc.com.au/1A-102">http://www.porkcrc.com.au/1A-102</a> Triticale Guide Final Fact Sheets.pdf



#### SECTION 1 TRITICALE

**TABLE OF CONTENTS** 





cereals, even in dry years. Farmers' experience on dry, rocky soils in South Australia has shown a 25% yield advantage for triticale compared with wheat. In these difficult conditions, the variety Rufus has proved most valuable.  $^6$ 

SOUTHERN

Triticale will grow on similar soils to wheat and barley, and is also adapted to soils that are too acid for the other cereals. It is relatively boron-tolerant and is tolerant to high-aluminium soils. On alkaline soils where other cereals are affected by manganese, zinc or copper deficiency, triticale is less affected.

Triticale can out-produce other winter cereals on lighter, lower fertility soils. It has more vigorous root system than wheat, barley or oats, and this allows it to bind light soils and extract more nutrients from the soil. <sup>7</sup>

Triticale and wheat are similar crops, but triticale represents a valuable alternative to wheat due to its greater biomass production and grain yield in Mediterranean-type growing conditions, such as in parts of southern Australia. 8

### IN FOCUS

# The impact of different soil moisture and soil compaction on the growth of triticale root systems

The effects of different soil moisture (i.e. soil drought and waterlogging) and soil compaction (1.33 g/cm<sup>-3</sup> and 1.50 g/cm<sup>-3</sup>) on the growth and morphological traits of the root system were studied in four breeding forms and seven cultivars of triticale. Morphological changes, including the restriction of root extension, expansion and proliferation of laterals roots, occur in plants grown in different soil moisture and in compacted soil.

The results demonstrated a relatively broad variation in the habit of the triticale root system (Photo 1). Plants grown in compacted soil and in soild with low or high water content showed a smaller number and less dry matter of lateral branching than plants grown in control conditions. The harmful effects of compacted soil and drought conditions on the growth of roots was greater when compared with that of plants exposed to waterlogging. The observed effects of all treatments were more distinct in drought-sensitive strains. The drought-resistant forms were more characterised by extensive rooting and by smaller alterations in the root morphology under the stress conditions compared with drought-sensitive ones (Photo 1). Results confirm that the breeding forms with a high drought susceptibility (CHD-12 and CHD-173) were found to be also more sensitive to periodic soil-water excess. A more efficient water use and a lower shoot to root (S:R) ratio were found to be major reasons for the greater resistance to stress of the breeding forms CHD-220 and CHD-247. The reasons for the different response of the examined breeding forms and cultivars to drought or waterlogging may be a more economical water balance and more favourable relations between the shoot and root dimensions in the drought-resistant forms and cultivars. 9



<sup>6</sup> J Roake, R Trethowan, R Jessop, M Fittler (2009) Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/1A-102\_Final\_Research\_Report\_.pdf">http://www.apri.com.au/1A-102\_Final\_Research\_Report\_.pdf</a>

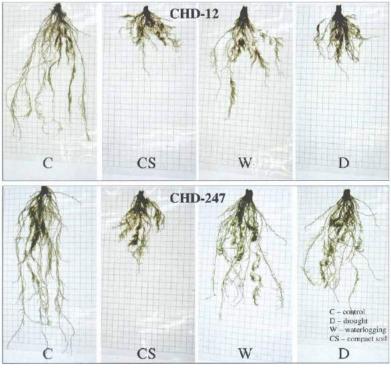
<sup>7</sup> Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, http://www.farmtrials.com.au/trial/13801

<sup>8</sup> S Bassu, S Asseng, F Giunta, R Motzo (2013) Optimizing triticale sowing densities across the Mediterranean Basin. Field Crops Research, 144, 167–178.

<sup>9</sup> S Grzesiak, MT Grzesiak, W Filek, T Hura, J Stabryła (2002) The impact of different soil moisture and soil compaction on the growth of triticale root system. Acta Physiologiae Plantarum, 24 (3), 331–342.

**TABLE OF CONTENTS** 

FEEDBACK



**Photo 1:** Effects of compacted soil (CS), waterlogging (W) and soil drought (D) on root growth of drought-resistant (CHD-247) and drought-sensitive (CHD-12) triticale seedlings that are three weeks old.

Soil compaction has been found to limit triticale growth. Severe soil compaction decreases leaf number, leaf area and dry matter of shoots and roots, while increasing the shoot-to-root dry matter ratio. In addition, high level of soil compaction strongly affects the length of seminal and seminal adventitious roots, and the number and length of lateral roots developed on the seminal root. Severely compacted soil also negatively impacts photosynthesis, gas exchange, transpiration rate and stomatal conductance. <sup>10</sup>

#### Soil pH

Key points:

- Triticale can grow on acidic soils (pH less than 4.5 CaCl<sub>2</sub>) and alkaline soils.
- Soil pH is a measure of the concentration of hydrogen ions in the soil solution.
- Low pH values (< 5.5) indicate acidic soils and high pH values (> 8.0) indicate alkaline soils
- Soil pH between 5.5 and 8 is not usually a constraint to crop or pasture production.
- In South Australia more than 60% of agricultural soils are alkaline.
- Outside of the optimal soil pH range, microelement toxicity damages crops.

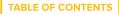
As a general rule, triticale's are suited to all soil types, but typically have a yield advantage over wheat and barley on light acidic soils higher in exchangeable



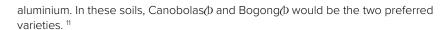
<sup>10</sup> MT Grzesiak (2009) Impact of soil compaction on root architecture, leaf water status, gas exchange and growth of maize and triticale seedlings. Plant Root, 3, 10–16.



#### SECTION 1 TRITICALE

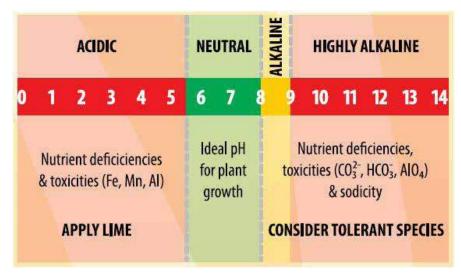






SOUTHERN

Hydrogen ion concentration in the soil, called pH, and is influenced by chemical reactions between soil components and water (Figure 2). Soil pH is affected by the varied combinations of positively charged ions (sodium, potassium, magnesium, calcium, aluminium, manganese and iron) and negatively charged ions (sulfate, chloride, bicarbonate and carbonate). Soil pH directly affects the concentration of major nutrients and the forms of microelements available for plant uptake, and can result in deficiencies or toxicities.



**Figure 2:** Classification of soils on the basis of pH, showing the implications for plant growth and some management options.

Source: Soilquality.org

#### What influences location of acidic and alkaline soils in Southern Australia

Acid soils occur in areas of southern Australia with high rainfall where basic ions (sodium, potassium, magnesium and calcium) have been removed by leaching. Nitrate leaching also contributes to significant soil acidification under high rainfall. Very frequent legume cropping can reduce pH in non-calcareous soils. Soils high in sulfur may become very acidic due to the dominance of certain chemical (oxidation-reduction) reactions.

Alkaline soils are found in arid and semi-arid regions because little leaching and high evaporation causes ions to concentrate in the soil.

#### Measurement of soil pH

Soil sampling and the measurement of pH helps to determine the practices necessary to manage land with low or high pH  $^{12}$ . Sampling strategies need to take into account the variation across a paddock and down the soil profile (see section below).

Soil pH can be measured by a simple device called an ion electrode, which is inserted into a mixture of one part soil to five parts water. Scientists dealing with acid soils with pH less than 5 prefer to measure soil pH using soil in calcium chloride solution. This is not suitable for soils with a pH greater than 5 because some of the ions in these soils (mainly bicarbonate and carbonate) become bound to the calcium and are removed from solution, which then causes an inaccurate pH reading. Soils with pH greater than 5 should be measured in water.

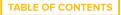


<sup>1</sup> Viterra (2010) Bogong and Canobolas triticale SA, Vic, NSW. Factsheet. Viterra, <a href="http://www.hartbrosseeds.com.au/f.ashx/Bogong-Canobolas-Factsheet.pdf">http://www.hartbrosseeds.com.au/f.ashx/Bogong-Canobolas-Factsheet.pdf</a>

<sup>12</sup> Soilquality.org (2011) Soil pH - SA. Soilquality.org, <a href="http://www.soilquality.org.au/factsheets/soil-ph-south-austral">http://www.soilquality.org.au/factsheets/soil-ph-south-austral</a>



#### SECTION 1 TRITICALE







WATCH: GCTV8: Liming Acids Soils



#### Managing soil pH

Acid soils

Acid soils can be managed economically by the addition of agricultural lime, usually crushed limestone. Sufficient lime should be added to raise the pH to above 5.5. The amount required to ameliorate acid soils will vary, mainly depending on the quality of the lime, the soil type and how acidic the soil is.

SOUTHERN

Soils prone to becoming acidic will need liming every few years. Seek advice on an appropriate regime from your local agricultural advisor. <sup>13</sup>

Alkaline soils

In South Australia more than 60% of agricultural soils are alkaline. Treating alkaline soils by the addition of acidifying agents is not generally a feasible option due to the large buffering capacity of soils and uneconomic amounts of acidifying agent (e.g. sulfuric acid, elemental sulfur or pyrites) required.

Gypsum will reduce sodicity, and this can reduce alkaline pH to some extent. Growing legumes in crop rotation may help in sustaining pH reduction.

In high pH soils, using alkalinity tolerant species and varieties of crops and pasture can reduce the impact.

#### 1.1.3 Sampling soil quality

Key points:

- The approach taken will be defined by the purpose of the investigation, variability in the area sampled, and the analysis and accuracy required.
- For many soil quality parameters, sampling is typically done to 10 cm, although 30 cm is required for carbon accounting purposes; stratification below 10 cm is recommended (e.g. 10–20, 20–30 cm).
- The sampling strategy should either integrate or describe the variation within the sampling area.
- Samples should be air-dried or kept below 4°C prior to analysis. For biological measurements, it is best to analyse as soon as possible.

Before deciding how to sample the soil, be clear about the purpose of your sampling. Different sampling approaches may be required depending on what you are sampling for, the soil type, the management unit (e.g. paddock), soil spatial variability (changes in soil type, dunes—swales, etc.), the accuracy required of the result, and the value placed on the information provided (Photo 2). Before starting, define very clearly the question you are asking of your soil samples. Consult a professional soil scientist, agronomist or your analytical laboratory to be sure that your soil samples are taken at the right time, from the right depth, in the right place and in the appropriate number, and are stored in such way that the required analysis is not compromised. If quantitative soil analyses (kg/ha) are required, soil bulk density must also be measured, and this requires considerable care. <sup>14</sup>



Soilquality.org. Soil pH: South Australia. Soilquaity,org, <a href="http://www.soilquality.org.au/factsheets/soil-ph-south-austral">http://www.soilquality.org.au/factsheets/soil-ph-south-austral</a>

<sup>14</sup> M Unkovich. Soil sampling for soil quality—South Australia. Soil Quality Pty Ltd, <a href="http://www.soilquality.org.au/factsheets/soil-sampling-for-soil-quality-south-australia">http://www.soilquality.org.au/factsheets/soil-sampling-for-soil-quality-south-australia</a>

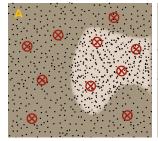


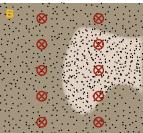
**Photo 2:** To be meaningful, soil sampling needs to take into account spatial variation in soil condition. Differences in soil type, nutrient status and other soil properties may be exhibited within a paddock.

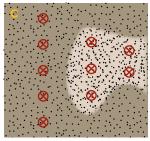
Source: Soil Quality Pty Ltd).

#### Sampling strategy

Soil properties and fertility often vary considerably, even over short distances, necessitating a sampling strategy that either integrates this variation by creating a composite sample (sampling across) or describes it by including replicate samples (sampling within). Describing the variation requires a defined sampling within each different soil patch and analysing replicate samples separately. Such an approach might be required where there are consistent zones within a field such as under controlled-traffic systems, perennial row or tree crops, or raised bed systems. More often, the variation within the field is integrated into a single sample by creating a composite. Examples of these are illustrated in Figure 3.







SOUTHERN

**Figure 3:** Sampling strategies used to create a composite sample that integrates variation across different soil types (A & B), and a strategy to describe variation by sampling zones and analysing samples separately (C). Panel A: haphazard samples strategically located to approximate the relative representation of different soil types. Panel B: samples taken along transects intersecting different soil types. Panel C: equal numbers of samples from each zone.

Source: Soil Quality Pty Ltd

#### Sampling equipment

Manual sampling is often used where sampling is only required to 10 cm and bulk density is not required. Small pogo-type samplers enable quick sampling for qualitative determinations such as nutrient concentrations or disease presence. To avoid contamination, ensure that your sampling equipment is cleaned before starting.





#### SECTION 1 TRITICALE





For greater depths, mechanical (hydraulic) samplers are usually required for most soil types. If using these for soil carbon sampling, take care not to contaminate samples with lubricating oil.

SOUTHERN

#### Sampling depth

Sampling for soil fertility or biological activity assessment is typically done to 10 cm depth because this is where most of the organic matter and nutrient cycling occurs. However, for mobile nutrients such as nitrate or K, deeper sampling may be required on sandier soils. Sampling to the rooting depth of a crop of interest might be useful for analysis of these nutrients or when studying water availability; otherwise, it is generally too onerous. When assessing soil carbon stocks for accounting or budgeting purposes, a sampling depth of 30 cm is required to conform to standard accounting procedures. When sampling below 10 cm, soil samples are usually stratified by depth increments (e.g. 10, 20, 30 cm), depending on the objectives. When characterising a soil for the first time, sampling corresponding to the different soil-layer depths (horizons) is often useful. Plant litter on the soil surface is not usually included in soil samples, whereas plant root material is usually included, although generally sieved out prior to analysis.

#### Sample handling

Samples can be stored in polyethylene bags but should generally be dried or kept cool prior to analysis. Air-drying ( $<40^{\circ}$ C) is usually sufficient and storage  $<4^{\circ}$ C usually arrests most biological activity. Dried samples can be broken up if clods are present, and any stones removed. If the amount of material collected is too great to manage and ship, it can be reduced in size by careful quartering, ensuring no discrimination against particular particle sizes. Samples are typically put through a 2-mm sieve prior to analysis. <sup>15</sup>

#### 1.1.4 Biological inputs

Key points:

- When evaluating a biological input for grain production, it may be useful to consider whether the input will alleviate yield constraints.
- The major yield constraints in the Southern Region are high soil density, sodicity and acidity.
- The biological inputs with the most potential to help alleviate these yield constraints are manure, compost, vermicompost, biochar and some bio-stimulants.

#### Yield constraints in the Southern Region

The Southern Region has soils with generally low fertility and many have subsoil constraints such as high soil density, salinity, sodicity, acidity and toxic levels of some elements. However, due to the diversity of soils in this region, some areas have very productive soils. Crop-production systems in the region are varied and they include many mixed-farming enterprises that have significant livestock and cropping activities.

Yield potential in the region depends on seasonal rainfall, especially in autumn and spring, with less dependence on stored soil moisture than in the Northern Region. <sup>16</sup>

#### 1.1.5 Paddock selection for forage cereals

Selecting a paddock for forage cereal production will depend on how the forage will be used on the dairy farm. If it is to provide additional grazing, choose a well-drained paddock that can resist pugging damage from dairy cows. A paddock that has higher fertility and is well drained should be chosen to provide maximum dry-matter production.



<sup>6</sup> J Carson. Soilquality.org. Biological inputs—Southern grain-growing region. Fact Sheet, Soil Quality Pty Ltd, <a href="http://www.soilquality.org">http://www.soilquality.org</a>.
au/factsheets/biological-inputs-southern-grain-growing-region



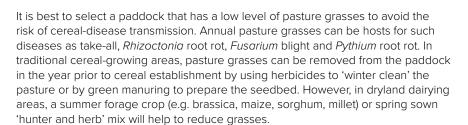
<u>Biological inputs – Southern grain</u> growing region





**TABLE OF CONTENTS** 





OUTHERN

Tough grasses such as bent grass, couches and kikuyu must be controlled before the autumn sowing of cereals. These grasses will compete with the cereal for nutrients and moisture, both in autumn at establishment and in the following spring. <sup>17</sup>

# 1.1.6 Weed burden and herbicide history

A high weed burden will influence the likelihood of cropping success. The species present or likely to occur based on previous years should influence the choice of crop variety to ensure that effective in-crop control measures are available.

Strategic and integrated weed management over a rotation can greatly increase the likelihood of being able to control weeds across all crops. For example, a grower planting paddocks to wheat in the first year of a rotation should have a vigilant strategy for the control and prevention of seedset of key broadleaf weeds prior to a rotation to canola or legume crops.

The use of pre-emergent herbicides should be considered, as well as cultural control methods such as species choice and row width.

Part of the management of herbicide resistance includes the rotation of herbicide groups. Therefore, consider the history of herbicide use in each paddock. Herbicide residues (e.g. sulfonylurea, triazines) may be a problem in some paddocks. Remember that plant-back periods begin after significant rainfall occurs.

For more information, see Section 6: Weed Control.

#### 1.1.7 Fallow moisture and management

Paddocks that have been well managed during fallow periods significantly lower the risk of poor crop and financial performance. A growing crop has two sources of water: the water stored in the soil during the fallow, and rainfall while the crop is growing. Growers have some control over the stored soil water, so it should be measured before planting. Long-range forecasts and tools such as the Southern Oscillation Index (SOI) indicate the likelihood of the season being wet or dry, and are a useful adjunct in deciding what to plant. Timely weed control can reduce moisture and nutrition loss, prevent an increase in the seedbank, and decrease the risk of disease being carried over. Absence (or restriction) of grazing maintains soil friability and groundcover. Prolonged grazing periods may create crop emergence problems through induced surface compaction. <sup>18</sup>

# 1.2 Paddock rotation and history

Paddock choice can determine the amount of disease, weed and nutrient pressure on the crop. Increasing interest in crop sequencing is providing more financial and agronomic data to help growers to choose crops and paddocks each year. Crop rotation is a key strategy for managing Australian farming systems, and improvements in legume and oilseed varieties and their management have facilitated this shift. Leading growers and advisers advocate sustainable crop sequences as a valuable strategy for southern farming systems. Many growers are sacrificing cereal yield and protein by not adopting current research findings on the use of the best sequences.



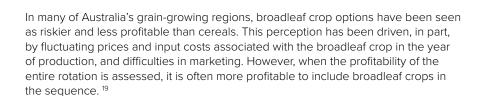
<sup>17</sup> Agriculture Victoria (2008) Establishing forage cereals. Note AG1269. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/dainy/pastures-management/forage-cereals/establishing-forage-cereals/">http://agriculturevic.gov.au/agriculture/dainy/pastures-management/forage-cereals/</a>

<sup>18</sup> N Border, K Hertel, P Barker (2007) Paddock selection after drought. NSW Department of Primary Industries, <a href="http://www.dpi.nsw.gov.au/content/agriculture/emergency/drought/drought-publication-archive/paddock-selection-after-drought">http://www.dpi.nsw.gov.au/content/agriculture/emergency/drought/drought-publication-archive/paddock-selection-after-drought</a>



**TABLE OF CONTENTS** 





SOUTHERN

### 1.2.1 Triticale as a rotation crop

Besides its use as a feed grain, triticale can be used as a forage crop for ruminants and as a cover crop.

When added to a rotation, triticale may increase yields of other crops in the rotation, reduce costs, improve rgw distribution of labour and equipment use, provide better cash flow, and reduce weather risk. Additionally, the production of triticale may provide environmental benefits such as erosion control and improved nutrient cycling. <sup>20</sup>

Triticale yields more than its wheat and rye ancestors in two types of marginal conditions: in highlands where acid soils, phosphorus deficiency and foliar diseases are dominant; and in the arid and semi-arid zones where drought affects crop production. <sup>21</sup>

Traits observed that suggest higher yields in triticale than in wheat include greater early vigour, a longer phase of spike formation with same duration to flowering, reduced tillering, increased remobilisation of carbohydrates to the grain, early vigorous root growth, and higher transpiration-use efficiency. <sup>22</sup>

Trials in the UK suggest that triticale gives a greater yield advantage than wheat when it is in the second cereal position in a rotation. The researchers suggest that the greater yield of triticale was due to its greater resistance to take-all. <sup>23</sup> However, there are some disadvantages to growing triticale (Table 1).



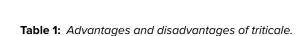
<sup>19</sup> GRDC (2011) Choosing rotation crops: short-term profits, long-term payback. Factsheet. GRDC, <a href="http://www.grdc.com.au/"/">http://www.grdc.com.au/"/</a> media/9219D55FFB4241DC9856D6B4C2D60569.pdf

<sup>20</sup> LR Gibson, C Nance, DL Karlen (2005) Nitrogen management of winter triticale. Iowa University, <a href="http://farms.ag.iastate.edu/sites/default/files/NitrogenManagement.pdf">http://farms.ag.iastate.edu/sites/default/files/NitrogenManagement.pdf</a>

M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>22</sup> S Bassu, S Asseng, F Giunta, R Motzo (2013) Optimizing triticale sowing densities across the Mediterranean Basin. Field Crops Research, 144, 167–178.

<sup>23</sup> S Clarke, S Roques, R Weightman, D Kindred (2016). Understanding triticale, AHDB Cereals and Oilseeds, <a href="https://cereals.ahdb.org.uk/media/897536/pr556-understanding-triticale.pdf">https://cereals.ahdb.org.uk/media/897536/pr556-understanding-triticale.pdf</a>



#### Advantages

Triticale is a hardy, relatively low input cereal crop with good disease resistance, particularly to rusts. It is as high a quality feed grain as wheat.

It is a tall crop bred for strong straw strength which can be useful in rocky paddocks or circumstances where crops have been known to lodge.

Triticale is more durable than wheat when grazed; which means it will remain healthier, and stand up to weeds, diseases and cold weather better than wheat.

Many growers use triticale as a disease break in their rotations and value the benefits of triticale for its contribution to soil conservation. It assists in maintaining soil health helping to reduce nematodes such as Pratylenchus neglectus and P. thornei (root lesion nematodes) and Heterodera avenae (cereal cyst nematode), and a number of fungi and bacteria. It is also resistant to Barley yellow dwarf virus, mildew and rusts, which may cause significant yield reductions in wheat, barley and oats. The extensive root system of triticale binds sandy soils, and the fibrous stubble reduces wind and water erosion. 24 Roots of triticale in nematode-infested soil have been found to contain fewer nematodes than other cereals. Triticale is thus a useful rotational crop for areas infested with the root lesion nematode. 25

#### Disadvantages

It is prone shattering. There is a spot about a quarter to a third of the way down from the tip on the rachis that is very weak. <sup>26</sup>

SOUTHERN

Stripe rust may be a problem in triticale (although there are now options to treat seed to provide seedling protection against stripe rust).

Triticale grain is softer than wheat and barley grain. Soft grain is more prone to attack from weevils and other grain-storage insects. <sup>27</sup>

It can be difficult to find a market for triticale.

#### Benefits of cereals as a rotation crop

Cereals present the opportunity to utilise residual N effectively. They also offer good options for broadleaf control, and also do not host many pulse crop and oilseed diseases. A major benefit of winter cereal crops is the high levels of groundcover they provide, helping the grower manage soil loss in following fallows and some subsequent pulse crops.

#### Disadvantages of cereals as a rotation crop

Growing cereals in continuous production is no longer a common practice because of the rising incidence of:

- Difficult-to-control and herbicide-resistant weeds, particularly grass weeds.
- Disease build-up, e.g. crown rot, tan (yellow) spot, nematodes.
- · Nitrogen (N) depletion and declining soil fertility.



<sup>24</sup> KV Cooper, RS Jessop, NL Darvey (2004) Triticale in Australia. In M Mergoum, H Gómez-Macpherson (eds), Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="mailto:tp://tp.fao.org/docrep/fao/009/v5553e02.odf">tp://tp.fao.org/docrep/fao/009/v5553e02.odf</a>

<sup>25</sup> V Vanstone, M Farsi, T Rathjen, K Cooper (1996) Resistance of triticale to root lesion nematode in South Australia. In Triticale: Today and Tomorrow Springer Netherlands, pp. 557–560.

<sup>26</sup> N Herdrich. Triticale for eastern Washington dryland area. Alternative crops. Washington State University, <a href="http://pnw-ag.wsu.edu/AgHorizons/crops/csr2no1.htm">http://pnw-ag.wsu.edu/AgHorizons/crops/csr2no1.htm</a>

<sup>27</sup> Agriculture Victoria (2012) Growing triticale. Note AG0497. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculturevic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>



**TABLE OF CONTENTS** 





Farmers use their soil intensively. There are pressures to grow more crop, in volume or value, to maintain profits. However, it is still important to grow cover crops. Cover (or break) crops include grasses such as triticale and oats, and legumes such as cowpeas and vetch. They may be ploughed in as 'green manure' crops, or they may be mulched, slashed or sprayed ('brown-manured') then sown into.

For more information, see Section 2: Pre-planting.

Although cover crops do not normally produce income, they are important because they protect the soil and give other benefits (Table 2). Bare soil is easily damaged, so it is best to protect it by maintaining plant cover. <sup>28</sup>

The main crops used for cover cropping, such as oats, triticale, brown (or Indian) mustard (*B. juncea*) and forage rape, host nematodes and many of them enable rapid multiplication of nematodes. Much of the practice being adopted on-farm in Australia involves the use of crops that can provide green-manure benefits, but in most cases, these crops host and multiply nematodes, and there is little information about their impacts on other soilborne fungi. <sup>29</sup>

**Table 2:** Advantages and disadvantages of including cover crops in growing rotations.

#### Advantages of cover cropping

**Protecting the soil:** much less soil erosion and less surface crusting

**Maintaining fertility:** by maintaining organic matter levels in the soil, and adding N (if a legume)

**Weed control:** a healthy cover crop keeps a paddock free of weeds

**Disease control:** by providing a break crop that helps to reduce disease, nematode and, perhaps, pest levels. For vegetable production, grasses rather than legumes tend to have most benefit

**Biological tillage:** less cultivation needed because cover crops loosen the soil

**Improved paddock access:** in areas of medium—high rainfall, cover crops can dry out a soil profile and promote timely farm operations

#### **Disadvantages of cover cropping**

SOUTHERN

**Loss of land for cash crops:** if an issue, do not grow the cover crops to maturity and grow only occasionally

Cost of seed and sowing: unavoidable but small. Costs usually associated with growing (e.g. watering) are generally avoidable

**Can become a weed**: usually not a problem in vegetable production

**Bulky crops**: can temporarily tie-up N and perhaps increase disease and have other effects. Trash can also get in the way



WATCH: <u>The importance of crop</u> rotation.



Source: NSW DPI



<sup>28</sup> A Senn (2007) Protect your land—use cover crops. NSW Department of Primary Industries, <a href="http://archive.dpi.nsw.gov.au/content/agriculture/horticulture/protect">http://archive.dpi.nsw.gov.au/content/agriculture/horticulture/protect</a>

<sup>29</sup> Good Fruit and Vegetables (2014) Cover cropping practices multiplying nematodes. AgTrader.com.au, <a href="http://www.goodfruitandvegetables.com.au/story/3554224/cover-crop-practices-multiplying-nematodes/">http://www.goodfruitandvegetables.com.au/story/3554224/cover-crop-practices-multiplying-nematodes/</a>

**TABLE OF CONTENTS** 



# 1.2.3 Long-fallow disorder

Soils naturally contain beneficial fungi that help the crop to access nutrients such as phosphorus (P) and zinc (Zn) by forming structural associations with the crop root, known as arbuscular mycorrhizae (AM). Many different species of fungi can have this association with the roots of crops, and many of these form structures called vesicles in the roots. The severe reduction or lack of AM shows up as long-fallow disorder—the failure of crops to thrive despite adequate moisture. Ongoing drought in the 1990s and 2000s has highlighted long-fallow disorder, where AM fungi have died out through lack of host plant roots during long fallow periods. As cropping programs restart after dry years, a yield drop is likely because of reduced levels of AM fungi and hence reduced development of AM, making it difficult for the crop to access nutrients. Long-fallow disorder is usually typified by poor crop growth. Plants appear to remain in their seedling stages for weeks and development is very slow.

SOUTHERN

Benefits of AM formation are:

- improved uptake of P and Zn
- · improved crop growth
- improved N<sub>2</sub> fixation
- · greater drought tolerance
- · improved soil structure
- greater disease tolerance.

In general, the benefits of AM are greater at lower soil P levels because AM increase a plant's ability to access this nutrient. Crops species vary in their dependency on AM for growth (Table 3).  $^{30}$ 

**Table 3:** The dependency of various crop species on mycorrhizae, with values decreasing as the phosphorus level in the soil increases.

Mycorrhiza dependency	Potential yield loss without mycorrhiza (%)	Crop
Very high	Greater than 90	Linseed
High	60–80	Sunflower, mungbeans, pigeon peas, maize, chickpeas
Medium	40–60	Sudan, sorghum, soybeans
Low	10–30	Wheat, barley, triticale
Very low	0–10	Panicum, canary
Nil	0	Canola, lupins

Source: DAF Qld

### 1.3 Fallow weed control

Paddocks with well-managed fallow periods significantly lower the risk of poor crop and financial performance. The best form of weed control is rotation. If spraying, the ideal time for control is when weeds are small (Photo 3).

When sowing dual-purpose varieties early, choose a paddock with low weed numbers and control weeds before the first grazing. Strategic grazing can be used to help manage weeds. Always check grazing withholding periods before you apply post-emergent herbicides when planning to graze the crop. <sup>31</sup>



<sup>30</sup> DAF QId (2010) Nutrition: VAM and long fallow disorder. Department of Agriculture and Fisheries Queensland, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/nutrition-vam">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/nutrition-vam</a>

<sup>31</sup> Waratah Seed Co. (2010) Triticale: planting guide. Waratah Seed Co., <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>

**TABLE OF CONTENTS** 

FEEDBACK





**Photo 3:** Spraying weeds when small is the key to effective long fallow.

Source: AGRONOMO

Paddocks generally have multiple weed species present at the same time, making weed-control decisions more difficult and often involving a compromise after assessment of the prevalence of key weed species. Knowledge of the paddock's characteristics and history, and early control of weeds, is important for good control (Photo 4). Information is provided below for the most common problem weeds; however, for advice on individual paddocks contact your local agronomist.

Benefits of fallow weed control are significant:

- Conservation of summer rain and fallow moisture (this can include moisture stored from last winter or the summer in a long fallow) is integral to winter cropping, particularly in low-rainfall cropping areas and in regions where the climate moves towards summer-dominant rainfall.
- Modelling studies show that the highest return on investment in summer weed control is for lighter soils or in situations where soil water that would support continued weed growth is present.

# IN FOCUS

Summer fallow weed control and residue management impacts on winter crop yield through soil water and N accumulation in a winter-dominant low rainfall region of southern Australia.

The majority of rain used by winter grain crops in the Mallee region of Victoria falls during the cooler months of the year (April–October). However, rain falling during the summer fallow period (November–March) and stored as soil moisture contributes to grain yield. Strategies to better capture and store summer fallow rain include:

- 1. retention of crop residues on the soil surface to improve water infiltration and to minimise evaporation; and
- 2. chemical or mechanical control of summer fallow weeds to reduce transpiration and available nutrient uptake.



<sup>32</sup> GRDC (2012) Summer fallow—make summer weed control a priority. GRDC Fact Sheet January 2012, <a href="https://grdc.com.au/"/media/91deacef2dd843f6bbf9fab09bfe0d65.pdf">https://grdc.com.au/"/media/91deacef2dd843f6bbf9fab09bfe0d65.pdf</a>



**TABLE OF CONTENTS** 





Despite the widespread adoption of no-till farming systems in the region, few published studies have considered the benefits of residue management during the summer fallow relative to weed control, and fewer quantify the impacts of summer fallow weeds or identify the mechanisms by which they influence subsequent crop yield. Over 3 years (2009–11), identical experiments on adjacent sand and clay soil types at Hopetoun in the southern Mallee were conducted to quantify the effects of residue management (standing, removed, or slashed) and summer fallow weed control (chemical control) compared with cultivation on accumulation of soil water and N and subsequent crop yield. The presence of residue (2.4-5.8 t/ha) had no effect on soil-water accumulation and a small negative effect on grain yield on the clay soil in 2011. Controlling summer weeds (Heliotropium europaeum (heliotrope) and volunteer crop species) increased soil-water accumulation (mean 45 mm) and mineral N (mean 45 kg/ha) before sowing on both soil types in two years of the experiment with significant amounts of summer fallow rain (2010 and 2011). Control of summer weeds increased grain yield of canola by 0.6 t/ha in 2010 and of wheat by 1.4 t/ha in 2011. Using the data from these experiments to parameterise the APSIM model, simulation of selected treatments with historical climate data (1958–2011) showed that an extra 40 mm of stored soil water resulted in an average additional 0.4 t/ha yield, most of which was achieved in dry growing seasons. An additional 40 kg N/ha increased yield in wetter growing seasons only (mean 0.4 t/ha on both soil types).

The combination of extra water and N that was found experimentally to result from control of summer fallow weeds increased subsequent crop yield in all season types (mean 0.7 t/ha on sand, 0.9 t/ha on clay). The co-limitation of yield by water and N in the Mallee environment means that yield increases due to summer weed control (and thus returns on investment) are very reliable.  $^{33}$ 

# 1.3.1 The green bridge

The green bridge provides a between-season host for insects and diseases (particularly rusts), which pose a threat to subsequent crops and can be expensive to control later in the season (Photo 4)  $^{34}$ .



<sup>33</sup> JR Hunt, C Browne, TM McBeath, K Verburg, S Craig, AM Whitbread (2013) Summer fallow weed control and residue management impacts on winter crop yield though soil water and N accumulation in a winter-dominant, low rainfall region of southern Australia. Crop & Pasture Science 64, 922–934, http://www.publish.csiro.au/CP/CP13237

<sup>34</sup> DAFWA (2016) Control of green bridge for pest and disease management. DAFWA, <a href="https://www.agric.wa.gov.au/grains/control-green-bridge-pest-and-disease-management">https://www.agric.wa.gov.au/grains/control-green-bridge-pest-and-disease-management</a>





GRDC factsheet, The essential crop management tool: green bridge control is integral to pest and disease management

Summer fallow weed management: A reference manual for grain growers and advisers in the southern and western grains regions of Australia



WATCH: GCTV5: Managing summer fallow



WATCH: Over the Fence south: Summer weed control saves moisture for winter crops





SOUTHERN

JANUARY 2018

Photo 4: Broad-leafed weeds and grasses form a green bridge in paddock.

Source: DAFWA

Key points for control of the green bridge:

- An outright kill of the weeds and volunteers is the only certain way to stop them from hosting diseases and insects.
- Diseases and insects can quickly spread from the green bridge, jeopardising crops and current control methods, including the effectiveness of chemicals and genetic breeding for resistance.
- Effective control of pest and disease risks requires neighbours to work together to eradicate weeds and crop volunteers simultaneously.
- Weed growth during summer and autumn depletes soil moisture and nutrients that would otherwise be available to following crops and can have an allelopathic effect. 35

#### 1.3.2 Management strategies

How farming country is managed in the months or years before sowing can be more important in lifting water-use efficiency (WUE) than in-crop management is. Of particularly high impact are strategies that increase soil capture and storage of fallow rainfall to improve crop reliability and yield.

Practices such as controlled-traffic farming and long term no-till seek to change soil structure to improve infiltration rates and thereby increase plants' access to stored water. This occurs when compaction zones are removed.

Shorter-term management decisions can have an equal or even greater impact on how much plant-available water (PAW) is stored at sowing. These include decisions such as crop sequence and rotation that dictate the length of the fallow and amount of stubble cover, how effectively fallow weeds are managed, stubble management, and decisions about whether to till at critical times.

Although many factors influence how much PAW is stored in a fallow period, good weed management consistently has the greatest impact. 36



 $<sup>{\</sup>sf GRDC}~(2014). Summer fallow weed management.~{\sf GRDC}, \\ \underline{{\sf https://grdc.com.au/Resources/Publications/2014/05/Summer-fallow-weed-f$ management







# Key points:

- Triticale stubble is coarser than either wheat or barley stubble. <sup>37</sup>
- Retaining stubble has several advantages for soil fertility and productivity.

**OUTHERN** 

- Retaining stubble can decrease erosion and increase soil-water content.
- The benefits of stubble retention are enhanced by reduced tillage and leguminous crop rotations.

Historically, stubble has been burnt in southern Australia because doing so results in easier passage for seeding equipment, enhances seedling establishment, and improves the control of some soil-borne diseases and herbicide-resistant weeds. However, the practice of burning stubble has recently declined due to concerns about soil erosion, loss of soil organic matter, and air pollution. Stubble retention has several advantages for soil fertility and productivity (see Photo 5).



Photo 5: Triticale sown into stubble.

Source: T Kaspar in MCCC

Summer rainfall and warmer conditions promote the decomposition of stubble.

#### Reducing erosion risk

One of the main benefits of stubble retention is reduced soil erosion. Retaining stubble decreases erosion by lowering wind speed at the soil surface and by decreasing run-off. At least 50% ground cover is required to reduce erosion; this is generally considered to be achieved by 1 t/ha of cereal stubble, 2 t/ha of lupin stubble or 3 t/ha of canola stubble. A study at Wagga Wagga, NSW, demonstrated that stubble retention reduced soil losses by almost two-thirds compared to burnt paddocks. It also increased infiltration of rainfall.

#### Increasing soil water content

A major advantage of retaining stubble is that it increases soil-water content by decreasing run-off and increasing infiltration (Figure 4). The actual benefits realised depend on the timing and intensity of rainfall as well as the quantity and orientation of the stubble. Rains in late summer—early autumn have more chance of improving the germination and establishment of the next crop. In addition, increased infiltration of water over summer can result in greater nitrogen mineralisation and availability for the subsequent crop.











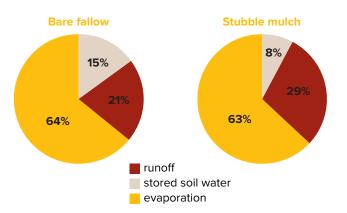


Developments in stubble retention in cropping systems in southern
Australia



WATCH: GCTV4: Managing stubble





SOUTHERN

**Figure 4:** Retained stubble leads to more stored soil water, mostly due to a reduction in runoff.

Source: Felton et al. 1987

#### Increasing soil carbon

Retaining stubble increases the input of carbon to soil. Stubble is approximately 45% carbon by weight and represents a significant input of carbon to soil. However, it can take decades for the practice of retaining stubble to increase the amount of soil organic carbon. In cropping trials with ley pasture rotations at Wagga Wagga, researchers showed that after 10 years, stubble retention generated 2 t/ha more soil organic carbon than burnt-stubble plots to a depth of 10 cm in a red chromosol. After 25 years the inclusion of a clover pasture in the rotation in the same trial had a greater effect on soil organic carbon increases, even with tillage, compared to stubble retention. Retaining stubble may only increase soil carbon where it is coupled with cultivation, but not with direct drilling.

The carbon to nitrogen ratio (C:N) of residues is an important factor in determining the contribution they will make to carbon sequestration, as the ratio governs how quickly residues decompose. Pulse residues (C:N 20:1 to 41:1) decompose faster than wheat residues (C:N 45:1 to 178:1). Faster decomposition may improve nutrient availability for the following crop, but reduce the sequestration of carbon from residues into soil.

#### Other benefits of stubble retention

Retaining stubbles returns nutrients to the soil, the amounts depend on the quality and quantity of stubble. Wheaten stubble from a high-yielding crop may return up to 25 kg of available nitrogen per hectare. The addition of organic matter with retained stubbles supports soil life, and can improve soil structure, infiltration and water-holding capacity. These benefits are greater when integrated with no-till practices. <sup>38</sup>

#### Management practices affecting stubble cover

Stubble burning, grazing and cultivation are the main management practices that reduce stubble cover. A single-tillage operation using a chisel plough, for example, can reduce stubble coverage by 30-40~% (Table 4)  $^{39}$ . It is recommended that stubble cover be maintained as long as possible in the fallow, and that planting and fertilising machinery be adapted to minimise disturbance. Where cultivation is required in order to control herbicide resistant weeds, this should be carried out as a one-off operation.  $^{40}$ 



<sup>38</sup> Carson J, Flower K. Benefits of retaining stubble: NSW. Soilquality.org, <a href="http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble-nsw">http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble-nsw</a>

<sup>39</sup> DEEDI (2011) Measuring and managing stubble cover: photostandards for cereals. Department of Employment, Economic Development and Innovation, <a href="https://www.grainsbmp.com.au/images/documents/Stubble cover final.pdf">https://www.grainsbmp.com.au/images/documents/Stubble cover final.pdf</a>

<sup>40</sup> Soilquality.org. Benefits of retaining stubble: Queensland. Soilquality.org, <a href="http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble-in-qld">http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble-in-qld</a>









WATCH: GCTV15: Stubble height—part 1 and part 2





WATCH: <u>Southern farm groups cutting</u> through stubble issues

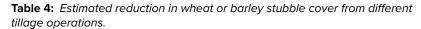


WATCH: Over the Fence south: Jim Cronin



WATCH: <u>Stubble</u> and soil binding of <u>pre-emergent</u> herbicides for annual ryegrass control in winter crops





SOUTHERN

Implement	Residue buried by each tillage operation (%)			
	Fresh stubble	Old (brittle) stubble		
Disc plough	60–80	80-90		
Chisel plough	30–40	40–60		
Blade plough	20-30	30–50		
Boomspray	Negligible	Negligible		

Source: DEEDI

For more information on weed control, see Section 6: Weed control.

# 1.4 Fallow chemical plant-back effects

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of the next crop.

Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods (e.g. sulfonylureas such as chlorsulfuron). This is shown in the Table 5 where known. <sup>41</sup> Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, as the sulfonylureas are. Labels display the plant-back periods, which are usually listed under a separate plant-back heading or under a heading such as 'Protection of crops' in the general instructions section. <sup>42</sup>

Part of the management of herbicide resistance includes rotating herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonyl urea, triazines) may be a problem in some paddocks. Remember that plant-back periods begin after rainfall occurs. <sup>43</sup>

**Table 5:** Residual persistence of common pre-emergent herbicides.

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high pH soils. Weed control commonly drops off within 6 weeks
Glean® (chlorsulfuron)	28–42	High. Persists longer in high pH soils. Weed control longer than Logran.
Diuron	90 (range 1 month to 1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Has been observed to have long-lasting activity on grass weeds such as black grass or stink grass ( <i>Eragrostis</i> spp.) and to a lesser extent broadleaf weeds such as fleabane.
Atrazine	60–100, up to 1 year if dry	High. Has been observed to have long-lasting (>3 months) activity on broadleaf weeds such as fleabane.
Simazine	60 (range 28–149)	Med-high. In high pH soils, 1 year. Has been observed to have long-lasting (>3 months) activity on broadleaf weeds such as fleabane.

<sup>41</sup> B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_ file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf



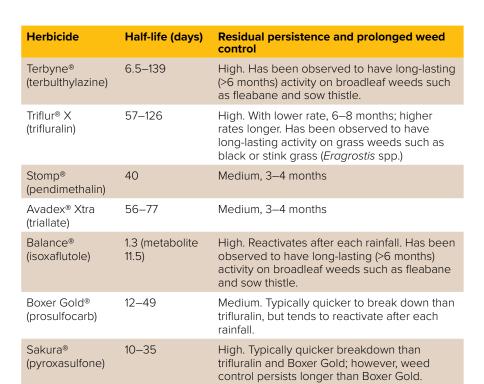
<sup>42</sup> B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

<sup>43</sup> B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <a href="http://www.dpi.nsw.qov.au/">http://www.dpi.nsw.qov.au/</a> data/assets/pdf. file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf



**TABLE OF CONTENTS** 





SOUTHERN

Note that residual persistence is from broad-acre trials and paddock experiences

#### Conditions required for breakdown

Most of the herbicide residues will be found in the topsoil. Warm, moist soils are required to break down most herbicides through the processes of microbial activity. For the soil microbes to be most active they need good moisture and an soil temperature range of 18–30°C. Temperatures above or below this range can adversely affect soil microbial activity, and slow herbicide breakdown. Soil type and pH also have an influence on the rate at which chemicals degrade. Very dry soil also reduces the rate of breakdown. To make matters worse, when the soil profile is very dry, a lot of rain is required to rebuild then maintain topsoil moisture for the microbes to be active for any length of time.

In those areas that do not experience conditions which will allow breakdown of residues until just prior to sowing, it is best to avoid planting a crop that is sensitive to the residues potentially present in the paddock, and opt for a crop that will not be affected.

If dry areas do get rain and the temperatures become milder, then they are likely to need substantial rain (more than is stated on the label requirement) to wet the subsoil, in order for the topsoil to remain moist for a week or more and allow the microbes to be active in the topsoil.  $^{44}$ 

#### Plant-back periods for fallowing herbicides

Herbicide plant-back restrictions should be taken into account when spraying fallow weeds prior to sowing winter crops. Many herbicide labels place time and/or rainfall restrictions on sowing certain crops and pastures after application, so as to avoid potential seedling damage. Crops such as canola, pulses and legume pastures are the most sensitive to herbicide residues, but cereal crops can also be affected.

When treating fallow weeds, especially in late summer or autumn, consideration must be given to the planned crop or pasture for the coming year. In some cases, next year's crop or pasture may an influence the grower's herbicide choice this season.



<sup>44</sup> Dow AgroSciences. Rotational crop plant-back intervals for southern Australia. Dow AgroSciences, <a href="http://msdssearch.dow.com/PublishedLiteratureDAS/dh\_0931/0901b80380931d5a.pdf?filepath=au&fromPage=GetDoc">http://msdssearch.dow.com/PublishedLiteratureDAS/dh\_0931/0901b80380931d5a.pdf?filepath=au&fromPage=GetDoc</a>





The following points are especially relevant:

Phenoxy herbicides such as 2,4D Ester, 2,4D Amine and Dicamba, require 15 mm of rainfall to commence the plant-back period when applied to dry soil.

SOUTHERN

- Group B herbicides such as Ally®, Logran® and Glean®, break down more slowly as soil pH increases. Recently applied lime can increase the soil surface pH to a point where the plant-back period is significantly extended.
- Lontrel®, Grazon® and Tordon® products break down very slowly under cold or dry conditions, and this can significantly extend the plant-back period.

Keeping accurate records of all herbicide treatments and planning crop sequences well in advance can reduce the chance of crop damage resulting from the presence of herbicide residues (Table 6). 45

**Table 6:** Indicative plant-back intervals for a selection of fallow herbicides.

Product	Rate	Wheat	Barley	Oats	Canola	Legume pasture	Pulse crops
2,4-D 680*	0-510 mL/ha	1 day	1 day	1 day	14 days	7 days	7 days
	510–1,150 mL/ha	3 days	3 days	3 days	21 days	7 days	14 days
	1,150–1,590 mL/ha	7 days	7 days	7 days	28 days	10 days	21 days
Amicide® Advance 700*	0–500 mL/ha	1 days	1 days	1 days	14 days	7 days	7 days
	500-980 m/ha	3 days	3 days	3 days	21 days	7 days	14 days
	980–1500 mL/ha	7 days	7 days	7 days	28 days	10 days	21 days
Kamba*	200 mL/ha	1	1	1	7	7	7
	280 mL/ha	7	7	7	10	14	14
	560 mL/ha	14	14	14	14	21	21
Hammer® 400 EC		No residua	l effects				
Nail® 240 EC		No residua	l effects				
Goal®		No residua	l effects				
Striker®		No residua	l effects				
Sharpen®	26 g/ha	_	_	_	16 weeks	_	_
Lontrel™	300 mL/ha	1 week	1 week	1 week	1 week	36 weeks	36 weeks
Garlon™ 600	Various	1 week	1 week	NS	NS	NS	NS
Ally®**	Various	2 weeks	6 weeks	36 weeks	36 weeks	36 weeks	36 weeks
Logran®#	Various	_	_	_	12 months	12 months	12 months
Glean®**	Various	-	9 months	6 months	12 months	12 months	12 months
Grazon™ Extra, Grazon™ DS	Rates up to 500 mL/ha	9 months	9 months	NS	9 months	24 months	24 months
Tordon™ 75-D, Tordon™ 242	Various	2 months	2 months	NS	4 months	9 months	6 months
FallowBoss Tordon™	Up to 700 mL/ha	9 months	9 months	NS	12 months	20 months	20 months

For triticale, plant-back periods for wheat or barley are a reference point.

\*15 mm rainfall required to commence plant-back period;

\*\*, period may extend where soil pH is >7;

Source: RMS Agricultural Consultants



<sup>#,</sup> assumes 300 mm rainfall between chemical application and sowing;

RMS Agricultural Consultants (2016) Plant-back periods for fallow herbicides in southern NSW. RMS, <a href="http://www.rmsag.com.au/2016/">http://www.rmsag.com.au/2016/</a> plant-back-periods-for-fallow-herbicides-in-southern-nsw/



**TABLE OF CONTENTS** 





# 1.4.1 Herbicide residues in soil: an Australia-wide study

The move to conservation tillage and herbicide-tolerant crop cultivars means that, more than ever before, many farmers rely on herbicides for weed control. Despite the provision of plant-back guidelines on herbicide product labels, site-specific factors such as low rainfall, constrained soil microbial activity and unfavourable pH may cause herbicides to persist in the soil beyond usual expectations. Because of the high cost of herbicide residue analysis, information about herbicide residue levels in Australian grain cropping soils is scarce.

In addition, little is known about how herbicides affect soil biological processes and what this means for crop production. This is especially the case for repeated applications over multiple cropping seasons. In Australia, herbicides undergo a rigorous assessment by the Australian Pesticides and Veterinary Medicines Association (APMVA) before they can be registered for use in agriculture. However, relatively little attention is given to the soil biology on the farm—partly because we are only now beginning to grasp its complexity and importance to sustainable agriculture. Although a few tests such as earthworm toxicity tests and effects on soil respiration are mandatory, ,functional services provided by soil organisms such as organic matter turnover, nitrogen cycling, phosphorus solubilisation and disease suppression are usually overlooked.

GRDC has co-funded a five-year project (DAN00180) to better understand the impact of greater herbicide use on the most important soil biological processes; the project will conclude in 2018. The national project, coordinated by the NSW Department of Primary Industries, and with partners in Western Australia, South Australia, Victoria and Queensland, is focussed on the effect of at least six classes of herbicides on the biology and function of five key soil types across all three grain-growing regions. <sup>46</sup>

There are already some results from the project. A field survey of herbicide residues in 40 cropping soils—15 in SA, 12 in WA, and 13 in NSW—Queensland—prior to sowing and pre-emergent herbicide application was conducted in 2015 (Table 7). The researchers are most interested in the effects of the herbicides that were most frequently detected. Recommendations are given to minimise potential impacts of herbicide residues on productivity and soil sustainability. We also provide detail plans for future research and the development of management tools for growers to monitor and predict herbicide persistence in soils.

The average and maximum estimated loads of glyphosate, trifluralin, diflufenican and diuron were all substantially higher in paddocks in WA compared with those in SA, NSW and Queensland. This probably reflects the lighter soil types, lower level of organic matter, dry summers and cool winters, which contribute to lower microbial activity and constrain herbicide breakdown. The higher load of atrazine in SA paddocks is probably a consequence of the higher persistence of s-triazine herbicides in alkaline soils; and the higher values for 2,4-D in the NSW–Queensland soil profiles was due to a high value in a single paddock which had recently been sprayed.

Notably, in a number of paddocks (especially in WA but also in other states), they found a higher load of glyphosate than was applied in the previous spray, demonstrating a degree of accumulation of glyphosate and its metabolite AMPA over time.



<sup>46</sup> GRDC (n.d.) DAN00180: Does increased herbicide use impact on key biological processes?, GRDC, <a href="http://projects.grdc.com.au/">http://projects.grdc.com.au/</a> projects.php?action=view\_project&project\_id=2416

**MORE INFORMATION** 

Herbicide residues in soils: are they

Weed control in winter crops

an issue?



**TABLE OF CONTENTS** 



Table 7: Residue loads (average and maximum) of herbicide active ingredients (a.i.) in the 0-30 cm soil profile of paddocks, by region.

Herbicide	Estimated average load across all sites (kg a.i./ha)*			Estimated maximum load detected (kg a.i./ha)*		
	NSW-Qld	SA	WA	NSW-Qld	SA	WA
AMPA	0.91	0.95	0.92	1.92	1.97	2.21
Glyphosate	0.56	0.48	0.79	2.05	1.05	1.75
Trifluralin	0.08	O.11	0.53	0.14	0.26	1.34
Diflufenican	0.01	0.03	0.04	0.02	0.05	0.09
Diuron	0.14	0.05	0.17	0.16	0.05	0.29
2, 4-D	0.20	0.02	0.01	1.00	0.05	0.02
MCPA	0	0	0	0	0	0
Atrazine	0.02	0.03	0.02	0.03	0.05	0.02
Simazine	0	0.04	0	0	0.05	0
Fluroxypyr	0.03	0	0	0.03	0	0
Dicamba	0	0	0	0	0	0
Triclopyr	0	0.04	0.01	0	0.07	0.01
Chlorsulfuron	0	0	0	0	0	0
Sulfometuron- methyl	0	0	0	0	0	0
Metsulfuron- methyl	0	0	0	0	0	0
Triasulfuron	0	0	0	0	0	0

<sup>\*</sup> Calculated by multiplying mass concentration (mg/kg) detected by area and average bulk density (derived from Soilquality.org) for each soil layer

Source: GRDC

Glyphosate, trifluralin and diflufenican are routinely applied in grain cropping systems, and their residues, plus the glyphosate-metabolite AMPA, are frequently detected at agronomically significant levels at the commencement of the winter cropping season.

The risk to soil biological processes was generally considered minor when herbicides are used at label rates and given sufficient time to dissipate before re-application. However, given the frequency of glyphosate application, and the persistence of trifluralin and diflufenican, further research is needed to define critical thresholds for these chemicals to avoid potential negative impacts to soil function and crop production. 47

For more information on herbicide residues, see Section 6: Weed control.

# Seedbed requirements

Seedbed preparation for triticale is very similar to that for wheat. As with all cereals, triticale should be planted into a firm seedbed near moisture. <sup>48</sup> A good seedbed is free of weeds, diseases and insects. To aid erosion control, use implements that will preserve previous crop residue. Substitution of herbicides for cultivation and seeding without pre-seeding tillage (minimum to no-tillage) are other practical considerations. Under conditions of dry or firm soil, seeding should be done with implements that minimise soil disturbance, such as air drills with disc or narrow openers together with press-wheels, to prevent soil drying.

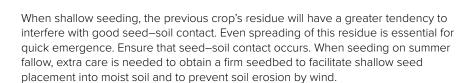


<sup>47</sup> M Rose, L Van Zwieten, P Zhang, D Nguyen, C Scanlan, T Rose, G McGrath, T Vancov, T Cavagnaro, N Seymour, S Kimber, A Jenkins, A Claassens, I Kennedy I (2016) Herbicide residues in soils—are they an issue? GRDC Update Paper, February 2016, <a href="https://grdc.com/ntesearch-and-Development/GRDC-Update-Papers/2016/02/Herbicide-residues-in-soils-are-they-an-issue">https://grdc.com/ntesearch-and-Development/GRDC-Update-Papers/2016/02/Herbicide-residues-in-soils-are-they-an-issue</a>

M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, http://www.fao.org/3/a-y5553e/y5553e00.pdf

**TABLE OF CONTENTS** 





**OUTHERN** 

Cereals can be conventionally sown or direct-drilled into a weed-free seedbed from March to mid-June.

If irrigating, pre-irrigation is favoured over 'irrigating up' after sowing, because seeds can swell and burst. Sowing should be as soon after pre-irrigation as soil conditions allow. For a pre-irrigation on 1 April, this delay may range from one week on light soils to three–four weeks on some heavy clay soils.

Subsequent irrigations should be at cumulative evaporation minus rainfall (E - R) of 75 mm on grey soils and 50 mm on red soils.

Pre-irrigation completed by 1 April is a safe option in most years. Later irrigations can cause problems by making the ground too wet for both sowing and grazing. If not pre-irrigated, then the crop should be sown following sufficient rainfall to wet the soil to 100 mm depth.  $^{49}$ 

Several approaches can be used to achieve a good seedbed preparation. The deciding factor in choosing an approach is how the various techniques manage harvest residues.

The seedbed lays the foundations for crop establishment. However, different techniques can be used to create a seedbed (refer to Figure 5):

- Conventional technique: ploughing in of straw, cultivation to sowing depth with a tyne/disc cultivator, conventional drilling, fertiliser spreading
- 2. Mouldboard ploughing + seed-drilling: ploughing-in of straw, shallow cultivation, drilling where seed and fertiliser are placed in the soil simultaneously
- 3. Minimal tillage: tillage of straw by cultivator, seed drilling where seed and fertiliser are placed simultaneously in the soil–straw layer
- 4. Shallow tillage: shallow burial of straw at the surface, seed-drilling where seed and fertiliser are placed simultaneously in the soil–straw layer.
- 5. Direct drilling: seed-drilling where seed and fertiliser are placed simultaneously without prior soil tillage; straw remains on the surface.

The technique used depends on many different factors, e.g. harvest residues, equipment available, soil type, climate, labour requirement.

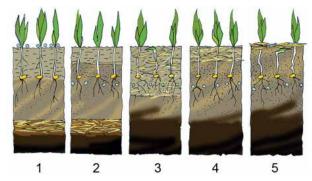


Figure 5: Different seedbed preparation techniques give different results.

Source: Vaderstad

Ploughing warms the soil and buries plant residues so that they do not obstruct sowing. However, ploughing also disrupts the soil structure and increases oxidation of



<sup>49</sup> Agriculture Victoria (2105) Managing winter cereals. State Government of Victoria EDJDR, <a href="http://agriculturevic.gov.au/agriculture/dainy/pastures-management/irrigated-pastures/managing-winter-cereals">http://agriculturevic.gov.au/agriculture/dainy/pastures-management/irrigated-pastures/managing-winter-cereals</a>





organic material. Without ploughing, organic material and soil structure are retained, but the straw can cause problems with sowing and can transmit diseases. <sup>50</sup>

**OUTHERN** 

JANUARY 2018

#### 1.5.1 Structural decline of seedbed soil

Key points:

- Hard-setting or crusting soils usually have poor structure.
- A 'massive' soil has significantly reduced pore space, resulting in poor infiltration and low water-holding capacity.
- Bulk density is a good indicator of soil structure.
- Increasing organic matter and decreasing traffic and stock can improve soil structure.
- Gypsum can help in alleviating problems with hard-setting or crusting.

#### **Background**

Structural decline of surface soil generally results in one of two things: hard-setting or crusting (Photo 6). <sup>51</sup> A surface crust is typically less than 10 mm thick and when dry can normally be lifted off the loose soil below. Crusting forces the seedling to exert more energy to break through to the surface, thus weakening it. A surface crust can also form a barrier reducing water infiltration.

Soil structure breakdown caused by rapid wetting can lead to hard-setting. Once wet, the unstable soil structure collapses, and shrinks as it dries. This leads to a 'massive' soil layer, with few or no cracks and greatly reduced pore spaces. This hard-set, massive structure is associated with poor infiltration, low water-holding capacity and a high soil strength. In many instances, this causes patchy establishment and poor crop and pasture growth.



**Photo 6:** Soil crusting (left) and cloddy seedbed (right) associated with high concentrations of exchangeable sodium.

Source: Soilquality.org

#### Management to improve seedbed soil structure

To decrease the level of crusting or hard-setting in soils, it is necessary to stabilise soil structure. For example, amelioration of a hard-setting grey clay was found to be most effective when using management practices that increased soil organic matter and reduced traffic, to improve the soil structure. Removing or reducing stock when the soil is saturated also helps avoid compaction, smearing and pugging of the soil surface. Another option for stabilising soil structure in dispersive soils prone to hard-setting or crusting is through the addition of gypsum. This effectively displaces sodium and causes clay particles to bind together, helping to create stable soil



<sup>50</sup> Väderstad (2015) Seedbed preparation, Väderstad AB, http://www.vaderstad.com/knowhow/seed-beds/seedbed-creation

 $<sup>51 \</sup>quad \text{Soilquality.org..} \ \text{Soilquality,} \ \underline{\text{http://www.soilquality.org.au/factsheets/seedbed-soil-structure-decline-queensland}$ 



**TABLE OF CONTENTS** 



aggregates. A resulting reduction in the Exchangeable Sodium Percentage (ESP) and increase in the calcium:magnesium ratio may be observed. The addition of lime also adds calcium to the soil, but this technique is generally only used for soils with a low pH.  $^{52}$ 

SOUTHERN

# 1.5.2 Tillage

Tilling mixes and buries soil amendments and crop residues, eliminates existing vegetation, reduces pest populations, promotes mineralisation of soil organic matter, and creates a seedbed that facilitates mechanical planting and seed-to-soil contact.

The use of minimum soil disturbance has advantages for the production of triticale. One study noted a slight yield advantage for triticale grown under zero tillage. 53

Research shows that one-time tillage with a chisel or offset disc in long-term, no-tillage system helped to control winter weeds, and slightly improved grain yields and profitability, while retaining many of the soil quality benefits of no-till farming systems (Photo 7). <sup>54</sup> Although tillage reduced soil moisture at most sites, this did not adversely affect productivity. This could be due to good rainfall received after tilling and before seeding that year. The occurrence of rain between tilling and sowing or immediately after sowing is necessary to replenish soil water lost from the seed zone. This suggests the importance of the timing of tillage and of considering the seasonal forecast. Future research will determine the best timing for strategic tillage in no-till systems (Photo 8). <sup>55</sup> Note that these results are from one season, and so are inconclusive. As research continues, and captures the effects of variances in seasonal conditions, more conclusive results will emerge.



**Photo 7:** The impact of tilling varies with the implement used: inversion tillage using a mouldboard plough, as pictured here, results in greater impacts than using a chisel or disc plough.

Source: GRDC



 $<sup>52 \</sup>quad \text{Soilquality.org. Seedbed soil structure decline.} \\ \underline{\text{www.soilquality.org.au/factsheets/seedbed-soil-structure-decline}}$ 

<sup>53</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>54</sup> GRDC (2014) Strategic tillage. Factsheet. GRDC, <a href="https://grdc.com.au/Resources/Factsheets/2014/07/Strategic-tillage">https://grdc.com.au/Resources/Factsheets/2014/07/Strategic-tillage</a>

<sup>55</sup> Y Dang, V Rincon-Florez, C Ng, S Argent, M Bell, R Dalal, P Moody, P Schenk (2013) Tillage impact in long term no-till. GRDC Update Paper February 2013. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Tillage-impact-in-long-term-no-till">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Tillage-impact-in-long-term-no-till</a>



**TABLE OF CONTENTS** 





WATCH: GCTV11: Strategic tillage—does no-till mean never till?



WATCH: Over the Fence south:
Andrew Simpson





SOUTHERN

JANUARY 2018

**Photo 8:** Strategic tillage can control herbicide-resistant weeds and those that continue to shed seed throughout the year. Here it has been used for control of barnyard grass in fallow.

Source: GRDC

On the downside, tillage can also result in more soil erosion and surface-water eutrophication. During the past decades, much progress has been made in reducing tillage. No-tillage crop production has increased 2.5-fold from about 45 million ha worldwide in 1999 to 111 million ha in 2009. The no-till trend has also come hand-in-hand with the increased use of herbicides to suppress weeds. <sup>56</sup>

In general, pre-plant tilling to prepare the seedbed, control weeds, and disrupt insect and disease life cycles improves crop establishment. However, no-till seeding is now the preferred method of crop establishment across the southern region and is highly suitable to the establishment of triticale across all soil types.

# IN FOCUS

#### Tillage, microbial biomass and soil biological fertility

In the mid-1990s, no-tillage farmers called for an experiment to test anecdotal reports that low-disturbance tillage increased total organic carbon (TOC) in soil.

A seven-year experiment was conducted in the central wheatbelt of Western Australia on a property with deep sandy soil that was using a lupin—wheat rotation. The experiment compared the effect of three tillage types on TOC, light-fraction organic carbon (LFC), soil microorganisms and crop yields:

- 1. No-tillage—no soil disturbance other than seeding
- 2. Conservation tillage—a single pass before seeding with 13-cm-wide tynes to a depth of  $^{\sim}$ 7.5 cm
- 3. Rotary tillage—a single intense cultivation before seeding to a depth of 8 cm, using a rotary hoe.



<sup>56</sup> MR Ryan, SB Mirsky, DA Mortensen, JR Teasdale, WS Curran (2011) Potential synergistic effects of cereal rye biomass and soybean planting density on weed suppression. Weed science, 59 (2), 238–246.



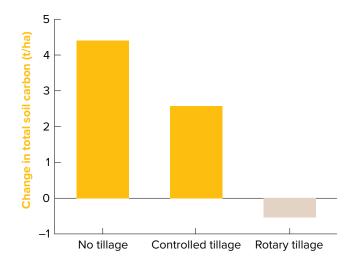




The TOC is a measure of all carbon contained within soil organic matter. Low levels can indicate problems with unstable soil structure, low cation exchange capacity and nutrient turnover (see Soil Quality Fact Sheet: <u>Total</u> organic carbon).

SOUTHERN

After seven years, TOC had increased by 4.4 t/ha under no-tillage and by 2.6 t/ha under conservation tillage (Figure 6), but had decreased by 0.5 t/ha under rotary tillage.



**Figure 6:** Change in total soil carbon content at 0–10 cm soil depth from 1998 to 2004 in crops under three tillage regimes. No-tillage and conventional tillage treatments were not significantly different from each other; rotary tillage was significantly different from both (at P = 0.05).

Source: Soilquality.org

#### Light-fraction organic carbon

The LFC consists of more recent, readily decomposable inputs of organic matter. LFC responds more quickly to management than TOC and better reflects changes in soil microbiology. The LFC decreased as tillage became more intensive.

By the end of the experiment, LFC in the top 10 cm was 0.83 t/ha under no-tillage, 0.73 t/ha under conservation tillage and 0.46 t/ha under rotary tillage.

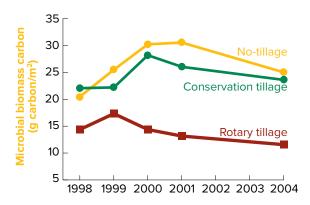
This may indicate that less intensively tilled soils are more biologically active and have higher potential for nutrient turnover, and that TOC may increase further in the future.

On the other hand, the losses with rotary tillage of both TOC and LFC could lead to degradation of soil structure and ultimately to a decline in productivity.

#### Soil microorganisms

Microbial biomass carbon is a measure of carbon in the soil microorganisms (see Soil Quality Fact Sheet: <u>Microbial biomass</u>). Microbial biomass carbon in 0–5 cm soil decreased under rotary tillage compared with no-tillage and conservation tillage (Figure 7).





SOUTHERN

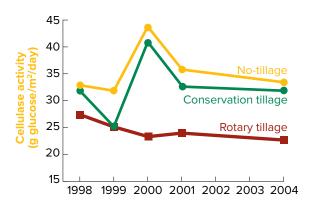
**Figure 7:** Microbial biomass carbon at 0–5 cm depth of cropped soil under three tillage regimes.

Source: Soilquality.org

Microbial biomass nitrogen was also higher under no-tillage and conservation tillage than under rotary tillage. By the end of the experiment, microbial biomass nitrogen under no-tillage and conservation tillage was 31% higher than under rotary tillage.

Tillage also decreased microbial activity in soil. The activity of the microbial enzyme cellulase at 0–5 cm soil depth was higher under no-tillage and conservation tillage than rotary tillage (Figure 8).

This indicates that less intensive cultivation may favour sustained microbial function in soil.



**Figure 8:** Activity of the microbial enzyme cellulase at 0–5 cm depth of cropped soil under three tillage regimes.

Source: Soilquality.org

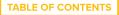
#### Crop yields

Tillage practice did not affect crop yields except in one year of the trial, 2003, when lupin grain yields were higher under no-tillage (2 t/ha) and conservation tillage (1.9 t/ha) than under rotary tillage (1.6 t/ha).

Although tillage did not affect wheat grain yield, it did affect the incidence of Rhizoctonia bare patch (caused by *Rhizoctonia solani*; see Soil Quality Fact Sheet: <u>Rhizoctonia</u>). Wheat plants grown under both no-tillage and











# **MORE INFORMATION**

GRDC, <u>Strategic tillage in no-till</u> <u>systems</u>

Organic carbon

Microbial biomass

Rhizoctonia



WATCH: Adoption of no till SA Mallee



conventional tillage were more visibly affected by Rhizoctonia bare patch than those grown under rotary tillage.

SOUTHERN

Although overall results for no-tillage and conservation tillage were similar, they may diverge in the longer term.  $^{57}$ 

#### 1.6 Soil moisture

Triticale performs well under rain-fed conditions throughout the world and excels when produced where there is good soil fertility and irrigation. <sup>58</sup> It is grown in areas with an annual average rainfall of about 300 mm to at least 900 mm. Very little triticale is irrigated. <sup>59</sup>

# 1.6.1 Dryland

Water availability is a key limiting factor for cereal production in the grainbelt of Australia. Varieties with improved adaptation to water-limited conditions are actively sought, and studies have been carried out to identify the physiological basis of the adaptive traits underpinning this advantage.

# IN FOCUS

# Soil-water extraction by dryland crops, annual pastures and lucerne in south-eastern Australia

The extraction of soil water by dryland crops and pastures in south-eastern Australia was examined in 3 studies. The first was a review of 13 published measurements of soil-water use under wheat at several locations in southern New South Wales. Of these, eight showed that crops extracted significantly more water when they were grown with an increased nitrogen supply or after a break crop. The mean additional soil-water extraction in response to extra N was 11 m, and after break crops was 31 mm.

The second study showed how good management can change crop yields and prevent the unnecessary loss of water. Researchers used the SIMTAG model to simulate growth and water use by wheat at Wagga Wagga. The model was set up to simulate two typical situations: crops that produced average district yields; and crops that might produce greater yields with good management. When simulated over 50 years of weather data, the combined water loss as drainage and run-off was predicted to be 67 mm/ year for poorly managed crops and 37 mm for well-managed crops. Water outflow was concentrated in 70% of years for the poorly managed crops and 56% for the well-managed crops. In those years the mean losses were estimated to be 95 mm and 66 mm, respectively.

The third study reported on soil water measured twice each year during a phased pasture—crop sequence over 6.5 years at Junee. Mean water content of the top 2.0 m of soil under a lucerne pasture averaged 211 mm



<sup>57</sup> M Roper, J Carson, D Murphy. Tillage, Microbial biomass and soil biological fertility. Soil Quality Pty Ltd, <a href="http://www.soilquality.org.au/">http://www.soilquality.org.au/</a> factsheets/fillage-microbial-biomass-and-soil-biological-fertility

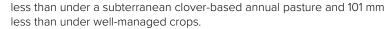
<sup>58</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

KV Cooper, RS Jessop, NL Darvey (2004) Triticale in Australia. In M Mergoum, H Gómez-Macpherson (eds), Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="ftp://ftp.fao.org/docrep/fao/009/y5553e/y5553e02.pdf">ftp://ftp.fao.org/docrep/fao/009/y5553e/y5553e02.pdf</a>



**TABLE OF CONTENTS** 





SOUTHERN

Collectively, these results suggest that lucerne pastures and improved crop management can result in greater use of rainfall than the other farming systems, which were based on growing annual pastures, and using fallow, and poor management techniques for growing crops. The tactical use of lucerne-based pastures in sequence with well-managed crops can help the dewatering of the soil and reduce or eliminate the risk of groundwater recharge. <sup>60</sup>

#### Monitoring soil moisture in dryland areas

Grain growers are under pressure to increase production across the seasons; adding to the complexity of this demand is the likelihood that, if the climate becomes more variable, rainfall may decrease or its distribution change. Even now, current cropping systems may not be maximising Water Use Efficiency, if growers are relying on subjective assessments. Few are able to monitor the amount of water available to the crop, and hence cannot supply the crop with the appropriate amount of inputs to maximise yield.

One tool that helps farmers improve Water Use Efficiency is the soil-moisture probe, but few farmers in the dryland cropping industry use it. To change that, Victoria's Department of Environment and Primary Industries will provide live deepsoil-moisture data to help dryland croppers, farmers, and advisers and managers validate the technology, as well as conducting training to interpret the data for crop decision-making. <sup>61</sup> Communication will include monthly broadcasts of 'The Break', soil-moisture products; and the government will piloting new formats to expand reach and impact.

This project will assist people in the grain sector to lift production and improve grain quality to meet the demand of the growing Asian consumer market (via the government's Food to Asia plan). Increasing targeted inputs and improving crop management will be accomplished by educating industry to understand soil and water interactions and critical crop growth stages, as well as factoring in seasonal forecasts.

Access to this data enables growers and advisers to:

- Measure moisture at one representative point in the paddock for a farm in the region.
- Use live soil-moisture data that is collected from a representative site for a particular rainfall region and soil type.
- Monitor local weather (rain, wind and temperature and humidity) and download historical data from an archive list for farm management records.
- Increase production and efficiencies.
- Help farmers to adapt to climate variability.
- Make informed decisions such as minimising input in low-decile years with a low soil-moisture base and maximising yield potential in more favourable conditions, based on current soil-moisture levels and incorporating knowledge from seasonal forecasts.
- Determine if measurements obtained through the life of the project could be relevant at whole-farm or even district level.



Soil moisture monitoring in dryland

**MORE INFORMATION** 

- 60 JF Angus, RR Gault, MB Peoples, M Stapper, AF Van Herwaarden (2001) Soil water extraction by dryland crops, annual pastures, and lucerne in south-eastern Australia. Crop and Pasture Science, 52 (2), 183–192.
- 61 Agriculture Victoria (2016) Soil moisture monitoring in dryland cropping areas. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/soil-moisture-monitoring-in-dryland-cropping-areas">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/soil-moisture-monitoring-in-dryland-cropping-areas</a>



cropping areas



**TABLE OF CONTENTS** 





# 1.6.2 Irrigation

Effective irrigation will influence the entire growth process, from seedbed preparation, germination and root growth, through nutrient utilisation and plant growth and regrowth, to yield and the quality of the yield.

The key to maximising irrigation efforts is uniformity. The producer has a lot of control over how much water to supply and when to apply it, but it is the irrigation system that determines uniformity. Deciding which irrigation systems is best for your operation requires a knowledge of equipment, system design, plant species, growth stage, root structure, soil composition, and land formation. Irrigation systems should encourage plant growth while minimising salt imbalances, leaf burn, soil erosion, and water loss. Water will be lost through evaporation, wind drift, run-off, and water (and nutrients) sinking deep below the root zone.

Proper irrigation management takes careful consideration and vigilant observation.

Irrigation allows primary producers to:

- · Grow more pastures and crops.
- Have more flexibility in their systems and operations as the ability to access
  water at times when it would otherwise be hard to achieve good plant growth
  (due to a deficit in soil moisture) is imperative. Producers can then achieve higher
  yields and meet market and seasonal demands, especially if rainfall events
  do no occur.
- Produce higher quality crops and pastures as water stress can dramatically impact on the quality of farm produce.
- Lengthen the growing season (or start the season earlier).
- Have 'insurance' against seasonal variability and drought.
- Stock more animals per hectare and practice tighter grazing management, due to the reliability of pasture supply throughout the season.
- Maximise benefits of fertiliser applications. Fertilisers need to be watered into the ground in order to best facilitate plant growth.
- Use areas that would otherwise be less productive. Irrigation can allow farmers
  to open up areas of their farms where it would otherwise be too dry to grow
  pasture or crops. This also gives them the capability to carry more stock or to
  conserve more feed.
- Take advantage of market incentives for unseasonal production.
- Be less reliant on supplementary feeding (i.e. grain, hay) in grazing operations due to the more consistent supply and quality of pastures grown under irrigation.
- Improve the capital value of their property. Since irrigated land can potentially support higher density crops, pasture and animal production, it is considered more valuable. The value of the property is also related to the water licensing agreements or water rights.
- Save costs or obtain greater returns. These occur from the more effective use of fertilisers and greater financial benefits as a result of more effective agricultural productivity (both quality and quantity) and for out-of-season production. <sup>62</sup>

Irrigation has also been found to be effective in increasing both shoot Zn content and Zn efficiency of cereal cultivars. It has been suggested that plants become more sensitive to Zn deficiency under rain-fed than irrigated conditions. <sup>63</sup>

The main commercial triticale varieties are relatively tall compared with newer wheat varieties, increasing the likelihood of lodging. However, in reality, in most of the newer



<sup>62</sup> Agriculture Victoria (2015) About irrigation. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/firrigation/about-irrigation">http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/firrigation/about-irrigation</a>

<sup>63</sup> H Ekiz, SA Bagci, AS Kiral, S Eker, I Gültekin, A Alkan, I Cakmak (1998) Effects of zinc fertilisation and irrigation on grain yield and zinc concentration of various cereals grown in zinc-deficient calcareous soils. Journal of Plant Nutrition, 21 (10), 2245–2256, <a href="https://www.researchgate.net/publication/249076820">https://www.researchgate.net/publication/249076820</a> Effects of Zinc fertilisation and irrigation on grain yield and zinc concentration of various cereals grown in zinc-deficient calcareous soils







varieties lodging is not considered a problem, although it is more the likely to occur with high rates of nitrogen fertiliser and under irrigated conditions (Table 8). 64

SOUTHERN

Table 8: Lodging scores in NVT trials, 2008.

Variety	Score
Bogong()	0/5
Jaywick(b	3/5
Tahara	3/5
Tobruk(D	0/5
Canobolas(b	0/5
Berkshire(b	1/5
JRCT 101	0/5
Yukuri	5/5
Rufus	5/5

Note: A score of 0 means the variety was not prone to lodging and a score of 5 means that the variety is prone to heavy lodging. Source: Jessop & Fittler 2009

# IN FOCUS

### Genetic improvement of triticale for irrigation in southeastern Australia

Research into winter cereal breeding in Australia has focused primarily on studying the effects of rain-fed environments. These studies typically show large genotype × environment (GE) interactions, and the complexity of these interactions acts as an impediment to the efficient selection of improved varieties. Wheat had been studied extensively; however, there were no published studies on the GE interactions of triticale in Australia under irrigated production systems.

To rectify this situation, researchers conducted trials on 101 triticale genotypes at two locations over four years. All the genotypes were subjected to intensive irrigation. The researchers measured the yield potential, GE interactions, heritability and estimated genetic gain of yield, lodging resistance, and several other traits important for breeding triticale. They found that high yield potential exceeding 10 t/ha-1 existed in the Australian germplasm tested and that, in these irrigated trials, genotype accounted for a high proportion of the variability in all measured traits. All genetic parameters such as heritability and estimated genetic gain were high compared with those tested in rain-fed environments.

They concluded that breeding triticale with improved yield and lodging resistance for irrigated environments is achievable and can be pursued with confidence in breeding programs. 65



<sup>64</sup> RS Jessop, M Fittler (2009) Appendix 1, Triticale production manual; an aid to improved triticale production and utilisation. In J Roake, n, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, http au/1A-102\_Final\_Research\_Report\_pdf

<sup>65</sup> A Milgate, B Ovenden, D Adorada, C Lisle, J Lacy, N Coombes (2015) Genetic improvement of triticale for irrigated systems in south-eastern Australia: a study of genotype and genotype× environment interactions. Crop and Pasture Science, 66 (8), 782–792.



**TABLE OF CONTENTS** 

FEEDBACK



# **MORE INFORMATION**

Agriculture Victoria: About irrigation

GRDC Update Paper: The Future of irrigation, what's in store

### The future of irrigation

Climate change is likely to lead to reductions in rainfall in south-eastern Australia. These reductions in rainfall will be amplified such that proportional reductions in runoff are likely to be two–four times larger. That is, a 10% rainfall reduction will lead to a 20–40% reduction in runoff. The runoff reductions will be larger in drier catchments, making the water supply systems with drier source catchments more vulnerable. The experience of the Millennium Drought has shown that reductions in runoff under persistent climate change (~10-year drought) are larger than reductions that occur for short droughts with similar rainfall reductions in many catchments. <sup>66</sup>

SOUTHERN

# 1.7 Yield and targets

Australia's climate, and in particular our rainfall, is among the most variable on earth; consequently, crop yields vary noticeably from season to season. In order to remain profitable, crop producers must manage their agronomy, crop inputs, marketing and finance to match each season's yield potential.

The average grain yield of triticale is about 2.5 t/ha, although yields vary locally from less than 1 t/ha in lower-rainfall areas and areas with soil problems to more than 7 t/ha in higher-rainfall areas with more fertile soils.  $^{67}$ 

In dry springs, triticale yields are 10-15% below wheat, due to triticale's longer grain-filling period. <sup>68</sup> However, under ideal conditions, researchers have found that triticale can out-yield wheat and barley, and sometimes oats. <sup>69</sup>

Observed traits suggested for the higher yields in triticale than wheat include greater early vigour, a longer spike-formation phase with same duration to flowering, reduced tillering, increased remobilization of carbohydrates to the grain, early vigorous root growth and higher transpiration use efficiency. 70

The southern region has soils with generally low fertility, and many have subsoil constraints such as salinity, sodicity and toxic levels of some elements. However, soils in the region are diverse and some areas have very productive soils. Crop-production systems in the region are varied and include many mixed-farming enterprises that have significant livestock and cropping activities.

Achieving yield potential in the southern region depends on seasonal rainfall, especially in autumn and spring There is less dependence on stored soil moisture in the south than in the northern region.

In the southern grain-growing region, the most significant yield constraints are high soil density, sodicity and acidity.  $^{71}$ 



<sup>66</sup> A Western, M Saft M, M Peel (2016): The future of irrigation—what's in store? GRDC Update Papers <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/The-future-of-irrigation-whats-in-store">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/The-future-of-irrigation-whats-in-store</a>

<sup>67</sup> KV Cooper, RS Jessop, NL Darvey (2004) Triticale in Australia. In M Mergoum, H Gómez-Macpherson (eds), Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="mailto:tp://ftp.fao.org/docrep/fao/009/y5553e02.pdf">tp://ftp.fao.org/docrep/fao/009/y5553e02.pdf</a>

<sup>68</sup> Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, http://www.farmtrials.com.au/trial/13801

<sup>69</sup> Agriculture Victoria (2012) Growing triticale. Note AG0497. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

<sup>70</sup> S Bassu, S Asseng, R Richards (2011) Yield benefits of triticale traits for wheat under current and future climates. Field Crops Research, 124 (1), 14–24.

<sup>71</sup> Carson J. Biological inputs: Southern Australia. Soilquality.org, <a href="http://www.soilquality.org.au/factsheets/biological-inputs-southern-grain-growing-region">http://www.soilquality.org.au/factsheets/biological-inputs-southern-grain-growing-region</a>



**TABLE OF CONTENTS** 



# **IN FOCUS**

SOUTHERN

# Triticale v. durum wheat: a yield comparison in Mediterranean-type environments

The productivity of modern triticales makes them increasingly viable as an alternative small-grain cereal crop to durum wheat in a Mediterranean climate. Researchers compared the two species, testing a substantial number of cultivars in 20 field experiments in Italy. Grain yield per environment ranged from 3.4–7.7 t/ha-1; in 11 of the environments, the triticales as a group out-yielded the durum wheats, while in the remaining nine, the two species yielded equally. The superiority of triticale derived from its combination of setting a higher number of grains per unit area (reflecting greater ear fertility) and a similar per-unit grain weight. Triticale is well adapted to the Mediterranean environment, provided that sowing density is no less than 300 seeds per m<sup>2</sup>, because ear fertility contributes more than tillering capacity to the number of grains set per m<sup>2</sup>. In the 20 environments tested, temperature and water availability in the generally favourable pre-anthesis period assured triticale the possibility of realising a grain yield at least comparable to that of durum wheat. At the same time triticale out-yielded durum wheat when its flowering time fell within an optimal window, and where the post-anthesis environment was not too stressful. High ear fertility should be treated as an important trait in the breeding of small grain cereals, because of its positive influence over both yield potential and yield stability. 72

Several tools are available to help growers maximise yields.

Before planting, identify the target yield required to be profitable:

- Do a simple calculation to see how much water you need to achieve this yield.
- Know how much soil water you have (treat this water like money in the bank).
- Think about how much risk your farm can take.
- Consider how this crop fits into your cropping plan, and consider whether the longer-term benefits to the system outweigh any short-term losses.

Avoiding a failed crop saves money now and saves stored water for future crops. 73

#### Estimating crop yields

Accurate, early estimation of grain yield is an important skill. Farmers require accurate yield estimates for a number of reasons:

- crop insurance purposes
- delivery estimates
- planning harvest and storage requirements
- · cash-flow budgeting.

Extensive personal experience is the best asset for estimating yield at early stages of growth. As crops near maturity, it becomes easier to estimate yield with greater accuracy.

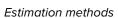


<sup>72</sup> R Motzo, G, Pruneddu, A, Virdis, F Giunta (2015) Triticale vs durum wheat: A performance comparison in a Mediterranean environment. Field Crops Research, 180, 63–71.

J Whish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Paper, 23 July 2013. GRDC, <a href="https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW">https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW</a>

**TABLE OF CONTENTS** 





Many methods are available for farmers and others to estimate yield of various crops. The method presented here is one that can be undertaken relatively quickly and easily. Steps are as follows:

SOUTHERN

- Select an area that is representative of the paddock. Using a measuring rod or tape, measure out an area 1 m<sup>2</sup> and count the number of heads/pods.
- 2. Do this five times to get an average for the crop: no. of heads per m² (e.g. 200).
- 3. Count the number of grains in at least 20 heads, and calculate the average: no. of grains per head (e.g. 24).
- 4. Determine the 100-grain weight for the crop (in grams) by referring to table 1 in: Estimating crop yields—a brief guide.
- 5. No. of grains per  $m^2$  = no. of heads per  $m^2 \times$  no. of grains per head; e.g. 200  $\times$  24 = 4800.
- 6. Yield per  $m^2$  (g) = (no. of grains per  $m^2/100$ ) × 100-grain weight; e.g. 4800/100 × 2.5 = 120 g.
- 7. Yield (t/ha) = numeric value of yield per  $m^2/100$ ; e.g. 120/100 = 1.2 t/ha.

Accuracy of yield estimates depends upon an adequate number of counts being taken to get a representative average of the paddock. The yield estimate determined will be a guide only.

This type of yield estimation should be able to be used in a number of situations on a grain-growing property. Grain losses both before and during harvest can be significant and an allowance for 5-10% loss should be included in your final calculations. <sup>74</sup>

#### Yield Prophet®

Scientists at the Agricultural Production Systems Research Unit (APRSU) have aimed to support farmers' capacity to achieve yield potential by developing the Agricultural Production Systems Simulator (APSIM). APSIM is a farming systems model that simulates the effects of environmental variables and management decisions on crop yield, profits and ecological outcomes.

Yield Prophet® delivers information from APSIM to farmers (and consultants) to aid their decision-making. Yield Prophet® has enjoyed a measure of acceptance and adoption amongst innovative farmers and has had valuable impacts in terms of assisting farmers to manage climate variability at a paddock level.

Yield Prophet® is an online crop production model designed to present grain growers and consultants with real-time information about their crops. This tool provides growers with integrated production risk advice and monitoring decision-support relevant to farm management.

Operated as a web interface for APSIM, Yield Prophet® generates crop simulations and reports to assist decision-making. By matching crop inputs with potential yield in a given season, Yield Prophet® subscribers may avoid over-investing or underinvesting in their crop.

The simulations provide a framework for farmers and advisers to:

- forecast yield
- manage climate and soil water risk
- make informed decisions about N and irrigation applications
- · match inputs with the yield potential of their crop
- assess the effect of changed sowing dates or varieties
- assess the possible effects of climate change.

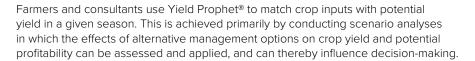


<sup>74</sup> Agriculture Victoria. Estimating crop yields; a brief guide. Victorian State Government EDJTR, <a href="http://agriculture.vic.gov.au/agriculture/">http://agriculture.vic.gov.au/agriculture/</a> grains-and-other-crops/crop-production/estimating-crop-yields-a-brief-guide



**TABLE OF CONTENTS** 





SOUTHERN

#### How does it work?

Yield Prophet® generates crop simulations that combine the essential components of growing a crop including:

- a soil test sampled prior to planting
- a soil classification selected from the Yield Prophet® library of ~1000 soils, chosen as representative of the production area
- historical and active climate data taken from the nearest Bureau of Meteorology weather station
- paddock-specific rainfall data recorded by the user (optional)
- individual crop details
- fertiliser and irrigation applications during the growing season.

#### 1.7.1 Seasonal outlook

Seasonal outlooks from the Bureau of Meteorology include:

- 3-month rainfall outlook a description of the outlook for north, south-east and western Australia
- <u>3-month rainfall outlook</u> maps and tables showing the chances of exceeding the median or of getting a certain amount
- <u>3-month temperature outlook</u> for north, south-east and western Australia
- <u>ENSO wrap-up</u> regular commentary on the El Niño Southern Oscillation
- <u>ENSO outlooks</u> forecast of El Niño and La Niña events a summary of the opinion of National Climate Centre climatologists on the outputs from eight reputable climate models
- BOM Climate Model Summary Australian climate is influenced by temperature
  patterns in the Pacific and Indian Oceans. This page provides information on
  Pacific and Indian Ocean outlooks for the coming 6 months based on a survey of
  international climate models. It is updated monthly.
- Northern rainfall onset prediction The Bureau's new northern rainfall onset outlook provides guidance on rainfall timing within the first months of the Australian northern wet season

For Victorian growers, the Department of Environment, Land, Water and Planning has a webpage, Monthly Water Report, that links to BOM's seasonal rainfall outlook.

Many researchers and developers are providing tools via mobile applications (apps) for smartphones and tablets for ground-truthing precision agriculture data. Apps and mobile devices are making it easier to collect and record data on the farm. The app market for agriculture is evolving rapidly, with new apps becoming available on a regular basis.

#### CliMate

Australian CliMate is a suite of climate analysis tools delivered on the web, iPhone, iPad and iPod Touch devices. CliMate allows you to interrogate climate records to ask questions relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, and well as El Niño—Southern Oscillation status. It is designed for decision makers such as farmers whose businesses rely on the weather.

Download from the <u>Apple iTunes store</u> or visit the <u>CliMate website</u>.

One of the CliMate tools, *Season's progress*?, uses long-term (1949 to present) weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years.



# MORE INFORMATION

#### **Yield Prophet**

GRDC Update Paper, <u>Managing data</u> on the modern farm

DELWP, <u>Monthly water report</u> web page

BOM, <u>Climate outlooks: monthly and seasonal</u>

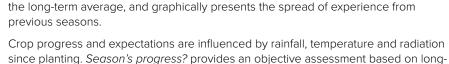
Climate kelpie





**TABLE OF CONTENTS** 





term records:
 How is the crop developing compared with previous seasons, based on heat sum?

It explores the readily available weather data, compares the current season with

 Is there any reason why my crop is not doing as well as usual because of belowaverage rainfall or radiation?

SOUTHERN

Based on seasons progress (and starting conditions from HowWet/N?), should I
adjust inputs?

For inputs, Season's progress? asks for the weather variable to be explored (rainfall, average daily temperature, radiation, heat sum with base temperatures of 0, 5, 10, 15 and 20°C), a start month and a duration.

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. <sup>75</sup>

#### **Climate Analogues**

<u>Climate Change in Australia</u> provides projections for Australia's natural resource management regions. Its <u>Climate analogues tool</u> matches the proposed future climate of a location of interest with the current climate experienced in another location by using annual average rainfall and maximum temperature.

For example, based on plausible assumptions about changes in temperature and rainfall, the future climate of Melbourne will be like the current climate of a location identified by this tool.

This approach was used to generate the analogue cases presented as examples in each of eight <u>Cluster Reports</u>. These reports are intended to provide regional detail for planners and decision makers. The results should capture sites of broadly similar annual maximum temperature and water balance. <sup>76</sup>

#### 1.7.2 Fallow moisture

For a growing crop there are two sources of water: the water stored in the soil during the previous fallow, and the rainfall that occurs while the crop is growing. As a farmer, you have some control over the stored soil water: you can measure how much you have before planting the crop. Even though Long-range forecasts and tools such as the SOI cannot guarantee that rain will fall when you need it, they are useful for indicating the likelihood of the season being wet or dry. <sup>77</sup>

#### HowWet/N?

HowWet? is a program developed by APSRU that uses records from a nearby weather station to estimate how much plant-available water has accumulated in the soil and the amount of organic N that has been converted to available nitrate during a fallow.

HowWet? tracks soil moisture, evaporation, runoff and drainage on a daily timestep. Accumulation of available N in the soil is calculated based on surface soil moisture, temperature and soil organic carbon. HowWet? provides a comparison with previous seasons.



<sup>76</sup> Climate Change in Australia. Climate analogues. Australian Department of the Environment, Bureau of Meteorology, <a href="http://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-analogues/analogues-explorer/">http://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-analogues/analogues-explorer/</a>



# **MORE INFORMATION**

Climate Analogues

Bureau of Meteorology, <u>Climate</u> outlooks: monthly and seasonal

Climate Kelpie



<sup>77</sup> J Whish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Paper, 23 July 2013. GRDC, <a href="https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW">https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW</a>

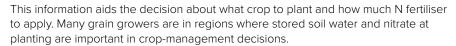


**MORE INFORMATION** 

How Wet/N?

**TABLE OF CONTENTS** 





SOUTHERN

Questions this tool answers:

- How much longer should I fallow? If the soil is near full, maybe the fallow can be shortened.
- Given the soil type on my farm and local rainfall to date, what is the relative soil
  moisture and nitrate-N accumulation over the fallow period compared with most
  years? Relative changes are more reliable than absolute values.
- Based on estimates of soil water and nitrate-N accumulation over the fallow, what adjustments are needed to the N supply?

#### Inputs:

- a selected soil type and weather station.
- an estimate of soil cover and starting soil moisture.
- rainfall data input by the user for the stand-alone version of *HowOften?*

#### Outputs:

- a graph showing plant-available soil water for the current year and for all other years, and a table summarising the recent fallow water balance
- a graph showing nitrate accumulation for the current year and all other years.

#### Reliability

HowWet? uses standard water-balance algorithms from <code>HowLeaky?</code> and a simplified nitrate mineralisation based on the original version of <code>HowWet?</code> Further calibration is needed before accepting with confidence absolute value estimates.

Soil descriptions are based on generic soil types with standard organic C:N ratios, and as such should be regarded as indicative only and best used as a measure of relative water accumulation and nitrate mineralisation. <sup>78</sup>

## 1.7.3 Water Use Efficiency

Water Use Efficiency (WUE) is the measure of a cropping system's capacity to convert water into plant biomass or grain. It includes the use of water stored in the soil and rainfall during the growing season. It relies on:

- The soil's ability to capture and store water.
- The crop's ability to access water stored in the soil and rainfall during the season.
- The crop's ability to convert water into biomass.
- The crop's ability to convert biomass into grain.

Triticale is thought to use water more efficiently than oats and rye do.  $^{79}$ 

One study showed that triticale had similar Water Use Efficiency and resulting yield to wheat under varying soil moisture conditions. 80

Researchers in southern Australia found that the total water use of triticale was less than that of wheat and rye, particularly at the higher rates of N. WUE of triticale was also higher at all levels of N, and increased with increasing N application, whereas the WUE in wheat and rye didn't increase after 50 kg N/ha.  $^{81}$ 



<sup>78</sup> Australian CliMate—How Wet/N. Managing Climate Variability R & D Program, http://www.australianclimate.net.au/About/HowWetN

<sup>79</sup> Mergoum, M., Pleiffer, W. H., Pena, R. J., Ammar, K., and Rajaram, S. (2004). Triticale crop improvement: the CIMMYT programme. In M. Mergoum and H. GomezMacpherson (Eds.), Triticale improvement and production (Vol. 179, pp. 11-26). Rome: Food and Agriculture Organization.

<sup>80</sup> PK Aggarwal, AK Singh, GS Chaturvedi, SK Sinha (1986) Performance of wheat and triticale cultivars in a variable soil—water environment II. Evapotranspiration, Water Use Efficiency, harvest index and grain yield. Field Crops Research, 13, 301–315.

<sup>81</sup> JB Golding (1989). Restricted tillering in triticale cv. currency-an impediment to grain yield? Fifth Australian Agronomy Conference, http://www.regional.org.au/au/asa/1989/contributed/crop/p1-20.htm









SOUTHERN

# IN FOCUS

# Triticale grain yield and physiological response to water stress

Water availability in semi-arid regions is becoming increasingly threatened by erratic rains and frequent droughts leading to over-reliance on irrigation to meet food demand. Improving crop Water Use Efficiency (WUE) has become a priority. To understand how triticale responds to water stress, researchers carried out a two-year study in which they subjected triticale to four moisture levels, ranging from well-watered (430–450 mm) to severe stress (220–250 mm). They worked with four commercial triticale genotypes and grew them under field conditions in a hot, arid, steppe climate in South Africa. The results showed that moisture level significantly influenced grain yield and intrinsic WUE in triticale. Well-watered conditions increased grain yield, which ranged from 3.5 to 0.8 t/ha–1 in 2013, and 4.9–1.8 t ha–1 in 2014. Intrinsic WUE increased with decreasing moisture level. Flag-leaf photosynthesis and pre-anthesis assimilates contribute much less carbon to grain filling under water stress than previously thought. 83

Water Use Efficiency can be considered at several levels:

- Fallow efficiency, the efficiency with which rainfall during a fallow period is stored for use by the following crop.
- Crop WUE, the efficiency with which an individual crop converts water transpired (or used) to grain.
- Systems WUE, the efficiency with which rainfall is converted to grain over multiple crops and fallows.

#### Ways to increase yield

In environments where yield is limited by water availability, there are four ways of increasing yield:

- Increase the amount of water available to a crop (e.g. good summer weed control, stubble retention, long fallow, sowing early to increase rooting depth).
- Increase the proportion of water that is transpired by crops rather than lost to evaporation or weeds (e.g. early sowing, early N, vigorous crops and varieties, narrow row spacing, high plant densities, stubble retention, good weed management).
- Increase the efficiency with which crops exchange water for carbon dioxide to grow dry matter, i.e. transpiration efficiency (e.g. early sowing, good nutrition, varieties with high transpiration efficiency).
- Increase the total proportion of dry matter that is grain, i.e. improve the harvest index (e.g. early-flowering varieties, delayed N, wider row spacing, low plant densities, minimising losses to disease, varieties with high harvest index).



<sup>82</sup> R Motzo, G Pruneddu, F Giunta (2013) The role of stomatal conductance for water and radiation use efficiency of durum wheat and

<sup>83</sup> L Munjonji, KK Ayisi, B Vandewalle, G Haesaert, P Boeckx (2016) Combining carbon-13 and oxygen-18 to unravel triticale grain yield and physiological response to water stress. Field Crops Research, 195, 36–49.

<sup>84</sup> JB Passioura, JF Angus (2010) Improving productivity of crops in water-limited environments. Chapter 2 in DL Sparks (ed.) Advances in Agronomy, Vol. 106. Academic Press. pp. 37–75, <a href="http://www.sciencedirect.com/science/article/pii/S0065211310060025">http://www.sciencedirect.com/science/article/pii/S0065211310060025</a>



**TABLE OF CONTENTS** 





#### The French-Schultz approach

In southern Australia, the French–Schultz model is widely used to provide growers with a benchmark of potential crop yield based on available soil moisture and likely in-crop rainfall.

In this model, potential crop yield is estimated as:

Potential yield (kg/ha) = WUE (kg/ha/mm)  $\times$  (crop water supply (mm) – estimate of soil evaporation (mm))

In the equation, crop water supply is an estimate of water available to the crop, i.e. soil water at planting plus in-crop rainfall minus soil water remaining at harvest.

We use a target WUE of 18 kg/ha/mm for wheat. From our benchmarking in 2014 of 149 wheat paddocks, 11% achieved this target, and 46% achieved 13–17 kg/ha/mm.

A practical WUE equation for farmers to use developed by James Hunt (CSIRO) is: WUE = (yield × 1000)/available rainfall, where available rainfall = (25% Nov.—March rainfall) + (growing season rainfall) - 60 mm evaporation.

# **▶** VIDEOS

WATCH: <u>GCTV12</u>: <u>Water Use</u> <u>Efficiency Initiative</u>



WATCH: GCTV10: Grazing stubbles and Water Use Efficiency



#### Agronomist's view

The French–Schultz model has been useful in providing growers with performance benchmarks. Where yields fall well below these benchmarks, it may indicate a problem with the crop's agronomy or a major limitation in the environment. There could be hidden problems in the soil such as root diseases, or soil constraints affecting yields. Alternatively, apparent underperformance could simply be due to seasonal rainfall distribution patterns, which are beyond the grower's control. <sup>85</sup>

In the grainbelt of eastern Australia, rainfall shifts from winter-dominated in the south (South Australia, Victoria) to summer-dominated in the north (northern NSW and Queensland). The seasonality of rainfall, together with frost risk, drives the choice of cultivar and sowing date, resulting in flowering time varying between October in the south and August in the north.

In eastern Australia, wheat crops are therefore exposed to contrasting climatic conditions during the critical period for grain formation (i.e. a window of ~20 days before and 10 days after flowering), and this affects yield potential and WUE.

Understanding how these climatic conditions affect crop processes and how they vary from south to north and from season to season can help growers and consultants to set more realistic target yields across sites, locations and seasons.

Researchers have analysed some of the consequences of the shift from winter to summer rainfall between southern and northern regions in terms of implications for management and breeding. They advise caution in the use of simple rules of thumb (French–Schultz) for benchmarking WUE, and discuss the importance of more integrative and dynamic modelling approaches to explore alternatives to increase WUE at the single-crop and whole-farming-systems levels (i.e. \$/ha.mm). <sup>86</sup>



<sup>85</sup> GRDC (2009) Water Use Efficiency—Converting rainfall to grain. GRDC Fact Sheet, <a href="http://www.grdc.com.au/"/media/607AD22DC6934BE79DEAA05DFBE00999.pdf">http://www.grdc.com.au/"/media/607AD22DC6934BE79DEAA05DFBE00999.pdf</a>

<sup>86</sup> Rodríguez (2008) Farming systems design and Water Use Efficiency (WUE). Challenging the French & Schultz WUE model. GRDC Update Papers, June 2008, <a href="https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/Farming-systems-design-and-water-use-efficiency-WUE-Challenging-the-French-Schultz-Wue-model">https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/Farming-systems-design-and-water-use-efficiency-WUE-Challenging-the-French-Schultz-Wue-model</a>



**TABLE OF CONTENTS** 

FEEDBACK



# **MORE INFORMATION**

Water Use Efficiency of grain crops in Australia: principles, benchmarks and management

Making the most of available water in wheat production

Recent WUE trials in Tasmania

The fundamentals of increasing nitrogen use efficiency

# 1.7.4 Nitrogen-use efficiency

Key points:

 Improving nitrogen-use efficiency begins with identifying and measuring meaningful NUE indices and comparing them with known benchmarks and contrasting N management tactics.

SOUTHERN

- Potential causes of inefficiency can be grouped into six general categories.
   Identification of the most likely groups is useful in directing more targeted measurement and helping identify possible strategies for improvement.
- As result of seasonal effects, NUE improvement is an iterative process; therefore, consistency in the investigation strategy used and good record keeping are essential.<sup>87</sup>

Nitrogen-use efficiency (NUE) is the efficiency with which soil nitrate-N is converted into grain N. The nitrate-N comes from fertiliser, crop residues, manures, and soil organic matter, but it is how well and quickly this fertiliser is converted into grain that is generally of greatest concern to growers. Efficiency is reduced by some seasonal conditions, crop diseases, losses of N from the soil as gases, N leaching, or immobilisation of N into organic forms.

The type of soil type, the intensity of rainfall and the timing of fertiliser application largely determine N losses from dryland cropping soils. Insufficient rainfall after a surface application of N fertilisers can result in losses from the soil through volatilisation. The gas lost in this case is ammonia. Direct measurements of ammonia losses have found that they are generally <15% of the N applied, and even less with in-crop situations. An exception can occur with the application of ammonium sulphate to soils with free lime at the surface, where losses have been recorded as >25% of the N applied. Recovery of N applied in-crop requires sufficient rainfall for plant uptake from an otherwise dry surface soil.

A balance of nutrients is essential for profitable yields. Fertiliser is commonly needed to add the essential nutrients P and N, although the lack of other essential plant nutrients may also limit production in some situations. Knowledge of the nutrient demand of crops is essential in determining nutrient requirements. Soil testing and nutrient audits assist in matching nutrient supply to crop demand. <sup>88</sup>

#### Optimising nitrogen-use efficiency

Nitrogen fertilisers are a significant expense for broadacre farmers. Optimising use of fertiliser inputs is therefore desirable. There are three main stores of nitrogen with the potential to supply N to crops: stable soil organic matter N, rotational (plant residue) N, and soil mineral N (ammonium and nitrate). To optimise the ability of plants to use soil N, growers should first be aware of how much of each source there is, and soil testing is the best method of measuring these N sources. <sup>89</sup>

In recent research in the UK, it was found that triticale had higher biomass and straw yields, lower harvest index and higher total N uptake than wheat. Consequently, triticale had higher efficiency of both the uptake and use of N. <sup>90</sup>

In another study, NUE decreased with increasing N fertiliser rates. At an N supply of 100 kg/ha–1, the NUE of triticale was 0.14 t dry biomass/kg N.  $^{91}$ 

# 1.7.5 Double-crop options

Double cropping is growing a winter and summer crop following one another.



<sup>87</sup> C Dowling (2014) The fundamentals of increasing nitrogen use efficiency. GRDC Update Paper, 11 February 2014. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/The-fundamentals-of-increasing-nitrogen-use-efficiency-NUE">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/The-fundamentals-of-increasing-nitrogen-use-efficiency-NUE</a>

<sup>88</sup> G Schwenke, P Grace, M Bell (2013) Nitrogen use efficiency. GRDC Update Paper, 16 July 2013. GRDC, <a href="http://www.grdc.com.au/">http://www.grdc.com.au/</a> Research-and-Development/GRDC-Update-Papers/2013/07/Nitrogen-use-efficiency

<sup>89</sup> Soilquality.org. Optimising soil nutrition, http://www.soilquality.org.au/factsheets/optimising-soil-nutrition

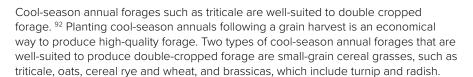
<sup>90</sup> S Roques, D Kindred, S Clarke (2016) Triticale out-performs wheat on range of UK soils with a similar nitrogen requirement. The Journal of Agricultural Science, 1–21.

<sup>91</sup> I Lewandowski, U Schmidt (2006) Nitrogen, energy and land use efficiencies of *Miscanthus*, reed canary grass and triticale as determined by the boundary line approach. Agriculture, Ecosystems & Environment, 112 (4), 335–346.



**TABLE OF CONTENTS** 





SOUTHERN

For autumn forage, the general concept is to take advantage of the potential growing degree-days following a grain harvest. Ideally, planting a forage double crop would occur as soon as possible following grain harvest since the growing degree-days available for plant growth rapidly decline through the late summer into early autumn. The risk of failure increases with later planting dates. However, establishment costs are often low enough for many of these forages that the successful years often outweigh the years in which failure occurs. <sup>93</sup>

For spring forage, the winter cereals triticale, rye and wheat tend to be the best choices.

# **IN FOCUS**

# Crop sequencing for irrigated double cropping in the Murrumbidgee Valley

A project in the Murrumbidgee Valley aimed to qualify and overcome some of the potential difficulties with double cropping systems, and to provide the opportunity for growers to capitalise on their investment in irrigated agriculture. The researchers addressed the issues of herbicide residues, irrigation layouts and management, stubble management, and quantifying achievable crop yield and profitability.

The researchers conducted the trials over two years, from winter 2014 to summer 2015–16. The project had two core sites, one in Boort (northern Victoria) and the other at the Leeton Field Station (LFS) in southern NSW. At the Victorian site they focused on the technical aspects of double cropping, including herbicide options and stubble management.

They experimented with seven double-cropping rotations. The wheat—fallow—wheat—fallow (T5) rotation had the lowest Gross Margin (GM) return per hectare, of only \$1,428/ha over the two years. Even though T5 had the lowest GM for \$/ha, it had a much better GM return on a megalitre basis, with \$216/ML.

The T5 effect is of interest, as while it had the lowest GM/ha for land use, it was one of the best for GM for water use. This implies that if water is limited, growers need to seriously consider increasing the percentage of winter crops within their rotation and using summer fallows as a break. In contrast, if water is plentiful and of low cost, a more summer crop-dominant rotation could be more profitable.  $^{94}$ 



<u>Crop sequencing for irrigated double</u> <u>cropping with the Murrumbidgee</u> Valley region



<sup>92</sup> ME Drewnoski, DD Redfearn (2015) Annual cool-season forages for late-fall or early-spring double-crop. No. G2262. NebGuide, http://extensionpublications.unl.edu/assets/odf/o2262.odf

<sup>93</sup> ME Drewnoski, DD Redfearn (2015) Annual cool-season forages for late-fall or early-spring double-crop. No. G2262. NebGuide, http://extensionpublications.unl.edu/assets/pdf/q2262.pdf

<sup>94</sup> T Napier, L Gaynor, D Johnston, G Morris, M Rollin (2016) Crop sequencing for irrigated double cropping within the Murrumbidgee Valley region. GRDC Update Paper. 27 July 2016. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/Crop-sequencing-for-irrigated-double-cropping-Murrumbidgee-Valley-site">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/Crop-sequencing-for-irrigated-double-cropping-Murrumbidgee-Valley-site</a>



# 1.8 Disease status of paddock

Crop sequencing and rotation are important components of long-term farming systems and contribute to the management of soil nitrogen status, weeds, pests and diseases.

In the paddock, considerations include soil-moisture levels before planting, current and desired stubble cover, and the history of herbicide use and history of diseases.

Crop sequencing is only a part of the integrated management of diseases. Other practices include:

- Maintaining sufficient distance from last year's paddock of the same crop, and maintaining sufficient distance from a paddock with residue infected with a pathogen of the intended crop.
- The use of high-quality, fungicide-treated seed.
- Planting within the planting window, variety selection.
- In-crop fungicide treatments. 95

Paddock selection is an important consideration for managing crown rot, in particular, and growers should select paddocks with a low risk of the disease. Paddock risk can be determined by one or both of these methods:

- Visually assessing the levels of crown rot and root-lesion nematode (RLN) (see section 1.9) in a prior cereal crop, paying attention to basal browning.
- Having soil samples analysed at a testing laboratory.

The presence of spores of tan (yellow) spot is also an important consideration, and effective management of this disease in cereals depends on decisions made before sowing.

# 1.8.1 Testing soil for disease

In addition to visual symptoms, the DNA-based soil test PreDicta  $B^{\mathbb{M}}$  can be used to assess the disease status of the paddock. Soil samples that include plant residues should be tested early in late summer to allow results to be returned before seeding. This test is particularly useful when sowing susceptible wheat varieties, and for assessing the risk after a non-cereal crop.

#### PreDicta B

Cereal root diseases cost grain growers in excess of \$200 million a year in lost production. Much of this can be prevented.

PreDicta B (the B stands for broadacre) is a DNA-based soil testing service that identifies which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding (Photo 9). It includes tests for:

- Take-all (Gaeumannomyces graminis var tritici (Ggt) and G. graminis var avenae (Gga)).
- Rhizoctonia barepatch (Rhizoctonia solani AG8).
- Crown rot (Fusarium pseudograminearum and F. culmorum).
- Blackspot of peas (Mycosphaerella pinodes, Phoma medicaginis var pinodella and Phoma koolunga).



Photo 9: PreDicta B sample.

Source: GRDC



<sup>95</sup> M Ryley (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Paper, 13 September 2011. GRDC, http://elibrary.grdc.com.au/arkl!33517/vhnf54 t/a9ft5hf



**TABLE OF CONTENTS** 

FEEDBACK



**MORE INFORMATION** 

PreDicta B

SARDI, Crop diagnostics

#### How to access the service

You can access PreDicta B diagnostic testing services through a SARDI-accredited agronomist. They will interpret the results and give you advice on management options to reduce your risk of yield loss.

SOUTHERN

Samples are processed weekly between February and mid-May (prior to crops being sown) every year.

PreDicta B is not intended for in-crop diagnosis. SARDI provides a diagnostic service for that.

# 1.8.2 Effects of cropping history

The main cropping history effects are based on the amount of nutrients available in a paddock. However, the previous crop will influence levels of both soil- and residue-borne diseases. Important diseases to consider include take-all, crown rot, yellow leaf spot, stripe rust, and Wheat streak mosaic virus. Transmission from neighbouring paddocks and volunteers are key concerns with some diseases. Controlling the 'green bridge' of over-summering cereals and weeds is an important strategy.

For diseases, there has been a focus on management of crown rot and RLN, yellow leaf spot in winter cereals, and the roles that rotational crops play, particularly the winter pulses. Crop sequences also affect the incidence and severity of major diseases of summer crops, especially those diseases that have several summer, and in some instances winter, crop hosts.

Crop sequencing is only a part of the integrated management of diseases. Other practices include maintaining sufficient distance from last year's paddock of the same crop or from a paddock with residue infected with a pathogen of the intended crop; the use of high-quality, fungicide-treated seed; planting within the planting window; variety selection; and in-crop fungicide treatments. <sup>96</sup>

Paddock histories likely to result in high risk of disease (e.g. Rhizoctonia) include:

- durum wheat in the past 1–3 years
- winter cereal or a high grass burden from last season—crown rot fungus survives in winter cereal residues, dense stubble cover or where dry conditions have made residue decomposition slow
- break crops, which can influence crown rot in cereals by manipulating the amount of N and moisture left in the soil profile
- paddocks that have high levels of N at sowing and/or low stored soil moisture at depth <sup>97</sup>
- varieties grown in previous year (Photo 10). 98



<sup>96</sup> M Ryley (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Papers, September 2011, <a href="http://eibrary.grdc.com.au/art/%21%2133517/vhnf54">http://eibrary.grdc.com.au/art/%21%2133517/vhnf54</a> t/a9ft5hf

<sup>97</sup> GRDC (2009) Crown rot in cereals. GRDC Fact Sheet May 2009, <a href="https://www.grdc.com.au/"/media/AF642FA0A889465089D2B6C59E5CA22E.pdf">https://www.grdc.com.au/"/media/AF642FA0A889465089D2B6C59E5CA22E.pdf</a>

<sup>98</sup> R Brill, S Simpfendorfer (2013) Resistance of eighteen wheat varieties to the root lesion nematode *Pratylenchus thornei*—Trangie 2011. Northern Grains Region Trial Results Autumn 2013, pp. 129–131. NSW Department of Primary Industries, <a href="http://www.dpi.nsw.gov.au/\_data/assets/pdf\_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf">http://www.dpi.nsw.gov.au/\_data/assets/pdf\_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf</a>



TABLE OF CONTENTS





SOUTHERN

**Photo 10:** Diseased patches of Rhizoctonia root rot from previous crops vary in size from less than half a metre to several metres in diameter.

Source: DAFWA

# 1.9 Nematode status of paddock

Root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) are migratory root endoparasites that are widely distributed in the wheat-growing regions of Australia. They can reduce grain yield by up to 50% in many current wheat varieties (Photo 11). *Pratylenchus neglectus* and *P. thornei* are the main RLNs causing yield loss in the southern agricultural region of Australia, and they often occur together. <sup>99</sup>

At least 20% of cropping paddocks in south-eastern Australia have populations of RLNs high enough to reduce yield.  $^{100}$ 



<sup>99</sup> DAF QId (2010) Test your farm for nematodes. DAF QId, <a href="https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematodes/test-your-farm-for-nematodes">https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematodes/test-your-farm-for-nematodes</a>

<sup>100</sup> G Holloway (2013) Cereal root diseases. Note AG0562. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases</a>



**TABLE OF CONTENTS** 





SOUTHERN

Photo 11: Paddock showing patches caused by root lesion.

Source: DAFWA

The roots of triticale in nematode-infested soil have been found to contain fewer nematodes than other cereals. Triticale is thus a useful rotational crop for areas infested with the root-lesion nematodes. <sup>101</sup>

# 1.9.1 Testing soil for nematodes

### PreDicta B

PreDicta B can also be used for testing for the presence of nematodes:

- Cereal cyst nematode (Heterodera avenae).
- Root lesion nematode (Pratylenchus neglectus and P. thornei).
- Stem nematode (Ditylenchus dipsaci).

See section 1.8.1 above for details, including how to access the service.

# 1.9.2 Effects of cropping history

- Well-managed rotations are vital. Avoid consecutive host crops to limit populations.
- Choose varieties with high tolerance ratings to maximise yields in fields where RLN is present.
- Choose rotation crops with high resistance ratings, so that fewer nematodes remain in the soil to infect subsequent crops.

For more information, see Section 8: Nematode control

# 1.10 Insect status of paddock

Pests such as redlegged earth mites, blue oat mites, nematodes and, in some seasons, cutworms, pose a risk in some paddocks (Photo 12). Risk should be assessed based on paddock history (including recent control) and crop susceptibility. Controlling weeds in summer fallows and around paddocks can also minimise some of these pests.



MORE INFORMATION

GRDC Tips and Tactics, Root-lesion

nematodes, southern region

<sup>101</sup> V Vanstone, M Farsi, T Rathjen, K Cooper (1996) Resistance of triticale to root lesion nematode in South Australia. In Triticale: Today and Tomorrow, Springer Netherlands, pp. 557–560.

Soil-dwelling insect pests can seriously reduce plant establishment and populations, and subsequent yield potential.





SOUTHERN

**Photo 12:** Armyworm on a severed stem (left) and the damage caused by a combination of armyworms and herringbone caterpillars to a cereal paddock (right).

Sources: Luke Maher, left, and James Mckee

#### Soil insects include:

- crickets
- <u>earwigs</u>
- <u>cutworms</u>
- false wireworms
- true wireworms

Soil-insect control measures are normally applied at sowing. Since different insects require different control measures, the species of soil insects must be identified before planting.  $^{102}$ 

# 1.10.1 Testing soil for insects

It is important to maintain a regular testing regime for the presence of insects in the soil. Recent seasons have seen a plethora of seemingly new pests and unusual damage in pulse and grain crops.

GRDC's advice to growers is to:

- Monitor crops frequently so as not to be caught out by new or existing pests.
- Look for and report any unusual pests or symptoms of damage photographs are good.
- Remember that just because a pest is present in large numbers in one year doesn't mean it will necessarily be so next year—another spasmodic pest, e.g. soybean moth, may make its presence felt instead.
- Be aware of cultural practices that favour pests, and rotate cops each year to minimise the build-up of pests and plant diseases.  $^{103}$

Sampling methods should be applied in a consistent manner between paddocks and on each sampling occasion. Any differences can then be confidently attributed to changes in the insect populations, and not to different sampling techniques.



<sup>102</sup> DAF Qld. (2011) How to recognise and monitor soil insects. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadcare-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadcare-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects</a>

<sup>103</sup> H Brier, M Miles (2015) Emerging insect threats in northern grain crops. GRDC Update Paper, 31 July 2015. GRDC, <a href="https://grdc.com.au/">https://grdc.com.au/</a> Research-and-Development/GRDC-Update-Papers/2015/07/Emerging-insect-threats-in-northern-grain-crops

**TABLE OF CONTENTS** 





SOUTHERN

## Using a sweep net

Most crop monitoring for insect pests is done visually or with a sweep net. Using a shake or beating tray is another technique. Sampling pastures mostly relies on visual assessment of the sward or the soil below it. The sweep net is the most convenient sampling technique for many insects. The net should be about 38 cm in diameter, and swept in a 180° arc from one side of the sweeper's body to the other. The net should pass through the crop on an angle so that the lower lip travels through the crop marginally before the upper lip. The standard sample is 10 sweeps, taken over 10 paces, which comprises one set. This technique should be repeated as many times as practicable across the crop, and at no less than five locations. After completing the sets of sweeps, count the insects captured and average the counts to give an overall estimate of abundance. Sweep nets tend to under-estimate the size of the pest population. Their efficiency is significantly affected by temperature, relative humidity, crop height, wind speed, plant density and the operator's vigour. 104

There are two other main sampling techniques.

## Soil sampling by spade

- Take a number of spade samples from random locations across the paddock.
- Check that all spade samples are deep enough to take in the moist soil layer. This is essential.
- Hand-sort samples to determine type and number of soil insects.

#### Germinating-seed bait technique

Immediately following planting rain:

- Soak insecticide-free crop seed in water for at least two hours to initiate germination.
- Bury a dessertspoon of the seed under 1 cm of soil. For each 100 ha, bury the seed at each corner of a 5 m by 5 m square at five widely spaced sites.
- Mark the position of the seed baits, as large populations of soil insects can destroy the baits.
- 4. One day after seedling emergence, dig up the plants and count the insects.

Trials have shown no difference in the type of seed used for attracting soil-dwelling insects. However, using the type of seed to be sown is likely to indicate the species of pests that could damage the proposed crop. The major disadvantage of the germinating-grain bait method is the delay between the seed placement and assessment. 105

#### Identifying insects

The South Australian Research and Development Institute (SARDI) Entomology Unit provides an insect identification and advisory service. The unit identifies insects to the highest taxonomic level for species where this is possible, and can also give farmers biological information and guidelines for controlling them. 106

GRDC's Insect ID ute guide is a comprehensive reference on the insect pests that commonly affect broadacre crops across Australia (Figure 9). It includes the beneficial insects that may help to control pests. Photos have been provided for multiple lifecycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored, and other pests they may be confused with. Use of this app should result in better management of pests, increased farm profitability and improved chemical usage. 107



<sup>104</sup> Department of Natural Resources and Environment (2000) Sampling methods for insects and mites. Department of Natural Resources and Environment (Victoria), http://ipmquidelinesforgrains.com.au/insectopedia/introduction/sampling.htm

DAF Qld (2011) How to recognise and monitor soil insects. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/ broadacre-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects

<sup>106</sup> PIRSA. Insect diagnostic service, <a href="http://pir.sa.gov.au/research/research\_specialties/sustainable\_systems/entomology/insect\_">http://pir.sa.gov.au/research/research\_specialties/sustainable\_systems/entomology/insect\_</a>

<sup>107</sup> GRDC. Insect ID: The ute guide. GRDC, https://grdc.com.au/Resources/Apps





Figure 9: Icon of GRDC's insect ID app.

Source: GRDC

#### App features

The features of the app are:

- · Region selection.
- Predictive search by common and scientific names.
- Comparison photos of insects side by side with insects in the app.
- Identification of beneficial predators and parasites of insect pests.
- The option to download content updates inside the app to ensure you're aware
  of the latest pests affecting crops for each region.
- Raises awareness of international biosecurity pests.

It is important to consider paddock history when planning for pest management. Resident pests can be easier to predict by using paddock history. Agronomic and weather data will also help to determine the likely presence (and numbers) of certain pests within a paddock. These will point towards the likely pest issues and allow growers to implement preventive options. <sup>108</sup> Reduced tillage and increased stubble retention have changed the cropping landscape with respect to soil-moisture retention, groundcover and soil biology, and these have also affected the abundance and types of invertebrate species being seen in crops. These systems increase invertebrate biodiversity but also create more favourable conditions for many pests such as slugs, earwigs, weevils, beetles and many caterpillars. In turn, they have also influenced beneficial species such as carabid and lady beetles, hoverflies and parasitic wasps. <sup>109</sup>

See Section 7: Insect control for more information.

# 1.10.2 Effects of cropping history

Where paddock history, paddock conditions or pest numbers indicate a high risk of pest damage a grower might decide to use pre-seeding controls to reduce pest pressure, apply a seed dressing to protect the crop during the seedling stage and plan to apply a foliar insecticide if pest numbers reach a particular level. <sup>110</sup>

Different soil insects occur under different cultivation systems and the way the farm is managed directly influences the type and number of these pests. Keep in mind the following:

• Weedy fallows and volunteer crops encourage soil insect build-up.



Pest Genie

Australian Pesticides and Veterinary Medicines Authority



SOUTHERN

JANUARY 2018

<sup>108</sup> R Jennings (2015) Growers chase pest-control answers. Ground Cover. No. 117. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover-Issue-117-July-August-2015/Growers-chase-pest-control-answers">https://grdc.com.au/Media-Centre/Ground-Cover-Issue-117-July-August-2015/Growers-chase-pest-control-answers</a>

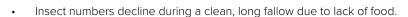
<sup>109</sup> Bowden P, Umina P, McDonald G. (2014). Emerging insect pests. <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Emerging-insect-pests">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Emerging-insect-pests</a>

O G Jennings (2012) Integrating pest management. SANTFA, <a href="http://www.santfa.com.au/wp-content/uploads/Santfa-TCE-Spring-12-Integrating-pest-management.pdf">http://www.santfa.com.au/wp-content/uploads/Santfa-TCE-Spring-12-Integrating-pest-management.pdf</a>



TABLE OF CONTENTS





• Large amounts of stubble on the soil surface can promote some soil insects because they are a food source, but this can also mean that pests continue feeding on the stubble instead of moving to germinating crops.

SOUTHERN

- No-tillage cropping encourages beneficial predatory insects and earthworms.
- Incorporating stubble promotes black field earwigs.
- False wireworms are found at all intensities of cultivation, but numbers decline if stubble levels are very low.

Soil-insect controls are normally applied at sowing. Since different insects require different control measures, the species must be identified before planting. Soil insects are often difficult to detect as they hide under trash or in the soil. Immature insects such as false wireworm larvae are usually found at the interface of moist and dry soil. <sup>111</sup>

For more information, see Section 7: Insect Control.



<sup>111</sup> DAF Old (2011) How to recognise and monitor soil insects. DAF Old, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects</a>





# **Pre-planting**

# Key messages

- Triticale has good natural vigour through its cereal rye heritage. It has good acid soil tolerance and where lime has not been applied it will out-yield wheat and barley.
- Triticale breeding programs have aimed at improving grain yield and dry-matter production, producing winter triticales with a wider range of sowing dates, improving the grazing habit (having the growing point closer to the ground), and incorporating new sources of rust resistance.
- These breeding programs have produced a number of new varieties designed for particular uses and regions.
- Triticale is extensively used in dual-purpose cropping systems, with varieties bred specifically for them.
- Ensure that seed quality is of a high standard. Check for damage and discoloration because affected seeds may have poor germination and emergence.
- The larger seed size of triticale means that emergence is consistently good; however, high-quality seed must be used.
- Consult local variety sowing guides for the best practices for your region.

Triticale has a niche on farms across Victoria due to several attributes. There are two types of triticale to choose from: grain-only, and dual-purpose (Photo 1). Grain-only varieties perform best in long-season environments rather than in the lower-rainfall regions with an unreliable spring. Dual-purpose varieties can be sown very early, grazed during winter, and then shut up for forage conservation or grain recovery. <sup>1</sup>

Long-season triticales may also be suitable to the Wimmera areas of Victoria and SA for sowing in early to mid-May.  $^{\rm 2}$ 



**Photo 1:** Triticale combines the high yield potential and good grain quality of wheat with the disease and environmental tolerance of rye.



<sup>1</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>

<sup>2</sup> University of Sydney (2012) Triticale. Plant Breeding Institute. University of Sydney, <a href="http://sydney.edu.au/agriculture/plant\_breeding-institute/key\_work\_results/triticale.shtml">http://sydney.edu.au/agriculture/plant\_breeding-institute/key\_work\_results/triticale.shtml</a>





# 2.1 Triticale as a dual-purpose crop

Key points:

- Advantages of dual-purpose crops include minimising risks, capitalising on early rainfall, flexibility in enterprise mix, and improved cash-flow.
- Dual-purpose crops require a high standard of management.
- Ideal grazing facilities would allow for an excellent water supply, shelter belts and rotational grazing, and drafting cattle into similar weight ranges before being placed onto grazing crops. Try to minimise handling and ensure that all animal health issues are addressed.<sup>3</sup>
- Triticale has excellent grazing and forage values.

Dual-purpose crops hold great potential for farmers to utilise early-season sowing opportunities to provide extra grazing for livestock and yet maintain grain yield. With good management, the period of grazing can increase net crop returns by up to \$600/ha, and give a range of system benefits including widening sowing windows, reducing crop height, filling critical feed gaps, and spelling pastures. Over 10 years of experiments, simulation studies and collaborative on-farm validation across Australia have demonstrated that many cereal varieties have the ability to recover after being grazed and go on to produce good crop yields. The combined livestock and crop gross margins can exceed grain-only crops, and increase whole-farm profitability. <sup>4</sup>

The Australian dual-purpose cereal crop (which includes triticale, wheat, oats, barley and cereal rye) is increasing in importance because of factors such as higher-value animal industries. The ability of several recent variety releases to provide valuable winter grazing, as well as a grain yield similar to grain-only crops, helps farmers to improve winter feed supply after pastures have been affected by drought. <sup>5</sup>

When a dual-purpose triticale is grown with the intention of providing winter grazing and then optimising grain production, the time of stock removal or lock-up is important.

# **2.1.1** Benefits of growing dual-purpose or winter-forage crops

#### 1. Minimises risks

Dual-purpose or winter-forage crops can mitigate the impacts of several natural hazards:

- Weather damage close to grain harvest, which have caused or can cause severe damage to ripening crops.
- Weather damage during the growing period of grazing crops, which can provide irrigation-type benefits.
- Weather damage in November—December, which are not so critical on grazing crops because the benefits have already been banked
- Minimise the risks associated with dry periods in late winter–spring, such as those in 2013, 2014 and 2015.
- Frost
- · Yield reductions due to heat shock during flowering

#### 2. Capitalises on early rainfall

Grazing or dual-purpose crops can be planted in late February and up till late March, thus capitalising on late-summer rain. It also spreads workloads.



<sup>3</sup> K Harris (2016) Dual purpose crops. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Dual-purpose-crops">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Dual-purpose-crops</a>

J Kirkegaard, S Sprague, J Lilley, L Bell L (2016) Managing dual purpose crops to optimise profit from grazing and grain yield north. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Managing-dual-purpose-crops-to-optimise-profit-from-grazing-and-grain-yield-north">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Managing-dual-purpose-crops-to-optimise-profit-from-grazing-and-grain-yield-north</a>

GRDC (2007) Dual-purpose crops: Adaptable triticale steps up. Ground Cover. No. 66. GRDC, <a href="https://grdc.com.au/Media-Centre/ground-Cover/Ground-Cover-Issue-66-January-February-2007/Dualpurpose-crops-Adaptable-triticale-steps-up">https://grdc.com.au/Media-Centre/ground-Cover-Issue-66-January-February-2007/Dualpurpose-crops-Adaptable-triticale-steps-up</a>



**MORE INFORMATION** 

Optimising grazing and grain yield in

Dual purpose crops: do they have a

fit in your system and how can they

be managed to optimise forage and

Dual-purpose crops

dual-purpose crops

grain production







- Spreads the sowing window and workloads.
- Early-sown crops will provide quality feed from mid-May in most seasons.

#### 3. Flexibility in enterprise mix

Dual-purpose or winter-forage crops mean that the farm business:

- Isn't totally vulnerable to fluctuations in grain prices, export markets, grain-quality issues, and downgrading because of weather damage.
- Can tap into the budget profits from weight gains available with buying and selling cattle
- Has the opportunity to 'background' cattle for feedlots and the potential to lock in sale prices at purchase
- Capitalise on cattle prices at feedlots, which are usually higher when grain prices are down—grain is a major input cost for feedlots and therefore it has a major impact on feedlot margins.
- Can delay the decision to lock up dual-purpose crops until late July—during a
  normal average season when late winter—early spring feed reserves (pastures)
  are looking good, dual-purpose crops can be locked up, top-dressed, or
  controlled for weeds if necessary, and kept for grain production.
- Can elect to continue to graze the crop, taking into account cattle and grain prices, levels of stored soil moisture, and the seasonal outlook.

## 4. Improved cash-flow

- Grazing crops can provide felxibility on both the production and financial side when conditions apply.
- Dual-purpose crops offer the benefit of generating early income from the start of the grazing period.
- Producers don't need to finish the cattle—the best returns are often obtained from backgrounding cattle for local feedlots. A good idea is for growers to speak with the feedlot before they buy cattle; alternatively, there may be an opportunity to background cattle on behalf of a feedlot, being paid for the weight gain only.
- A well-managed forage crop can provide sufficient early-season feed for weaners. Therefore, early income can potentially be paid in August.
- There is no need to wait until December or January (6–8 months) to realise cash-flow.
- For grain recovery in dual-purpose crops in northern areas, growers should budget 50% of un-grazed crops. <sup>6</sup>

# 2.1.2 When to graze

Dual-purpose varieties can be sown early for winter grazing (30–90 grazing days) and can then be locked up at spring time. The ideal stage to start grazing dual-purpose varieties is when plants are well anchored and the canopy has closed (growth stages GS21–GS29). Do not graze below 5 cm with prostrate varieties and below 10 cm for erect varieties (Photo 2). <sup>7</sup>

In the Southern region, do not graze past Growth stage 31, when the first node on the main shoot is 3-5 cm above the ground. Grazing beyond this growing point can reduce grain yield recovery significantly.

Agronomist's view

SOUTHERN
JANUARY 2018



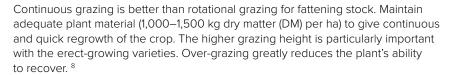
<sup>7</sup> Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, <a href="http://www.farmtrials.com.au/trial/13801">http://www.farmtrials.com.au/trial/13801</a>





**TABLE OF CONTENTS** 





SOUTHERN

The crop must be monitored regularly (at least twice a week) for stem elongation and the appearance of the first node. This indicates that the plant has gone into reproductive mode and grazing from this time onwards will reduce grain yield. Once the crop reaches this stage grazing should cease. <sup>9</sup>



Photo 2: Triticale grazed by cattle and used to clean up a paddock.

Source: EverGraze

In southern trials, grain yields were generally reduced by grazing, possibly because grazing was allowed to continue to about GS31, and is likely to have resulted in the removal of the growing point of the primary tiller, resulting in fewer productive heads. Varieties that produced the highest grain yield when not grazed actually had the greatest yield loss when grazed. Protein content was reduced by grazing in all cereals, and 1,000-grain weight was reduced by grazing in wheat and triticale. As long as farmers stop grazing their cereals before they get to GS30–GS31 they can get a reasonable amount of grazing from the crop, and still realise a good grain yield. It is a matter of farmers trying to get some grazing in winter (when dedicated pastures are growing slowly and under pressure due to low dry-matter levels) and then removing the stock to harvest a reasonable grain yield. <sup>10</sup>

Researchers have found in trials that of four commonly used cereal cover crops (triticale, oats, wheat and barley), triticale produced the highest grain yield following grazing.  $^{\rm 11}$ 



Yorke Peninsula and Mid-North trials highlight benefits of grain and graze

Effect of cutting on early sown triticale and wheat



<sup>8</sup> P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/001t/272945/winter-crop-variety-sowing-guide-2016.pdf

<sup>9</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102">http://www.porkcrc.com.au/1A-102</a> Triticale Guide Final Fact Sheets pdf

<sup>10</sup> M Roberts (2013) YP and Mid-North trials highlight benefits of grain and graze. Grain and Graze, <a href="http://www.grainandgraze3.com.au/resources/343\_YPandMidNorthtrialshighlightbenefitsofGG.pdf">http://www.grainandgraze3.com.au/resources/343\_YPandMidNorthtrialshighlightbenefitsofGG.pdf</a>

<sup>11</sup> L Serafin, M Gardner, J Fleming, D Pottie, S Harden (2013) Dual purpose cereals: varieties and management for the northern slopes and plains. GRDC Update paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Dual-Purpose-Cereals-Varieties-and-Management-for-the-Northern-Slopes-and-Plains">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Dual-Purpose-Cereals-Varieties-and-Management-for-the-Northern-Slopes-and-Plains</a>



**TABLE OF CONTENTS** 





# Evaluation of triticale as dual-purpose forage and grain crops

Two cultivars of triticale, Tiga and Empat, were compared with existing commercial cultivars of triticale, cereal rye and forage oats, for grain yield and dry-matter (DM) production. Their performance was evaluated at Armidale, New South Wales, over 3 years, using four regimes: uncut to grain yield, cut in late autumn, cut in autumn and winter, and cut in winter only. Grain yields (up to 4.0 t/ha) of the highest-yielding triticale cultivar (Empat) were equal to, or greater than, the best oats cultivar (Blackbutt). Generally, the highest winter growth rates, dry-matter yield at maturity and grain yield were recorded from uncut plots. Cutting only in autumn had small negative effects on grain yields, but cutting in both autumn and winter reduced total dry-matter yields at maturity by 30%, and grain yields by 50%. Cutting only in winter resulted in higher vegetative forage yields than a double cut (autumn and winter), but the single winter cut subsequently produced lowest dry-matter yields at maturity. The high grain yields of triticale were linked to rapid spring growth. Harvest indices of triticale cultivars were generally lower than those of the oat cultivars. The results indicate the potential of triticale, as a dual-purpose forage and grain crop.  $^{\rm 12}$ 

# 2.1.3 Breeding dual-purpose triticale

Grain producers on the south-western slopes have expressed the importance of dual-purpose triticale varieties, as they want to graze the crop through autumn and winter, and have a subsequent grain crop, to increase their gross margin per hectare and also provide an insurance against harvest failure. Grazing cereals produce twice the amount of dry matter than pastures during the autumn and winter, and also allow pastures to be rested over the winter, thus allowing for better production in the spring. Long-season triticales may also be suitable to the Wimmera areas of Victoria and SA for sowing in early to mid-May.

There can be a high demand for feed grain in these regions, especially for triticale from the dairy and pig industries. The reduced transport costs and the slightly higher price for triticale compared to other feed grains makes triticale an attractive proposition. Triticale is particularly suited to some areas due to its tolerance of acid soils and the high levels of exchangeable aluminium in these soils, especially where the subsoil is acidic and cannot be easily corrected by liming.

Recently the demand for triticale is highly variable. Before making commitments to growing Triticale for grain, growers should assess the market opportunities for their district.

Agronomist's view

SOUTHERN

With support from the GRDC, the University of Sydney aims to improve the productivity of dual-purpose triticales through plant breeding. This involves improving the grain yield and dry-matter production, producing winter triticales so there is a wider range of sowing dates, improving the grazing habit (so that the growing point



<sup>12</sup> AC Andrews, R Wright, PG Simpson, R Jessop, S Reeves, J Wheeler (1991) Evaluation of new cultivars of triticale as dual-purpose forage and grain crops. Animal Production Science, 31 (6), 769–775.









# **MORE INFORMATION**

<u>Dual Purpose Triticale Improvement</u> <u>program</u>

Triticale: grazing guide

is closer to the ground), and incorporating new sources of rust resistance. Shorter triticales are also produced to reduce the amount of stubble after harvest, suiting conservation-tillage farming practices, and also to improve grain yield.

Hybrid triticale is also being developed to increase yield by exploiting heterosis (hybrid vigour), the superiority of the F1 hybrid over the highest-yielding inbred varieties.

SOUTHERN

The breeding program is also seeking to enhance grain quality, with the aim of improving ruminant productivity on triticale feed. (Grain quality for pigs is being covered by the Pork CRC.)  $^{13}$ 

# 2.1.4 Triticale grain for livestock

The major uses for triticale grain are as a feed supplement in the dairy industry, as a component in feeds used in beef feedlots, and as a constituent of compound rations for intensive pig and poultry farming. In livestock diets, triticale has a similar role to other cereals (Tables 1 and 2) <sup>14</sup>: it is primarily a good source of energy, as it has a moderate amount of protein and high amounts of starch and other carbohydrates.

A key physical feature of triticale is that it is a soft grain; it has a hardness index almost half that of wheat and barley. This is an advantage in that less mechanical energy is required to mill triticale than wheat and barley prior to inclusion in livestock diets.

**Table 1:** Crude protein concentration and yield and% digestible dry matter IVDDM and yield of four grain species harvested at the milk stage of maturity.

Species	Crude	protein	IVDDN	<b>/</b> 1*
	% T/A		%	T/A
Spring wheat	15.7	0.43	63.3	1.72
Triticale	15.2	0.45	66.4	1.95
Oat	14.6	0.44	61.5	1.86
Barley	15.7	0.50	68.5	2.20

IVDDM = in vitro dry-matter digestibility Source: Oelke, Oplinger and Brinkman

**Table 2:** Forage and diet composition (dry matter basis).

Item	Alfalfa (%)	Triticale (%)	Oats (%)
Forage			
Dry matter	43.5	37.8	28.0
Crude protein	22.6	17.5	142.0
Neutral detergent fibre	43.8	54.8	52.4
Acid detergent fibre	32.9	32.1	31.1
Calcium	1.69	.56	.42
Phosphorus	.43	.56	.39
Diet			
Dry matter	58.1	52.4	43.7
Crude protein	16.4	17.2	17.3
Neutral detergent fibre	30.3	36.9	36.0
Acid detergent fibre	18.0	19.8	19.3

Source: Oelke, Oplinger and Brinkman



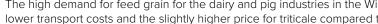
<sup>13</sup> University of Sydney (2012) Triticale. Plant Breeding Institute. University of Sydney, <a href="http://sydney.edu.au/agriculture/plant\_breeding-institute/key\_work\_results/triticale.shtml">http://sydney.edu.au/agriculture/plant\_breeding-institute/key\_work\_results/triticale.shtml</a>

EA Oelke, ES Oplinger, MA Brinkman (n.d.) Triticale. In Alternative Field Crops Manual. University of Wisconsin, <a href="https://www.hort.purdue.edu/newcrop/afcm/triticale.html">https://www.hort.purdue.edu/newcrop/afcm/triticale.html</a>









The high demand for feed grain for the dairy and pig industries in the Wimmera, the lower transport costs and the slightly higher price for triticale compared to other feed grains, makes triticale an attractive proposition for growers in the southern region. 16

On the farm, triticale can be fed to livestock in the same way wheat or barley would

SOUTHERN

**Table 3:** Effect of forage on milk yield and milk composition.

be. 15 It is well suited to feeding dairy cows (Table 3).

Item	Forage sou		
	Alfalfa	Triticale	Oats
No. of cows	15	15	12
Milk yield and composi	tion		
3.5% FCM 2 (lb/cow/day)	64.7ab	71.9a	60.7b
fat, %	3.7	3.7	3.9
protein, %	3.4	3.4	3.4
total solids, %	13.3	13.3	13.4

ab = Means differ (P 0.05).

Source: Oelke, Oplinger and Brinkman

A guide to the use of triticale in livestock feeds

Triticale: stock feed guide

**MORE INFORMATION** 

How much protein is in triticale grain is thought to depend most on the cultivar, less on the weather conditions of the growth year, and least on nitrogen fertiliser application. 17

# 2.1.5 Triticale as a cover crop

A cover crop is planted primarily to manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity and wildlife in an agro-ecosystem.

Triticale has a heavy residue on the surface, much like that of cereal rye if allowed to reach maturity, making it a good choice for weed suppression. 18

Triticale is a hardy cover crop that can suppress weeds and produce a moderate to high amount of biomass. Triticale will not produce as much biomass as rye, and may not tie up as much N in the spring.

Triticale is thought to be able reduce soil compaction, loosen topsoil and remove excess soil moisture. 19

One approach used in southern cropping regions involves annual crops being sown into established lucerne, a practice known as lucerne inter-cropping (Figure 1). 20 The benefits of doing this include reducing the risk of rainfall leakage during the cropping phase, as well as eliminating the costs of lucerne removal and re-establishment.



 $A griculture\ Victoria\ (2012)\ Growing\ triticale.\ Note\ AGO497.\ Revised.\ A griculture\ Victoria\ , \underline{http://agriculture.vic.gov.au/agriculture/grains-properties-formula-formul$ 15

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Natural Resources Conservation Service (2011) Cover crop: Planting specification guide NH-340. NRCS, http://www.nrcs Internet/FSE\_DOCUMENTS/stelprdb1081555.pdf

 $Agriculture\ Victoria\ (2015)\ Farmers'\ experiences.\ Agriculture\ Victoria\ , \\ \underline{http://agriculture.vic.gov.au/agriculture/dairy/pastures-resulture}$ management/managing-dryland-lucerne/farmers-experiences

**TABLE OF CONTENTS** 

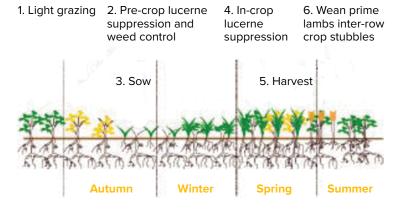


## **Under-sowing lucerne**

In Victoria, triticale ca be used for inter-cropping with Lucerne.  $^{21}$  Triticale has poor tillering capacity and good tolerance to shattering. This makes it a useful cereal as a cover crop to establish under-sown lucerne (Photo 3)  $^{22}$  or medic, although seeding rates may need to be reduced  $^{23}$  e.g. to approximately 10 to 20% of normal, targeting 15–30 plants per  $^{24}$ 

SOUTHERN

JANUARY 2018



**Figure 1:** Lucerne inter-cropping practice.

Source: Agriculture Victoria

When under-sowing:

- Use a grain-only variety with the earliest available maturity suited to your region
- Sow the triticale at lower seeding rate than used for optimising grain yield
- Choose a paddock with low weed numbers as the combination of species can dramatically reduce herbicide options.
- Expect a reduction in grain yield. 25



Photo 3: A paddock of cereal under-sown with lucerne.

Photos: Andy Howard



<sup>21</sup> Agriculture Victoria (2015). Farmers' experiences. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/dairy/pastures-management/managing-dryland-lucerne/farmers-experiences">http://agriculturevic.gov.au/agriculture/dairy/pastures-management/managing-dryland-lucerne/farmers-experiences</a>



**MORE INFORMATION** 

Farmers' experience with lucerne

Break benefits on Mallee soils

inter-cropping

<sup>22</sup> A Howard (2015) Hubert Charpentier, Brive, France: Lucerne as a living mulch, 4th May 2015. Blog post. Andy Howard's Nuffield Scholarship Journey, <a href="https://andyhowardnuffield15.wordpress.com/page/8/">https://andyhowardnuffield15.wordpress.com/page/8/</a>

<sup>23</sup> Agriculture Victoria (2012) Growing triticale. Note AG0497. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

<sup>24</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102">http://www.porkcrc.com.au/1A-102</a> Triticale. Guide Final Fact. Sheets.pdf

<sup>25</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/IA-102">http://www.porkcrc.com.au/IA-102</a> Triticale Guide Final Fact Sheets.pdf









<u>Triticale variety sowing guide – 2015</u>

Triticale variety trials - 2015

Triticale variety trials - 2011

As far as amount of growth to expect, it is very similar to that of a cereal rye plant, growing 0.9–1.5 m in height. Triticale also has a fibrous root system that makes it an excellent choice for preventing erosion, scavenging for nutrients, and building soil structure.

SOUTHERN

# 2.2 Varietal performance and ratings yield

Table 5 gives yield and protein estimates in different parts of the southern region. <sup>26</sup> Growers should be wary when choosing a variety as results can vary year to year. Long term comparisons for triticale varietal performance are yield are limited.

**Table 4:** 2015 triticale yield (as a percentage of the site mean yield) and protein (%). In all trials except Yarrawonga there were multiple frosts and extreme heat conditions. Interpret data with caution.

	Yield (%)						Protein (%)					
	Mallee		North East		South West	Mallee		North East		South West		
	Ultima	Walpeup	Rutherglen	Yarrawonga	Streatham	Ultima	Walpeup	Rutherglen	Yarrawonga	Streatham		
Sowing date	22/5/15	7/5/15	13/5/15	11/5/15	15/5/15							
Astute(b	106	127	93	107	115	12.4	11.3	_	12.5	14.9		
Berkshire(b	108	70	107	102	98	13.4	12.4	9.9	14.4	16.2		
Bison(b	114	131	106	113	110	12.5	11.2	9.3	13.4	15.5		
Bogong(D	99	95	109	108	105	13.1	11.1	9.5	13.2	14.6		
Canobolas(1)	82	97	97	109	99	13.7	11.7	9.6	14.4	16.2		
Chopper(D	112	97	91	104	-	11.9	11.7	9.9	12.7	_		
Endeavour(D	_	_	95	92	_	_	_	10.0	13.7	_		
Fusion(D	100	99	100	106	116	12.5	11.3	9.4	13.6	14.4		
Goanna	102	93	102	95	93	13.3	11.7	9.7	13.4	17.1		
Hawkeye(b	95	109	106	91	107	13.4	11.3	9.5	13.6	16.5		
Jaywick(1)	78	105	98	98	85	14.0	11.6	9.1	13.6	17.3		
KM10	83	55	-	-	-	12.4	12.0	_	-	-		
Rufus	109	86	90	91	73	12.8	12.7	10.0	14.4	17.0		
Tahara	90	96	91	86	94	13.3	12.0	10.1	14.0	15.8		
Tuckerbox	_	_	85	86	85	_	_	9.8	12.9	16.4		
Yowie	79	102	100	89	93	13.4	11.9	9.5	13.5	15.9		
Yukuri	_	_	_	_	74	_	_	_	_	16.0		
Site Mean (t/ ha)	0.67	1.50	5.86	2.25	3.08							
CV (%)	5	8	7	8	7							
LSD (%)	9	13	12	13	11							

Source: Agriculture Victoria



<sup>26</sup> Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary</a>





Variety	Origin	Purpose		infall zone and vironment		Height	Maturity	Head Type	Stripe Rust	CCn Resistance / Tolerance	Pratylenchus neglectus Resistance / Tolerance	Pratylenchus thornei Resistance / Tolerance																		
Chopper(1)	SA	Grain		Suited to late sowing		S-M	Very E	W/ Awned	MSS	R	-	-																		
Berkshire(b	NSW	Grain				Т	E-M	W/ Awned	MS	-	-	-																		
Bison(D	SA	Dual Purpose				Т	E-M	W/ R Awn	MR^	-	-	-																		
Bogong(b	NSW	Grain				M-T	М	W/ Awned	MS	MS/T	-	-																		
Canobolas(b	NSW	Grain				M-T	М	W/ Awned	MSS	-	-	-																		
Fusion()	SA	Grain				M-T	М	W/ Awned	MSS	R	-	-																		
Goanna	SA	Grain				Т	E-M	W / Awned	MRMS^	R	-	-																		
Hawkeye(1)	SA	Grain									M-T	М	W/ Awned	MR*	R	-	-													
KM10	SA	Grain																						M-T	E-M	W/ R Awn	MR^	S	-	-
Jaywick(b	SA	Grain	mm)							(mith.		M-T	М	W/ Awned	MR*	R	-	-												
Rufus	NSW	Dual Purpose	Low rainfall (<375 mm)			Т	М	W/ R Awn	MRMS	R/T	MRR/MT	MRR/MT																		
Tahara	VIC	Grain	ainfall			Т	М	W/ Awned	MS	R/T	MRR/MT	R / MT																		
Yowie	SA	Grain	Low r			M-T	М	W / Awned	MRMS	R	-	-																		
Endeavour(b	NSW	Dual Purpose		Suits long season, high rainfall	0 mm+)	-	L	W/ R Awn	R	R	-	-																		
Tuckerbox	SA	Dual Purpose		(450 mm+) environments as a grain	(450 mm+) OS environments as a grain	(450 mm+) (450 m	(450 mm+) ( environments as a grain	(450 mm+) Comments as a grain	(450 mm+) OS III of Line (450 mm+) OS III of L	High rainfall (500 mm+)	Т	М	W/ R Awn	MR	R	-	-													
Yukuri	NSW	Dual Purpose		crop		-	M-L	W/ R Awn	RMR	S	-	-																		

Height: S = Short, M = Medium, T = Tall.

 $\label{eq:Maturity: E = Early, M = Mid, L = Late.} \\$ 

Disease resistance: S = Susceptible, MS = Moderately Susceptible, MR = Moderately Resistant, R = Resistant. (\*some Susceptible plants in mix, 'limited data

Disease tolerance: T = Tolerant, MT = Moderately Tolerant.

Note that all recommended varieties are MR-R to stem and leaf rust, yellow leaf spot, mildew and scald. All varieties are S to crown rot and MS to common root rot.

Source: PIRSA

# 2.2.1 Varieties

## New: Astute(1)

Astute(b) is a new, mid-season triticale that is an alternative to Hawkeye(b) Bison(b) It was bred by AGT (as TSA0466), was first listed in 2015 and was available to growers in 2016. It is a fully-awned variety suited to medium—high-yielding environments, and with excellent agronomic characteristics for grain production. It is rated:

- · stem rust—RMR
- stripe rust—RMR#
- leaf rust—RMR



**SOUTHERN** 



**TABLE OF CONTENTS** 

FEEDBACK



# **MORE INFORMATION**

AGT, Astute(D

Berkshire() brings home the bacon

Bogong(D and Fusion(D inseparable in 2014 trials

Bogong(D and Canobolas(D—SA, Vic, NSW

AGT's aim was to produce a very high-yielding triticale which would be the choice for growers looking to maximise the production from their triticale crops in high-potential environments. Astute(b combines broad adaptation, resistance to rust and CCN, good physical grain quality, and top-end yield capabilities.

SOUTHERN
JANUARY 2018

Astute(b is suited to high yield potential areas of NSW and Victoria, with a very similar flowering time to Hawkeye(b) and Fusion(b.

#### Berkshire(1)

Berkshire(b) is a mid-season, awned variety with good straw strength. It is rated:

- stem rust—R
- stripe rust—MRMS#
- leaf rust—R.

This variety has been purpose bred for high yield and feed quality traits for pigs by the University of Sydney and Pork CRC; it was registered in 2009. Its characteristics are:

- Improved ileal digestible energy—13 MJ/kg compared to Tahara at 12 MJ/kg.
- Reduced fibre content—5% to 10% less than Tahara.
- Excellent yield—equivalent to best grain-only varieties currently available.
- · Good straw strength.
- · Quick to mid-season maturity.
- Moderately resistant to WA and Jackie strains of stripe rust.

#### New: Bison(1)

An early- to mid-season reduced-awn variety, Bison(b is best suited to low-medium-yielding environments. It was intended as a replacement for Rufus. It is rated:

- · stem rust-RMR
- stripe rust—R#
- leaf rust—RMR
- CCN—resistant.

Its characteristics are:

- Early-mid maturing, feed quality triticale.
- Tall plant type, with reduced awns and excellent disease resistance.
- Suited to central western NSW, southern NSW, northern Victoria, and SA.
- Moderately resistant to yellow leaf spot, and resistant–moderately resistant to Septoria tritici blotch.
- · Tolerant to acid soils.

#### Bogong(1)

Bogong(b) (tested as H127) was released by the University of New England, Armidale, in 2008. It is a grain variety with early- to mid-season flowering (similar to Treat). It is fully awned and stiff-strawed. It has good resistance to all common field strains of rust. Bogong(b) has been one of the top-yielding varieties in evaluation trials across all environments in the seven seasons to 2015, up to 15% above Tahara. It is a widely adapted spring variety that is moderately susceptible to CCN.  $^{27}$ 

## Canobolas(1)

This is an early- to mid-season awned variety with stiff straw, shorter than Tahara. it was bred by the University of New England, and registered in 2009. It is a widely adapted spring variety and tolerates acid soil. It is rated:

- stem rust—R
- stripe rust—MRMS#



<sup>27</sup> C Jeisman (2015) Triticale variety sowing guide 2015. PIRSA, <a href="http://www.pir.sa.gov.au/">http://www.pir.sa.gov.au/</a> data/assets/pdf\_file/0003/237909/triticale.pdf



**TABLE OF CONTENTS** 

FEEDBACK



# **MORE INFORMATION**

AGT, Chopper(D

GRDC, Fusion(D

Ground Cover Radio 110: Triticale program further lifts crop productivity

Goanna

· leaf rust—RMR.

## Chopper(1)

Chopper(b) is an awned, semi-dwarf spring variety which resists lodging in high-yielding environments; it is significantly shorter than all other currently available triticale varieties (15% shorter than Tahara). It matures very early: 3–4 days earlier than Speedee, and 7–15 days earlier than Tahara. It has good grain quality, and performs best in short growing seasons or late-sowing situations. It is rated:

SOUTHERN
JANUARY 2018

- stem rust—MR
- stripe rust—MRMS#
- leaf rust—R.

The variety was released in 2010.

#### Fusion 1

Fusion(b) is a mid-season variety (similar to Tahara), fully awned, grain-only spring triticale. It has moderate plant height, slightly taller than Hawkeye(b) and Jaywick(b), and similar height to Rufus. It yields well in dry or sudden finishes. It is rated:

- stem rust—R
- stripe rust—RMR#
- · leaf rust-R
- CCN—resistant.

It was released in 2012. Fusion(b produces large grain with low screening losses. Hectolitre weight is similar to that of Hawkeye(b and Jaywick(b, the benchmark varieties for this attribute. Its desirable sowing time is similar to Hawkeye(b and Tahara. Fusion(b is a fully awned triticale variety. It was released in 2012.

#### Goanna

Goanna is an early- to mid-season, fully awned, grain-only spring triticale, with a similar heading time to Treat, Tickit, Rufus and Hawkeye() It is a tall, white-chaffed variety. It is rated:

- stem rust—R
- stripe rust—RMR#
- leaf rust—R
- CCN—resistant.

It was released in 2011.

#### **KM10**

KM10 is a fast-growing early- to mid-season awned variety. It has excellent early forage production in all rainfall zones. It tends to have a smaller grain, and is ideally suited to grain production in short-season environments. It is rated:

- stem rust—R
- stripe rust—R#
- —leaf rust—MRMS
- CCN—susceptible.

It was released in 2014.

#### **Tahara**

A variety that has been widely grown for many years because of its reliability across a range of environments, Tahara is now outclassed by newer options. It may lodge in high-yielding situations. Tahara is suited to most districts with rainfall up to 550 mm. It is rated:

• stem rust—R











Yowie

Endeavour(D

- stripe rust—MRMS#
- leaf rust—R
- CCN—resistant
- · root-lesion nematode-resistant.

Its resistance makes it a valuable disease-break option. Released 1987 by the Victorian Department of Agriculture, Tahara has long been the benchmark variety for use in cereal rotations in most districts up to 500 mm average annual rainfall.

SOUTHERN
JANUARY 2018

#### Yowie

Yowie is a medium to tall mid-season spring grain triticale that has slightly later heading than Tahara. It is fully awned and white-chaffed. It is rated:

- stem rust—R
- stripe rust—MR#
- leaf rust—R
- CCN—resistant.

It was released in 2010, and has shown similar yield performance to other triticale varieties in the National Variety Trials.

## Hawkeye(1)

Hawkeye(b) (tested as TSA0108) was released by AGT in 2007, and is a broadly adapted, mid-maturing variety with high yield potential. It produces large grain with low screenings (similar to Tahara) and good test weight (like Treat), and is considered to be a high-yielding alternative to Tahara. It has CCN resistance, and good resistance to all rusts, making it a good alternative to Kosciuszko.

## Jaywick(1)

Jaywick(b) (tested as TSA0124) was released by AGT in 2007 and is a broadly adapted, mid-maturing variety with high yield potential. It produces large grain with low screenings and good test weight. It is considered a slightly earlier, higher-yielding alternative to Tahara. It has CCN resistance, and moderate to good resistance to all rusts.

# 2.2.2 Dual-purpose triticales

These varieties can be grazed early and then allowed to produce grain or cut for hay.

#### Endeavour(1)

Endeavour() is a long-season variety with similar maturity to Breakwell(). It is semi-awnless and has good straw strength, with excellent dry-matter production and excellent grain recovery after grazing. It is rated:

- stem rust—R
- stripe rust—RMR#
- leaf rust—R.

It was registered in 2008.

#### Rufus

Rufus is a mid-season-maturing variety, with a tall growth habit and reduced awns, making it favoured for hay production. Grain yields in higher-rainfall regions have been superior to Tahara, but may also cause lodging. It is rated:

- stem rust—R
- stripe rust—MRMS#
- leaf rust—R
- CCN—resistant.











Tobruk(D

Triticale trials

It was released in 2005 by the University of New England.

#### **Tobruk**(1)

With a strong winter habit Tobruk(b is a dual-purpose triticale, or a long-season grain-only variety with excellent grain yield. This variety, which was released in 2007, flowers earlier than Breakwell(b) and Endeavour(b). It is rated:

SOUTHERN

- stem rust—R
- stripe rust—MR#
- leaf rust—R.

Its characteristics are:

- · Seedling susceptible, but adult plant resistant to the Jackie strain of stripe rust.
- In some environments, it is affected by stripe rust head infection.
- Strong winter habit.
- Excellent yield after grazing compared to all other varieties in the NSW mixed cereal trials.
- Easy threshing.

#### **Tuckerbox**

Tuckerbox is a late-medium season, tall, high-tillering variety. It is a reduced-awn head type, and may be grown for forage or grain. It was released in 2009. It is rated:

- stem rust—MR
- stripe rust—MR#
- leaf rust—R
- CCN—resistant.

#### Yukuri

Yukuri was bred by the University of New England in 2004, and is a late-medium season variety and a reduced-awn head type. It is suitable for forage and grain production in environments with 450 mm+ rainfall. It has very good rust resistance, but is susceptible to CCN.

As triticale is a minor crop in Australia there is limited long term trial information available about the above vareties from NVT trials across the southern region.

# 2.3 Planting-seed quality

Before determining seed-sowing rates, seed-germination levels need to be known. For purchased seed this will be stated on the bags supplied. For home-grown seed, the percentage likely to germinate can be simply estimated by moistening the seed in blotting paper on a saucer, and covering with another, inverted saucer. The seed should be kept warm (20°C) and moist for 10 days. After that period, the percentage of seeds that have germinated can be recorded, and used as a guide for planting. Seed with approximately 90% germination or more is suitable for sowing. Seed produced in cooler tableland environments may tend to have poorer germination levels than seed produced in warmer regions, hence the need to check the germination rate. <sup>28</sup>

To receive the most accurate seed germination estimate, a professionally conducted seed test should be conducted by an accredited laboratory.

Heat damage in seeds causes slower germination, delayed emergence of the primary leaf, stunted growth, or even termination of the germination process (Photo 4). <sup>29</sup> In severe cases, seeds may die. During bulk storage, areas of excessive



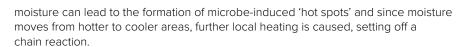
<sup>28</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="https://www.apri.com.au/A-102 Final Research Report.ord">http://www.apri.com.au/A-102 Final Research Report.ord</a>

<sup>29</sup> Grain SA (2012) Factors affecting wheat seed germination. Grain SA, http://www.grainsa.co.za/factors-affecting-wheat-seed-germination



**TABLE OF CONTENTS** 





SOUTHERN



**Photo 4:** Normal seed (left) compared to heat-damaged seed (right). Note the distinct colour difference.

Source: Grain SA

Seed impurities can occur from contamination through harvest, storage and machinery. Measurement of seed impurity will be included in a seed-purity certificate. Varieties that have been retained for multiple generations have a greater risk of seed impurity, with the build up of multiple chances for contamination. Ensuring that seed comes from clean, pure and even crops is imperative, and even so seed-purity tests should be carried out. Growers should conduct paddock audits prior to harvest to establish which paddocks best meet these criteria.

With dramatic increases in herbicide resistance, growers need to take seed purity into account when selecting paddocks for seed. This is because ryegrass and black oats now frequently appear in harvested grain samples, and have the potential to infest otherwise clean paddocks. <sup>30</sup>

## 2.3.1 Seed size

Seed size is an important physical indicator of seed quality that affects vegetative growth and is frequently related to yield, market grade factors and harvest efficiency. A wide array of different effects of seed size has been reported for seed germination, emergence, and related agronomic aspects in many crop species. <sup>31</sup> Generally, large seed has better field performance than small seed. Triticale has the largest seed size of all common small-grained cereal crops (Photo 5). <sup>32</sup>

In triticale, higher germination and emergence has been noted with bigger seed size. Large seeds show a higher emergence potential than smaller seeds (Photo 6). Larger seeds are capable of emerging from greater planting depths and have shown an enhanced ability to penetrate ground cover and survive burial by litter. <sup>33</sup>



<sup>30</sup> S Simpfendorfer, A Martin, M Sutherland (2012) Seed impurity undermines stripe rust resistance. 16th Australian Agronomy Conference, <a href="http://www.regional.org.au/au/asa/2012/disease/8325\_simpfendorfer.htm#TopOfPage">http://www.regional.org.au/au/asa/2012/disease/8325\_simpfendorfer.htm#TopOfPage</a>

<sup>31</sup> DAFWA (2014) Diagnosing poor quality seed in canola. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-poor-quality-seed-canola">https://www.agric.wa.gov.au/mycrop/diagnosing-poor-quality-seed-canola</a>

<sup>32</sup> Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary">http://agriculturevic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary</a>

<sup>33</sup> S Ambika, V Manonmani, G Somasundaram (2014) Review on effect of seed size on seedling vigour and seed yield. Research Journal of Seed Science, 7, 31–38.









SOUTHERN
JANUARY 2018

**Photo 5:** *Triticale* seed (*left*) is much larger than wheat seed (*right*). Source: Alberta Agriculture and Forestry

Large seed Small seed

**Photo 6:** Plants from small seeds have less vigour and lower yield (right). Source: DAFWA

Early researchers of triticale found that plants from larger seed were superior in total germination, seedling dry weight, and in seedling establishment than those from small seed. Large seed of a given cultivar gave 51% higher field stand, 62% more seedling dry weight and 37.8% higher grain yield than plants from small seed. <sup>34</sup> Note that this information is from one trial and may not represent all farm situations. Ultimately,



<sup>34</sup> UR Bishnoi, VT Sapra (1975) Effect of seed size on seedling growth and yield performances in hexaploid triticale. Cereal Research Communications, 49–60.



**TABLE OF CONTENTS** 



triticale naturally has good early vigour which gives it advantages over wheat and barley and an advantage in adverse soils and seasonal conditions.

**OUTHERN** 

Early seedling growth relies on stored energy reserves in the seed. Good seedling establishment is more likely if seed is undamaged, stored correctly, and comes from a plant that had adequate nutrition. Seed should not be kept when it comes from paddocks that were rain-affected at harvest. Seed grading is an effective way to separate good-quality seed of uniform size from small or damaged seeds and other impurities, such as weed seeds. Seed size is also important: the larger the seed, the greater the endosperm and starch reserves. Although size does not alter germination, bigger seeds have faster seedling growth, a higher number of fertile tillers per plant and potentially higher grain yield.

Seed size is usually measured by weighing 1,000 grains, known as the 1000-grain weight. Sowing rate needs to vary according to the 1,000-grain weight for each variety, in each season, in order to achieve desired plant densities. <sup>35</sup> To measure 1,000-grain weights, count out 10 lots of 100 seeds, then combine and weigh the whole lot. When purchasing seed, remember to request the seed-analysis certificate, which includes germination percentage, and the seed weight of each batch where available.

For a seed to emerge successfully from the soil, the seed should never be planted deeper than the coleoptile length. The coleoptile is the pointed, protective sheath that encases the emerging shoot as it grows from the seed to the soil surface (Photo 7). Coleoptile length is an important characteristic to consider when planting a crop, especially in drier seasons when sowing deeper to reach soil moisture. Sowing varieties with short coleoptile lengths too deep can cause poor establishment, because the shoot will emerge from the coleoptile underground and it may never reach the soil surface. <sup>36</sup>

Coleoptile length is influenced by seed size and several other factors, including variety, temperature, low soil water and certain seed dressings, such as those with the active ingredient triadimenol or flutriafol. Trifluralin and several Group B preemergent chemicals can also affect coleoptile length. Growers should read the label when using any seed-dressing fungicide for wheat, in order to see what affect it may have on coleoptile length.  $^{37}$ 

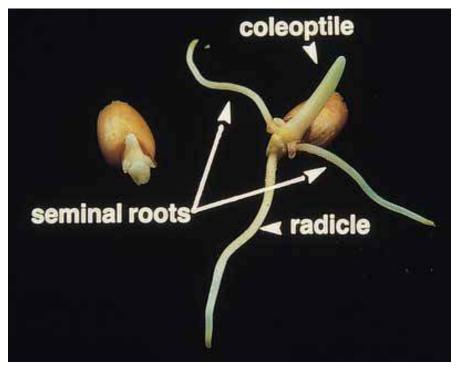


<sup>35</sup> NSW DPI District Agronomists (2007) Wheat growth and development. Procrop Series. NSW DPI, <a href="http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/w

<sup>36</sup> J Pumpa, P Martin, F McCrae, N Coombes (2013) Coleoptile length of wheat varieties. NSW DPI, <a href="http://www.dpi.nsw.qov.au/agriculture/broadacre-crops/winter-crops/wheat,-barley-and-other-winter-cereals/coleoptile-length">http://www.dpi.nsw.qov.au/agriculture/broadacre-crops/winter-crops/wheat,-barley-and-other-winter-cereals/coleoptile-length</a>

<sup>37</sup> J Pumpa, P Martin, F McCrae, N Coombes (2013) Coleoptile length of wheat varieties. NSW DPI, <a href="http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat\_-barley-and-other-winter-cereals/coleoptile-length">http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat\_-barley-and-other-winter-cereals/coleoptile-length</a>





**Photo 7:** Coleoptile length is important to consider when sowing seed. Varieties with short coleoptiles cannot be sown deep.

Photo: David L. Hansen, University of Minnesota

# 2.3.2 Seed germination and vigour

Seed germination and vigour greatly influence establishment and yield potential. Germination begins when the seed absorbs water, and ends with the appearance of the radicle. It has three phases:

- water absorption (imbibition)
- activation
- visible germination <sup>38</sup>

Triticale has excellent vigour due to its hybrid characteristics <sup>39</sup>, and germination increases with increasing seed size. Seed vigour affects how well the seed or seed lot germinates and emerges. Loss of seed vigour is related to a reduction in the ability of the seeds to carry out all of the physiological functions that allow them to grow well. This process, called physiological ageing (or deterioration), starts before harvest and continues during harvest, processing and storage. Seed performance is progressively reduced due to changes in cell membrane integrity, enzyme activity and protein synthesis. These biochemical changes can occur very quickly (a few days) or more slowly (years), the timescale depending on genetic, production and environmental factors that are not yet fully understood. The end point of this deterioration is death of the seed (i.e. complete loss of germination).

However, seeds lose vigour before they lose the ability to germinate. That is why seed lots that have similarly high germination values can differ in their physiological age (the extent of deterioration) and so differ in vigour and therefore the ability to perform.  $^{40}$ 

For more information on factors affecting germination, see <u>Section 4: Plant growth</u> and physiology.



<sup>38</sup> NSW DPI Agronomists (2007) Wheat growth and development. Procrop Series. NSW DPI, <a href="http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat-barley-and-other-winter-cereals/growth-and-development">http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat-barley-and-other-winter-cereals/growth-and-development</a>

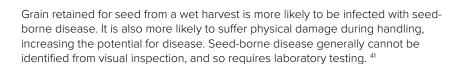
<sup>39</sup> AGF Seeds (2012) Triticale. AGF Seeds, <a href="https://agfseeds.com.au/">https://agfseeds.com.au/</a>

<sup>40</sup> ISTA Vigour Test Committee (1995) Understanding seed vigour. International Seed Testing Association, <a href="http://www.seedtest.org/upload/pri/product/UnderstandingSeedVigourPamphlet.pdf">http://www.seedtest.org/upload/pri/product/UnderstandingSeedVigourPamphlet.pdf</a>



**TABLE OF CONTENTS** 





SOUTHERN

For purchased seed, request a copy of the germination and vigour-analysis certificate from your supplier. For seed stored on the farm, you can send a sample to a laboratory for analysis.

While a laboratory seed test for germination should be carried out before seeding so you can calculate seeding rates, a simple on-farm test can be done in soil at harvest and during storage:

- Use a flat, shallow, seeding tray (about 5 cm deep). Place a sheet of newspaper
  on the base to cover the drainage holes, and fill with clean sand, potting mix
  or freely draining soil (Photo 8). 42 Ideally, the test should be done indoors at a
  temperature of ~20°C or lower.
- Alternatively, lay a well-rinsed plastic milk container on its side and cut a window in it. Place unbleached paper towels or cotton wool in the container, and lay out the seeds on this. Moisten and place on a window-sill. Keep moist, and count the seeds.
- Randomly count out 100 seeds. Do not discard damaged ones, and sow 10 rows
  of 10 seeds at the correct seeding depth. This can be achieved by placing the
  seed on the smoothed soil surface and pushing in with a pencil marked to the
  required depth. Cover with a little more sand or soil and water gently.
- Keep the soil moist but not wet, as overwatering will result in fungal growth and possible rotting.
- After 7–10 days, most of the viable seeds will have emerged.
- Count only the normal, healthy seedlings. If you count 78 normal vigorous seedlings, the germination percentage is 78%.
- Germination of 80% is considered acceptable for cereals.
- The results from a laboratory seed-germination test should be used for calculating seeding rates. <sup>43</sup>



<sup>41</sup> GRDC (2011) Saving weather damaged grain for seed, northern and southern regions. Retaining Seed Fact Sheet. GRDC, <a href="http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC\_FS\_RetainingSeed2.pdf">http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC\_FS\_RetainingSeed2.pdf</a>

<sup>42</sup> P Matthews, D Holding (n.d.) Germination testing and seed rate calculation. Pulse Point 20. NSW DPI, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0005/157442/pulse-point-20.pdf

<sup>43</sup> GRDC (2011) Saving weather damaged grain for seed, northern and southern regions. Retaining Seed Fact Sheet. GRDC, <a href="http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC\_FS\_RetainingSeed2.pdf">http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC\_FS\_RetainingSeed2.pdf</a>



**TABLE OF CONTENTS** 



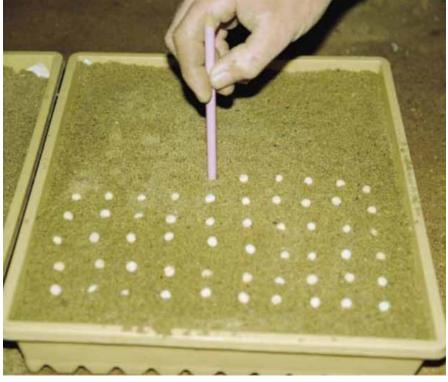


Germination testing and seed rate calculation



WATCH: Over the Fence: Insure seed viability with aerated storage





**Photo 8:** Use can use a pencil or straw to poke holes in a testing tray.

Source: NSW DPI

# 2.3.3 Seed storage

The aim of storage is to preserve the viability of the seed for future sowing and maintain its quality for market. A seed is a living organism that releases moisture as it respires.

Triticale is a softer grain than wheat and barley, which may make it easier to mill for livestock diets, but also means that it is more susceptible to insect damage in long-term storage.  $^{44}$  The ideal storage conditions are listed below.

- Temperature <15°C (if possible)—high temperatures can quickly reduce seed quality and its ability to germinate. This is why germination and vigour testing prior to planting is so important.
- Moisture control—temperature changes cause air movements inside the silo, carrying moisture to the coolest parts of the seed. Moisture is carried upwards by convection currents in the air; these are created by the temperature difference between the warm seed in the centre of the silo and the cool silo walls, or vice versa. Moisture carried into the silo head space may condense and fall back as free water, causing a ring of seed to germinate against the silo wall.
- Aeration slows the rate of deterioration of seed with 12.5–14% moisture content.
   Aeration markedly reduces grain temperature and evens out temperature differences that cause moisture movement.
- No pests—a temperature of <15°C stops all major grain insect pests from breeding, arresting activity at all stages of the life cycle so that they cause little or no damage. 45

For more information, see Section 13: Storage.



SOUTHERN

<sup>44</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/lA-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/lA-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>

<sup>45</sup> NSW DPI Agronomists (2007) Wheat growth and development. Procrop Series, NSW DPI, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/ pdf\_file/0008/516185/Procrop-wheat-growth-and-development.pdf



**TABLE OF CONTENTS** 





## 2.3.4 Safe rates of fertiliser to sow with seed

A productive triticale will require the application of phosphorous (P) and nitrogen (N) at sowing. Additional nitrogen is likely to be required for maximum dry-matter production for grazing and grain yield, particularly if the crop has been grazed.

Consider applying 15–20 kg P/ha at sowing. This is equivalent to 75–100 kg of mono-ammonium phosphate (MAP) per ha, which will also include 7.5–10 kg N/ha. A triticale used for grazing as well as grain production will require significant N.  $^{46}$ 

As with most crops, rates of fertiliser application should be based on soil testing and other historical response information as well as anticipated costs and returns.

Crop species differ in tolerance to N fertiliser applied with the seed at sowing. Research funded by Incitec Pivot Fertilisers has shown that the tolerance is related to the fertiliser product (ammonia potential and osmotic potential), the application rate, row spacing, and equipment used (e.g. disc or tyne), and soil characteristics such as moisture content and texture. 47

The safest application method for high rates of fertilisers that contain high amounts of ammonium is to place them away from the seed by physical separation (for combined N–phosphorus products) or by pre- or post-plant application (for straight N products). For fertilisers with a lower ammonium content, e.g. MAP, close adherence to the safe rate limits set for the crop species and the soil type is advised.

High rates of N fertiliser applied at planting in contact with, or close to, the seed may severely reduce seedling emergence. If a high rate of N is required, it should be applied before planting, or at planting but not in contact with the seed (i.e. banded between and below sowing rows). Rates should be reduced by 50% for very sandy soil and increased by 30% for heavy-textured soils or if soil-moisture conditions at planting are excellent. <sup>48</sup>

Nitrogen rates should be significantly reduced when using narrow points and press wheels or disc seeders. When moisture conditions are marginal for germination, growers need to reduce N rates if fertiliser is to be placed with, or close to, the seed.

For more information, see Section 5: Nutrition and Fertiliser.



<sup>46</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>

<sup>47</sup> Big N (2014) Nitrogen fertiliser placement and crop establishment. Incitec Pivot Fertilisers, <a href="http://bign.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers">http://bign.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bign.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bign.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bigm.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bigw.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bigw.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bigw.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bigw.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bigw.com.au/Big%20N%20Benefits/Nitrogen%20Fertilisers</a>, <a href="http://bigw.com.au/Big%20N%20Benefits/Nitrogen%20N%20Benefits/Nitrogen%20N%20Benefits/Nitrogen%20N%20N%20Be

<sup>48</sup> Farmer Community (2014) Guidelines for suggested maximum rates of fertiliser applied with the seed in winter crops. Fertiliser Facts. Incitec Pivot Fertilisers, <a href="https://tarmercommunity.incitecpivotfertilisers.com.au/Guides%20and%20Publications/Fertiliser%20Facts/Urea">https://tarmercommunity.incitecpivotfertilisers.com.au/Guides%20and%20Publications/Fertiliser%20Facts/Urea</a>







# **Planting**

# Key messages:

Triticale is not usually prone to infection from smuts and bunt. However, it is good
insurance to apply a seed dressing to the grain when it is being graded.

SOUTHERN

- Triticale generally has a similar sowing time requirement to other cereals, and should take a priority in the sowing schedule commensurate with its importance to the overall cropping enterprise. Triticale often suffers more from frost damage than wheat, hence it should generally be sown later.
- Aim to achieve the same plant populations as for wheat, i.e. set the seeder 25–40% above the setting recommended for wheat, as triticale grain is larger than wheat grain, and because plants tiller less than wheat.
- Depending on seed size, triticale should be sown at a seeding rate of 75–100 kg/ha.
- Recommended sowing depth for triticale ranges between 2–5 cm.<sup>2</sup>

Most cultural practices needed for growing triticale can be taken directly from wheat. These include:

- managing for seedbed preparation
- seeding rate
- · seeding depth
- · seeding date
- seeding methods<sup>3</sup>

#### 3.1 Innoculation

Not applicable to this crop.

## 3.2 Seed treatments

Seed treatments are applied to seed to control diseases, such as smuts, bunts or rust, and insects. Triticale is not usually prone to infection from smuts and bunt; however, it is good insurance to apply a seed dressing to the grain when it is being graded. Stripe rust may be a problem in triticale, and there are now options to treat seed to provide seedling protection against stripe rust. <sup>4</sup>

Fungicide seed dressings are used to protect the triticale crop from seed borne disease, such as loose smut. This treatment should form an integral part of the triticale disease management program, and will vary with variety and sowing time. It is recommended that growers seek local advice. <sup>5</sup>

When applying seed treatments, always read the chemical label and calibrate the applicator. Seed treatments are best used in conjunction with other disease-management options, such as crop and paddock rotation, clean seed, and resistant varieties, especially when managing diseases such as stripe rust.

There are risks associated with using seed treatments. Research shows that some seed treatments can delay emergence by:

• slowing the rate of germination



Birchip Cropping Group (2004) Triticale agronomy—2004. http://www.farmtrials.com.au/trial/13801

<sup>2</sup> DAFWA (2015) Monitoring sowing depth, Department of Agriculture and Food, Western Australia. <a href="https://www.agric.wa.gov.au/mycrop/monitoring-sowing-depth">https://www.agric.wa.gov.au/mycrop/monitoring-sowing-depth</a>

<sup>3</sup> E Collier, L Oatway (2016) Triticale crop production, Alberta Agriculture and Forestry. <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571</a>

<sup>4</sup> Agriculture Victoria (2012) Growing triticale. <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

Waratah Seed Co Ltd (2010) Triticale: planting guide. <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>



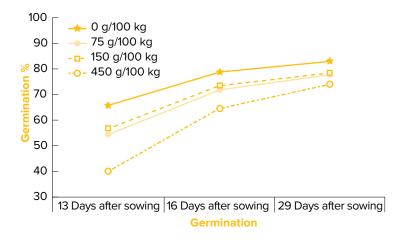






SOUTHERN

If there is a delay in emergence due to decreased vigour, it increases exposure to pre-emergent attack by pests and pathogens, or to soil crusting; this may lead to a failure to emerge. The risk of emergence failure increases when seed is sown too deeply or into a poor seedbed, especially in varieties with shorter coleoptiles. As the amount of certain fungicides increases, the rate of germination slows (Figure 1).



**Figure 1:** Impact of seed-treatment fungicide on the rate of germination.

Source: NSW DPI based on P Cornish, 1986

Product registrations change over time, and may differ between states and between products containing the same active ingredient. The registration status for the intended use pattern in your state must be checked on the current product label prior to use.  $^6$ 

# 3.2.1 Emergence problems

Caution should be taken in using seed treatment products for smut and foliar disease control, as they may reduce coleoptile length and cause emergence problems under some conditions.

Factors other than seed treatments can cause poor seedling emergence. These include deep sowing, surface crusting, short coleoptile varieties, soil temperatures and trifluralin.

Sowing too deep is a common cause of emergence problems. The coleoptile, which surrounds the first leaf until the shoot emerges, protects and guides the shoot as it grows through the soil. If seed is sown deeper than the length of the coleoptile, the plant can fail to emerge.

Because coleoptile lengths vary from one variety to another some varieties can tolerate deeper sowing than others. Coleoptile lengths vary greatly from one batch of seed to another. The source of seed is often more critical than the variety in determining coleoptile length. For this and other reasons, farmers should seek to use the best seed possible.

Most emergence problems occur in heavy clay soils where surface sealing occurs. Extra care is required when treated seed and/or trifluralin is used in such soils. <sup>7</sup>



Cereal seed treatments 2016



<sup>6</sup> NSW DPI District Agronomists (2007) Wheat growth and development, PROCROP Series, NSW Department of Primary Industries, <a href="http://www.dpi.nsw.qov.au/">http://www.dpi.nsw.qov.au/</a> data/assets/pdf\_file/0008/516185/Procrop-wheat-growth-and-development.pdf

H Wallwork (2016) Cereal seed treatments 2016, SARDI. <a href="http://www.pir.sa.gov.au/\_data/assets/pdf\_file/0005/237920/cerealseedtreat2017\_web.pdf">http://www.pir.sa.gov.au/\_data/assets/pdf\_file/0005/237920/cerealseedtreat2017\_web.pdf</a>



**TABLE OF CONTENTS** 

FEEDBACK



# **MORE INFORMATION**

GRDC Fact sheet: Targeted nutrition at sowing

GRDC Fact sheet: Time of sowing— Southern Region



# **VIDEOS**

WATCH: <u>GCTV Extension files: Wheat sowing strategies</u>



WATCH: <u>GCTV Extension files: Early</u> sowing opportunities



WATCH: GRDC: <u>Early sowing in the</u> LRZ



# 3.2.2 Fertiliser at seeding

The amount of nitrogen safely placed with the seed will vary depending on soil texture, amount of seedbed utilisation and moisture conditions. Higher amounts of nitrogen can be safely applied with the seed if it is a polymerised form of urea where the nitrogen is released over the period of several weeks. If soil moisture is marginal for germination, high rates of fertiliser should not be placed with the seed. Both nitrogen and phosphorous can be banded prior to seeding, but take care to avoid loss of seedbed moisture and protective crop residue. Place phosphorous with or near the seed at seeding time or band prior to seeding. 8

SOUTHERN

# 3.3 Time of sowing

Triticale generally has a similar sowing time requirement to other cereals and should take a priority in the sowing schedule commensurate with its importance to the overall cropping enterprise. Optimum time of sowing depends largely on the variety being grown (Table 1). Triticale often suffers more from frost damage than wheat, hence it should generally be sown later.

In the Victorian Mallee, the first two weeks of May are the ideal time to sow triticale, although the seasonal break often dictates the actual sowing opportunity. For the Wimmera and north central, mid-to-late May is generally the optimum sowing time. For north-eastern Victoria, depending on the variety, the whole month of May is potentially ideal. In the case of a long season variety (e.g. Jackie), sowing in the northeast can begin from early April. South-western Victoria has a wider sowing window due to a longer growing season and, depending on the variety, crops may be sown from early May to late June.

Acting promptly when a sowing window is available has proven critical over many seasons. Delayed sowing has generally proven costly, although to sow very early increases frost risk. Triticale appears to be more sensitive to frost damage than other cereals. Dry sowing for a portion of the crop is an option that has been very successful, and can be considered for triticale as well as other cereals. <sup>9</sup>

Long season varieties, such as Endeavour(b and Tobruk(b, can be sown as early as mid-February if seasonal conditions (i.e. rainfall) allows. Tobruk(b should only be sown this early if it is going to be grazed. Main season varieties, such as the traditional Tahara and Berkshire(b, should be sown at the same time as main season wheat, during May and early June.



Alberta Government (2016) Fall rye production. http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/agdex1269/\$file/f17\_20-1.pdf

Agriculture Victoria (2012) Growing triticale. <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>









WATCH: GCTV15: Optimal flowering—follow up



WATCH: Over the Fence south: <u>Early</u> sowing protects crops from winter <u>wet</u>



**Table 1:** Triticale time of sowing guide. This table is a guide only and has been compiled from breeder observations and local departmental agronomists.

SOUTHERN

MALLEE	April		М	ay			Ju	ne			Ju	ly
Berkshire(), Bison(), Chopper(), Fusion(), KM10, Rufus, Tahara, Goanna, Yowie		>	>	X	X	X	X	X	<	<		
WIMMERA	April		M	ay			Ju	ne			Ju	ly
Astute(b, Berkshire(b, Bison(b, Fusion(b, Rufus, Tahara, Goanna, Yowie				>	>	X	X	X	X	X	X	<
Chopper(b, KM10					>	>	Χ	Χ	Χ	Χ	Χ	Χ <
NORTH CENTRAL	April		M	ay			Ju	ne			Ju	ly
Astute(1), Berkshire(1), Bison(1), Credit, Fusion(1), Rufus, Tahara, Goanna, Yowie			>	>	Χ	X	Χ	Χ	<	<		
Chopper(b, KM10				>	>	Χ	Χ	Χ	<	<		
NORTH EAST	April		M	ay			Ju	ne			Ju	ly
Jackie	X X	X >	X	X	<							
Abacus		>	X	Χ	Χ	<	<					
Astute(b, Berkshire(b, Bison(b, Credit, Fusion(b, Tahara, Goanna, Yowie			>	×	X	X	<					
Chopper(1)				>	Χ	Χ	Χ	<				
SOUTH WEST	April		M	ay			Ju	ne			Ju	ly
Endeavour(), Jackie		>	X	Χ	Χ	Χ	Χ	Χ	<	<		
Abacus, Prime 322			>	>	Χ	X	Χ	Χ	Χ	Χ	<	<
Astute(b, Berkshire(b, Bison(b, Credit, Fusion(b, Kosciuszko, Tahara, Tobruk(b				>	>	X	X	X	X	X	<	<

>earlier than ideal, X optimum sowing time, < later than ideal but acceptable Source: Agriculture Victoria

### Lodging

Triticale can lodge because of:

- height
- · lush growth under conditions of high moisture and fertility
- high seeding rates

Lodging in cereal crops is influenced by structural plant traits as well as environmental conditions. Lodging in cereals is often a result of the combined effects of inadequate standing power of the crop and adverse weather conditions, such as rain, wind, and/ or hail. Lodging is also cultivar dependent. For example, a tall, weak-stemmed wheat cultivar has a greater tendency to lodge than a semi- dwarf cultivar with stiffer straw. Under conditions of high moisture and nitrogen fertility, semi-dwarf varieties are less prone to lodging than standard ones. Furthermore, short thick-strawed cultivars resist lodging better than tall cultivars. <sup>10</sup>

Triticale can be prone to lodging, however, earlier seeding appears to reduce this tendency towards lodging.  $^{\rm 11}$ 



<sup>10</sup> Brook H, Nelson M. (2015). Lodging of cereal crops. Alberta Agriculture and forestry. <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/crop1271">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/crop1271</a>

E Collier, L Oatway (2016) Triticale crop production, Alberta Agriculture and Forestry. <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571</a>



# 3.4 Targeted plant population

The range of sowing rates varies with variety and end use (Table 2). Because triticale grain size is larger than wheat, higher sowing rates are needed to achieve the same plant density. Sowing rates approximately 20% higher than those for wheat are recommended (Photo 1). Before determining seed sowing rates, seed germination levels need to be known. <sup>12</sup>

SOUTHERN



**Photo 1:** Triticale paddock sown according to targeted plant population. Source: Liebman M in  $\underline{\texttt{MCCC}}$ 

For information on seed quality testing, see Section 2: Pre-planting.

Aim to achieve the same plant populations as for wheat; i.e. set the seeder 25-40% above the setting recommended for wheat, as triticale grain is larger than wheat grain, and because plants tiller less than wheat. <sup>13</sup>

Table 2: Recommended plant populations for different uses of triticale. 14

Purpose/growing conditions	Best sowing rate (kg/ha)
Grain only	60–90
Grain and grazing	100–120
Undersowing pastures	35–45
Irrigation/high rainfall	100–120



<sup>2</sup> RS Jessop, M Fittler (2009) Triticale production manual: an aid to improved triticale production and utilisation, in Improved triticale production through breeding and agronomy, Cooperative Research Centre for an Internationally Competitive Pork Industry. <a href="http://www.apri.com.au/1A-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/1A-102\_Final\_Research\_Report\_pdf</a>

<sup>13</sup> Birchip Cropping Group (2004) Triticale agronomy—2004. http://www.farmtrials.com.au/trial/13801

<sup>14</sup> Birchip Cropping Group (2004) Triticale agronomy—2004. http://www.farmtrials.com.au/trial/13801

Target plant populations for triticale can also vary according to rainfall (Table 3).

**Table 3:** Plant establishment densities for triticale.

Average rainfall (mm)	Planting populations (plants/m²)
250–350	160–180
350-450	180–200
450-550	200–220

Source: Crop Monitoring Guide (Victoria)—Top Crop Australia (Incitec/GRDC) in GRDC Cereal Crop Growth Stages

Triticale does not tiller well. The desired plant density for triticale is  $180 \text{ plants/m}^2$  up to  $200 \text{ plants/m}^2$  in high rainfall zones. Depending on seed size this equates to a seeding rate of 75–100 kg/ha. If sowing is delayed (or if sowing in light, sandy soils), the higher plant density should be the target. <sup>15</sup>

Triticale sown for grazing should be sown at a seeding rate to obtain 150 plants per  $m^2$ , which is the same as grazing wheat. The target population of grain-only triticale can be reduced to 100 to 120 plants per  $m^2$ , as for main season grain-only wheat.

APSIM modelling was conducted (using the Agricultural Production Systems slMulator) to explore the optimal sowing density of triticale in Mediterranean-type environments. The tested model was then used to explore management options to maximize triticale yield. The response to sowing density was cultivar and rainfall-environment dependent. The simulation analysis indicated there was no yield advantage in higher sowing densities with a tall cultivar type in high yielding environments, despite its higher biomass growth rates. The highest yields were achieved at the early sowing date, at the sowing densities between 100 and 300 plants/m², in the high rainfall regions for both short and the tall cultivars. The simulation study suggests that sowing a short cultivar with a reduced radiation use efficiency but early vigour growth could increase current yields across different regions, seasons and management options in the Mediterranean climate. <sup>16</sup>

When sowing triticale as a cover crop (i.e. undersown with pasture), reduce the seeding rate to approximately 10 to 20% of normal, targeting 15-30 plants per m<sup>2</sup>. <sup>17</sup>

Plant more weight of triticale seed per unit area than when planting wheat. This is because triticale has larger seeds than wheat (Table 4).

**Table 4:** Typical values for characteristics of triticale.

Seeds/kg	Volumetric	Bulk der	nsities
	grain weight (kg/hL)	kg/m³	t/m³
23,000	65	650	0.65

Source: NSW DPI

Seed size influences plant density, with large seeds requiring a higher sowing rate than smaller seeds to target the same population. '1000 seed weight' is a measure of seed size. It should be determined for each seed lot, as results vary depending on how old the seed is and conditions it has been grown under. <sup>18</sup>

Despite the ability to compensate, targeting a variety's optimum plant density at sowing makes the most efficient use of water and nutrients. To reach a target



**OUTHERN** 

<sup>15</sup> Agriculture Victoria (2012) Growing triticale. <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

<sup>16</sup> S Bassu, S Asseng, F Giunta, R Motzo (2013) Optimizing triticale sowing densities across the Mediterranean Basin. Field Crops Research 144, 167–178.

Waratah Seed Co Ltd (2010) Triticale: planting guide. <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>

<sup>18</sup> K Condon (2003) Targeting optimum plant numbers, NSW Agriculture. <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0007/168523/targeting-optimum-plant-numbers.pdf



**TABLE OF CONTENTS** 





- sowing date—higher rates with later sowings
- seed germination percentage
- seed size
- · seedbed conditions
- tillage, e.g. no-till
- double-cropping
- · soil fertility
- soil type
- · soil moisture and seasonal outlook
- weed seed burden—higher sow rates for increased plant competition, e.g. if combatting herbicide-resistant ryegrass populations.

TOPCROP Victoria investigated sowing rates for wheat to achieve target plant densities using large-scale paddock demonstrations during the 2000 season. TOPCROP farmer groups established 30 sites across Victoria comparing 75%, 100%, 150% and 200% of the district practice for sowing rate. Initial findings indicated that poor seeder calibration and a lack of understanding of the influence of grain size has led to target plant densities not being reached. This highlights the need for sowing recommendations to be based on target plant densities rather than sowing rates. <sup>20</sup>

# 3.5 Calculating seed requirements

#### Key points:

- Plant more weight of triticale seed per unit area than when planting wheat. This is because triticale has larger seeds than does wheat.
- Adjust seeding rates to achieve targeted plant densities for specific triticale uses and conditions.
- Keep in mind that optimum seeding rates vary, depending on what the triticale will be used for.
- Choose and manage seeding rates to achieve target plant stand densities in the field.
- Triticale has the largest seed size of all common small-grained cereal crops.
   Ensure that your seed rate compensates for this.
- Rates are usually adjusted upwards when seeding forage mixtures or intercropped triticale.
- For mono-crop triticale forage production, recommended seeding rates are usually 25% higher than seeding rates for grain production.
- In two-component forage-crop blends using triticale, one guideline suggests each component consist of 75% of the normal seeding rate for the individual components alone. <sup>21</sup>

It is best to calculate the seeding rate using target plant population, germination percentage and seed count per kilogram, which is specified on the Seed Analysis Certificate (available on request when you purchase the seed). <sup>22</sup>

The desired plant density for triticale is 180 plants/m<sup>2</sup> up to 200 plants/m<sup>2</sup> in high rainfall zones. Depending on seed size this equates to a seeding rate of 75–100 kg/



NSW DPI District Agronomists (2007) Wheat growth and development, PROCROP Series, NSW Department of Primary Industries, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0008/516185/Procrop-wheat-growth-and-development.pdf

<sup>20</sup> A Johnson, M Evans, K Wansink (2001) Challenging sowing rates for wheat to achieve target plant densities, 10th Australian Agronomy Conference, Australian Society of Agronomy/The Regional Institute Ltd, <a href="http://agronomyaustraliaproceedings.org/images/sampledata/2001/p/10/iohnson.pdf">http://agronomyaustraliaproceedings.org/images/sampledata/2001/p/10/iohnson.pdf</a>

<sup>21</sup> E Collier, L Oatway (2016) Triticale crop production, Alberta Agriculture and Forestry. <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nst/all/fcd10571">http://www1.agric.gov.ab.ca/\$department/deptdocs.nst/all/fcd10571</a>

Waratah Seed Co Ltd (2010) Triticale: planting guide. <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>



**TABLE OF CONTENTS** 



ha. If sowing is delayed, or when sowing on light sandy soils, the higher plant density should be the target.  $^{\rm 23}$ 

SOUTHERN

Within limits, higher seeding rates in triticale lead to:

- higher crop yields
- better weed competition
- earlier maturity
- · fewer tillers per plant
- shorter plant height

Seeding rates should generally be adjusted upwards for:

- · large seed size
- low seed germination rate
- deep seeding (not a recommended practice)
- high moisture and yield potential conditions
- · heavy textured soils
- rough seedbed
- heavy weed pressure conditions (especially in organic production)

Lower seeding rates may be suitable for dry conditions. Triticale does not tiller as freely as wheat, and has greater difficulty in compensating for low stand establishment. Use your own experience to adjust plant density targets to your local conditions.  $^{24}$ 

Because seed sizes may vary depending on production years and variety type, a fixed quote for the weight of seed needed to sow one hectare is not always an accurate measure for obtaining a desired plant population per hectare. Note that triticale has a much larger 1000 kernel weight than do other cereals. Average graded seed sizes are:

large: 24,000 seeds/kg

medium: 27,500 seeds/kg

small: 30,000 seeds/kg

The formula in Figure 2 can be used to calculate sowing rates, taking into account:

- target plant density
- · germination percentage
- seed size
- establishment, usually 80%, unless sowing into adverse conditions

To calculate 1000-seed weight:

- count out 200 seeds
- weigh to at least 0.1 g
- multiply weight (g) by 5 <sup>25</sup>



<sup>23</sup> Agriculture Victoria (2012) Growing triticale. <a href="http://agriculture.vic.gov.au/agriculture/qrains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/qrains-and-other-crops/crop-production/growing-triticale</a>

<sup>24</sup> E Collier, L Oatway (2016) Triticale crop production, Alberta Agriculture and Forestry. http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571

<sup>25</sup> P Matthews, D McCaffery, L Jenkins (2014) Winter crop variety sowing guide 2014. NSW Department of Primary Industries, <a href="http://www.dpi.nsw.qov.au/agriculture/broadacre/quides/winter-crop-variety-sowingquide">http://www.dpi.nsw.qov.au/agriculture/broadacre/quides/winter-crop-variety-sowingquide</a>

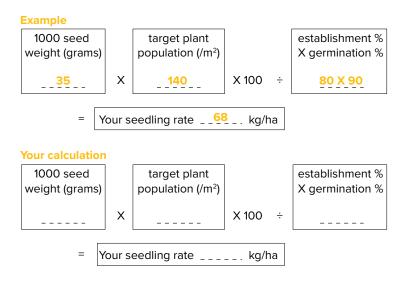


Figure 2: Seeding rate calculator.

#### 3.6 Sowing depth

Optimum planting depth varies with planting moisture, soil type, seasonal conditions, climatic conditions, and the rate at which the seedbed dries. The general rule is to plant as shallow as possible, provided the seed is placed in the moisture zone, but deep enough that the drying front will not reach the seedling roots before leaf emergence, or to separate the seed from any pre-emergent herbicides used. <sup>26</sup>

Recommended sowing depth for triticale ranges between  $2-5\,$  cm.  $^{27}$ 

When using triticale as a forage crop, sowing depth will depend on seasonal conditions, and the species and cultivar being sown. As a general rule, forage cereals are sown at an average depth of 3–4 cm. Sowing too deep can affect emergence, and shallow sowing can risk desiccation or damage from herbicide uptake. <sup>28</sup>

Triticale seed size is generally bigger than that of commonly grown wheat varieties. Consequently, triticale can be seeded deeper than other small cereals, and therefore benefit from stored moisture in the soil, which allows better crop establishment early in the season, particularly in drought-prone areas. Seeding equipment needs to be set to account for a seed that may be 10 to 20% larger than wheat.

Seed placement during the sowing process is very important when dealing with triticale cultivars. Triticale varieties equal—and in many cases exceed—the winter hardiness of the best wheats, if planted early during autumn and if planted shallowly (no more than 2.45 cm deep). At this depth, crops should see uniform seedling emergence and early weed competition. <sup>29</sup>

Shallow seeding allows for:

- more rapid emergence
- early vigour
- · improved competition with weeds



SOUTHERN

JANUARY 2018

<sup>26</sup> NSW DPI District Agronomists (2007) Wheat growth and development, PROCROP Series, NSW Department of Primary Industries, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0008/516185/Procrop-wheat-growth-and-development.pdf

<sup>27</sup> DAFWA (2015) Monitoring sowing depth, Department of Agriculture and Food, Western Australia. <a href="https://www.agric.wa.gov.au/mycrop/monitoring-sowing-depth">https://www.agric.wa.gov.au/mycrop/monitoring-sowing-depth</a>

<sup>28</sup> Agriculture Victoria (2012) Establishing forage cereals. <a href="http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/forage-cereals/establishing-forage-cereals">http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/forage-cereals/establishing-forage-cereals</a>

M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="https://www.fao.org/3/a-v5553e/v5553e00.pdf">https://www.fao.org/3/a-v5553e/v5553e00.pdf</a>







Due to its large seed size, triticale is able to emerge from deep seeding. It usually results in decreased emergence and less plant vigour, however.  $^{30}$ 

SOUTHERN

Seed size influences coleoptile length, which is sensitive to sowing depth. Sowing depth influences the rate of emergence and the percentage that emerges. Deeper seed placement slows emergence; this is equivalent to sowing later. Seedlings emerging from greater depth are also weaker, more prone to seedling diseases, and tiller poorly (Photo 2).



**Photo 2:** Reduced vigour with increased sowing depth.

Source: DAFWA

Recent research has confirmed the importance of avoiding smaller-sized seed when deep sowing.

Crop emergence is reduced with deeper sowing because the coleoptile may stop growing before it reaches the soil surface, with the first leaf emerging from the coleoptile while it is still below the soil surface. As it is not adapted to pushing through soil (does not know which way is up), the leaf usually buckles and crumples, failing to emerge and eventually dying. <sup>31</sup>

For more information, see <u>Section 4: Plant growth and physiology</u>.



10

<sup>30</sup> E Collier, L Oatway (2016) Triticale crop production, Alberta Agriculture and Forestry. http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571

<sup>31</sup> NSW DPI District Agronomists (2007) Wheat growth and development, PROCROP Series, NSW Department of Primary Industries, <a href="http://www.dpi.nsw.gov.au/\_data/assets/pdf\_file/0008/516185/Procrop-wheat-growth-and-development.pdf">http://www.dpi.nsw.gov.au/\_data/assets/pdf\_file/0008/516185/Procrop-wheat-growth-and-development.pdf</a>



**TABLE OF CONTENTS** 





WATCH: GCTV17: SFS seeder trial



WATCH: GCTV19: Different seeders
different yields. Local R&D – valuable
solutions for the HRZ grain growers



#### 3.7 Sowing equipment

The use of minimum soil disturbance has advantages for the production of triticale. One study noted a slight yield advantage for triticale grown under zero tillage. Seeding equipment needs to be set to account for a seed that may be 10 to 20% larger than wheat.  $^{32}$ 

SOUTHERN

JANUARY 2018

As much as 60% of the final yield potential for a crop is determined at planting. Seeding too thinly, using poor quality seed, and uneven stands result in end-of-season yield losses that usually cannot be overcome. <sup>33</sup>

Seeder calibration is important for precise seed placement, and seeders need to be checked regularly during sowing (Photo 3).

Most growers in the Southern Region use either a knife-point/press-wheel tyne system or a single disc. Disc seeders can handle greater quantities of stubble but experience crop damage issues with pre-emergent herbicide use. Tyne seeding systems do not have the same herbicide safety issues but, in high stubble load situations, require some form of post-harvest stubble treatment, such as mulching or burning.



**Photo 3:** Seeder calibration is important for precise seed placement and seeders need to be checked regularly during sowing.

Photo: Rohan Rainbow



<sup>32</sup> M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="https://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>33</sup> W Thomason (2004) Planting wheat: seeding rates and calibration. Virginia Cooperative Extension, <a href="http://www.sites.ext.vt.edu/newsletter-archive/cses/2004-10/plantingwheat.html">http://www.sites.ext.vt.edu/newsletter-archive/cses/2004-10/plantingwheat.html</a>





# Plant growth and physiology

#### **Key Messages:**

 Triticale is quite similar to wheat except it has spreading growth until stem elongation, when the stems extend in the normal erect growth form of wheat.

**SOUTHERN** 

- Triticale tillers less than wheat.
- Germination optimum temperature is 20°C.
- Growth optimum temperature is 10–24°C.
- Maximum temperature of survival is 33°C.
- Though triticale is generally considered tolerant to salt stress, studies have found that cultivars are slightly less salt tolerant at germination.<sup>2</sup>
- Since the early development of triticale, its tolerance to drought stress has increased compared to other cereals.

#### 4.1 Identifying triticale

The key characters of triticale are (see Table 1):

- Emerging leaves are rolled in the shoot.
- The leaf blade is flat with a clockwise twist.
- It has a short, membranous ligule.
- It has auricles.
- Seed is a grain similar to that of wheat. 3
- It grows to a height of about 1–1.5 m.
- The leaves are like those of wheat, but larger and thicker. The spikes are also larger. <sup>4</sup>



Hill Laboratories. Crop guide: Triticale. KB item 28750v1. Hill Laboratories, http://www.hill-laboratories.com/file/fileid/34912

<sup>2</sup> LE Francois, TJ Donovan, EV Maas, GL Rubenthaler (1988) Effect of salinity on grain yield and quality, vegetative growth, and germination of triticale. Agronomy Journal, 80 (4), 642–647.

<sup>3</sup> HerbiGuide. Triticale. HerbiGuide, <a href="http://www.herbiguide.com.au/Descriptions/hg\_Triticale.htm">http://www.herbiguide.com.au/Descriptions/hg\_Triticale.htm</a>; see also HerbiGuide, <a href="https://www.herbiguide.com.au/Descriptions/hg\_Triticale.htm">www.herbiguide.com.au/Descriptions/hg\_Triticale.htm</a>; see also HerbiGuide, <a href="https://www.herbiguide.htm">www.herbiguide.htm</a>; see also HerbiGuide, <a href="https://www.herbiguide.htm">www.herbiguide.htm</a>; see also HerbiGuide, <a href="https://www.herbiguide.htm">www.herbiguide.htm</a>; see also HerbiGuide, <a href="https://www.herbiguide.htm">https://www.herbiguide.htm</a>; see also HerbiGuide, <a href="https://www.herbiguide.htm">www.herbiguide.htm</a>; see also HerbiGuide, <a h

<sup>4</sup> Infoagro (n.d.) Triticale growing. Infoagro Systems, <a href="http://agriculture.infoagro.com/crops/triticale-growing/">http://agriculture.infoagro.com/crops/triticale-growing/</a>







**Table 1:** Main features of triticale.

Plant part	Description
Cotyledons	1
First leaves	Single, and similar to later leaves
Leaves	Emerging leaves rolled in the shoot
	Blade: parallel sided, flat, clockwise twist when viewed from above, 30–300 mm long, 10–20 mm wide
	Ligule: short membrane
	Auricles: present, occasionally with hairs on the shoulders
	Sheath: rolled, prominent veins, often bluish-green at the base
Stems	Many, unbranched stems arise from base, erect, up to 1,500 mm tall, hollow with solid nodes
Flower head	Compact spike, squarish in cross-section, awned (Figure 1) 5



SOUTHERN

**Photo 1:** vA comparison of flower heads. A: Bread wheat, B: Cereal rye and C: Triticale.

Source: Palomar College

Fruit Grain





**TABLE OF CONTENTS** 

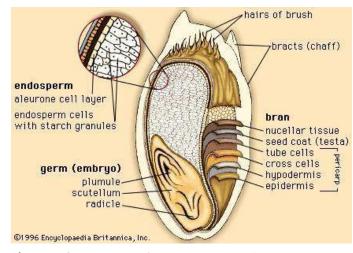




Seeds

Pale brown, dull, elongated oval, wrinkled grain, 8-12 mm long  $\times$  2.5-4 mm wide, 23-36 grains per gram; easily rubbed from the husks (Figure 2)

SOUTHERN



**Figure 1:** Cross-section of cereal grain seed. This is rye, but triticale is similar.

Source: Encyclopaedia Britannica

Roots Fibrous 2 <sup>6</sup>

Source: Wheat and triticale are difficult to distinguish, since their vegetative characteristics are similar. Removal of the seedling from the soil and observation of the grain shell may be a means of distinguishing wheat from triticale. Wheat grain shells tend to be lighter in colour than triticale. Wheat shells are oval; triticale grain shells are oblong. 7 In both, the auricles are blunt and hairy, and the leaf sheath and blade hairy too. The ligule is of medium length. Leaf blades twist clockwise.

#### 4.2 Germination and emergence

Germination begins when the seed absorbs water and ends with the appearance of the radicle. Germination has three phases:

- water absorption (imbibition)
- activation
- visible germination

The growth stages of cereals are numbered according to the Zadoks scale (see section 4.4.1).

#### Phase 1: Water absorption

Phase 1 starts when the seed begins to absorb moisture. This is growth stage 1 (GS01) in the Zadoks scale. Generally, a seed needs to reach a moisture content of around 35–45% of its dry weight to begin to germinate. Water vapour can trigger germination as rapidly as liquid can.

Seeds begin to germinate at a relative humidity of 97.7%. Soil so dry that roots cannot extract water from it still has a relative humidity of 99%, which is much higher than that of a dry seed. So even in dry conditions there can be enough moisture for the seed to absorb moisture and begin Phase 1, but it takes longer than in moist conditions.



<sup>6</sup> HerbiGuide. Triticale. HerbiGuide, <a href="http://www.herbiguide.com.au/Descriptions/hg\_Triticale.htm">http://www.herbiguide.com.au/Descriptions/hg\_Triticale.htm</a>; see also HerbiGuide, <a href="http://www.herbiguide.com.au/Descriptions/hg\_Triticale.htm">www.herbiguide.com.au/Descriptions/hg\_Triticale.htm</a>; see also HerbiGuide, <a href="http://www.herbiguide.htm">www.herbiguide.htm</a>; see also HerbiGuide.htm</a>; see also HerbiGuide.htm

<sup>7</sup> Agriculture Victoria (2012) Identification of cereal seedlings. Note AG0102. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/identification-of-cereal-seedlings">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/identification-of-cereal-seedlings</a>



#### Phase 2: Activation

Once the embryo has swollen, it produces hormones that stimulate enzyme activity (GS03). This is Phase 2. The enzymes break starch and protein stored in the seed into sugars and amino acids, which provide energy to the embryo. The larger the seed, the more starch, and therefore energy it will have stored. If the seed dries out before the embryo starts to grow, it remains viable. Phase 2 continues until the rupture of the seed coat, the first visible sign of germination.

SOUTHERN

#### Phase 3: Visible germination

In Phase 3 (GS05–GS09), the embryo starts to grow visibly. The radicle emerges, followed soon after by other primary roots and the coleoptile. The enzymes produced in Phase 2 mobilise sugars and amino acids stored in the seed, and enable their transfer to the growing embryo.  $^{\rm 8}$ 

#### Conditions of germination

Triticale cultivation can be carried out in subtropical, moderately mild and moderately cold climates. Optimal temperatures are:

- for germination, 20°C
- for growth, 10-24°C

In a study comparing the tolerance of cereal seeds to a range of temperatures, triticale was found to be more sensitive than wheat and barley to germination temperature. <sup>9</sup> Very low temperatures can damage triticale seedling during germination and emergence (Photo 2). <sup>10</sup>

The minimum temperature at which triticale can survive is  $-10^{\circ}\text{C}$ , and the maximum is 33°C. <sup>11</sup>

The thermal time to the emergence of the first seedling for triticale has been recorded at 113–119 degree-days, and 127–130 degree-days for 95% emergence. This equates to a rate of seedling emergence of 3.3–3.1% seedlings per degree-day (°Cd-1 or thermal time).



Photo 2: Cold-temperature damage in emerging triticale.

Source: Alberta Agriculture and Forestry



<sup>8</sup> NSW DPI District Agronomists (2007) Wheat growth and development. Procrop Series. NSW DPI, <a href="http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat-barley-and-other-winter-creeals/growth-and-development">http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat-barley-and-other-winter-creeals/growth-and-development</a>

T Buraas, H Skinnes (1985) Development of seed dormancy in barley, wheat and triticale under controlled conditions. Acta Agriculturae Scandinavica, 35 (3), 233–244.

<sup>10</sup> Alberta Agriculture and Forestry (2016) Triticale crop production. Revised. Alberta Agriculture and Forestry, <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571</a>

<sup>11</sup> Infoagro (n.d.) Triticale growing. Infoagro Systems, <a href="http://agriculture.infoagro.com/crops/triticale-growing/">http://agriculture.infoagro.com/crops/triticale-growing/</a>



**TABLE OF CONTENTS** 





Though triticale is generally considered to be tolerant to salt stress, studies have shown that cultivars are slightly less salt tolerant at germination than they became after the three-leaf stage of growth. <sup>12</sup> Early researchers found that saline soils could impair triticale emergence, although the application of calcium sulfate (CaSO4) helped to increase emergence in these conditions. <sup>13</sup>

In one study, researchers found that drought conditions had more negative effects on triticale germination percentage and seedling growth than sodium chloride. Germination and seedling growth were higher in large seeds than in small seeds in control solution and under osmotic stress. In addition, it was observed that seedlings obtained from larger seeds could survive under more intense conditions than those that grew from small seeds. <sup>14</sup>

Excessive herbicide treatments may also limit germination in triticale. The successive effect of five herbicide variants (isoxaben, chlorsulfuron, isoproturon, chlortoluron and a control) on the germination and plant growth of triticale cultivars has been explored. Germinative energy and germinating power of winter triticale seeds, obtained from plants treated with herbicide, were generally lower, in particular for the isoproturon and chlorsulfuron variants. <sup>15</sup>

Aeration of seed during storage can help to ensure high seed viability and germination rates. <sup>16</sup>

As the first primary roots appear, the coleoptile (Photo 3) bursts through the seed coat and begins pushing towards the surface. Emergence is when the coleoptile or the first leaf becomes visible above the soil surface. The coleoptile is well developed in the embryo, where it forms a thimble-shaped structure covering the seedling tube leaf and the shoot. Once the coleoptile emerges from the seed, it increases in length until it breaks through the soil surface. The fully elongated coleoptile is a tubular structure about 50 mm long and 2 mm in diameter. It is white, except for two strands of tissue that contain chlorophyll. The end of the coleoptile is bullet-shaped and is closed except for a small pore, 0.25 mm long, a short distance behind the tip.



<sup>12</sup> LE Francois, TJ Donovan, EV Maas, GL Rubenthaler (1988) Effect of salinity on grain yield and quality, vegetative growth, and germination of triticale. Agronomy Journal, 80 (4), 642–647.

<sup>3</sup> JD Norlyn, E Epstein (1984) Variability in salt tolerance of four triticale lines at germination and emergence. Crop Science, 24(6), 1090–1092.

D Kaydan, M Yagmur (2008) Germination, seedling growth and relative water content of shoot in different seed sizes of triticale under osmotic stress of water and NaCl. African Journal of Biotechnology, 7 (16), 2862.

S Sławomir, M Robert (1996) Successive effect of herbicides on triticale seed germination and plant growth. In H Guedes-Pinto, N Darvey, V Carnide (eds) Triticale: Today and Tomorrow. Springer Netherlands, pp. 743–747.

<sup>16</sup> N Baxter (2014) Study finds aeration improves seed germination. Ground Cover. No. 113, November–December. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-113-NovDec-2014/Study-finds-aeration-improves-seed-germination">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-113-NovDec-2014/Study-finds-aeration-improves-seed-germination</a>



**TABLE OF CONTENTS** 

FEEDBACK



SOUTHERN

**Photo 3:** Cereal seed germination showing the coleoptile (green) emerging to reach soil surface.

Source: Crop Gene Bank

When the coleoptile senses light it stops growing and the first true leaf pushes through the pore at the tip. Up to this point, the plant has been living on reserves within the seed. <sup>17</sup> A difference between the coleoptile and the first true leaf is that the coleoptile knows which way the soil surface is. If it does not reach the surface, the first leaf may emerge under the soil and grow in any direction. This is one reason that planting depth is so important.

Optimum planting depth varies with planting moisture, soil type, seasonal conditions, climatic conditions, and the rate at which the seedbed dries. The general rule is to plant as shallow as possible, provided the seed is placed in the moisture zone, but deep enough that the drying front will not reach the seedling roots before leaf emergence, and to separate the seed from any pre-emergent herbicides used. <sup>18</sup>

When shallow seeding, the previous crop's residue will have a greater tendency to interfere with good seed-to-soil contact. To enhance quick emergence, it is important that previous crop residue is evenly spread (Photo 4). Make sure seed-to-soil contact occurs. <sup>19</sup>



<sup>17</sup> NSW DPI District Agronomists (2007) Wheat growth and development. Procrop Series. NSW DPI, <a href="http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat,-barley-and-other-winter-cereals/growth-and-development">http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat,-barley-and-other-winter-cereals/growth-and-development</a>

<sup>18</sup> NSW DPI Agronomists (2007) Wheat growth and development. Procrop Series. NSW DPI, <a href="https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat,-barley-and-other-winter-cereals/growth-and-development">https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat,-barley-and-other-winter-cereals/growth-and-development</a>

<sup>19</sup> Alberta Agriculture and Forestry (2016) Fall Rye Production. Agdex 117/20-1. Revised. Alberta Agriculture and Forestry, <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nst/all/agdex1269/\$file/117\_20-1.pdf">http://www1.agric.gov.ab.ca/\$department/deptdocs.nst/all/agdex1269/\$file/117\_20-1.pdf</a>



**TABLE OF CONTENTS** 





**SOUTHERN** 

IANUARY 2018

Photo 4: Triticale seedlings emerge.

Source: Midwest Cover Crops Council

Sowing depth may influence the rate of emergence and the percentage of seedlings that emerge. Deeper seed placement may slow emergence if the soil is dry; this is equivalent to sowing later. Seedlings emerging from greater depth may be weaker and more prone to seedling diseases, however this is more likely due to unsuitable temperature, moisture or nutritional conditions (see Photo 5). <sup>20</sup> Crop emergence can be reduced with deeper sowing because the coleoptile may stop growing before it reaches the soil surface, with the first leaf emerging from the coleoptile while it is still below the soil surface. As it is not adapted to pushing through soil (i.e. does not 'know' which way is up), the leaf usually buckles and crumples, failing to emerge and eventually dying. <sup>21</sup> Recent research has confirmed the importance of avoiding smaller-sized seed when deep sowing.



<sup>20</sup> N Poole (2005) Cereal Growth Stages. GRDC, <a href="https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf">https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf</a>

<sup>21</sup> NSW DPI Agronomists (2007) Wheat growth and development. Procrop Series, NSW DPI, <a href="http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat-barley-and-other-winter-cereals/growth-and-development">http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat-barley-and-other-winter-cereals/growth-and-development</a>



**TABLE OF CONTENTS** 





**Photo 5:** By the stage of the first unfolded leaf, GS11, there is a noticeable difference in vigour between a deep-sown seedling (left) and correctly sown seedling (right).

Source: GRDC

#### 4.2.1 Soil moisture

Soil moisture influences the speed of germination. Germination is rapid if the soil is moist. When the soil dries to near the permanent wilting point, the speed of germination slows. Instead of taking five days at 7°C, the germination speed with adequate moisture, at the point of permanent wilt, the seed will take 10 days at 7°C to germinate.

The germination process in a seed may stop and start in response to available moisture. Therefore, seeds that have taken up water and entered Phase 2, but not reached Phase 3, remain viable if the soil dries out. This can happen when dry sowing is followed by a small amount of rain that keeps the soil moist for a few days before drying out. When the next rain comes, the seed resumes germinating, taking up water and moving quickly through Phase 2, so that germination is rapid. This ability to start and stop the germination process before the roots and coleoptile have emerged is an important consideration when dry sowing. If the seedbed dries out before the coleoptile has emerged, the crop needs to be monitored to determine whether it will emerge, so the critical decision to re-sow can be made.

Soil moisture also affects emergence. Sowing into hard-setting or crusting soils that dry out after sowing may result in poor emergence. The hard soil makes it difficult for the coleoptile to push through to the surface, particularly in varieties with short coleoptiles. In some crusting soils, gypsum and/or lime may improve soil structure and assist seedling emergence.

Stubble reduces the impact of raindrops on the soil surface and helps to prevent formation of soil crusts. Stubble retention also encourages biological activity and



SOUTHERN

JANUARY 2018







increases the amount of organic matter, which improves the stability of the soil by binding the soil particles together.  $^{22}$ 

SOUTHERN

## 4.3 Effect of temperature, photoperiod and climate on plant growth and physiology

#### 4.3.1 Temperature

One study explored the effect of high temperatures at different growth stages on triticale. Thermal treatments consistently reduced grain yield (P < 0.05), the magnitude of the effect ranging between 5% and 52%. The greatest effect (46% yield decrease) was found when temperature increased during stem elongation, and the least (15%) when treatments were imposed during heading—anthesis; an intermediate effect (27%) was found when treatments were imposed during booting—anthesis. Greatest yield losses were seen when plants were exposed to high temperatures in the booting—anthesis stage.  $^{23}$ 

Temperature can also affect the photosynthesis and respiration rates of triticale, leading to changes in growth.  $^{24}$ 

High temperatures are known to induce rapid growth which diminishes the cell pool of metabolites (e.g. amino acids, nitrates, carbohydrates) and therefore nutritional quality.  $^{25}$ 

#### 4.3.2 Photoperiod

There is limited research into the effects of photoperiod on triticale growth, and results vary between studies.

Spring is thought to be triticale is insensitive to photoperiod. During the early stages of triticale breeding, spring types used in northern latitudes tended to be daylight-sensitive, requiring more than 12 hours of light to initiate the change from the vegetative state. The development of daylight-insensitive types has greatly eliminated this problem for the production of triticale at lower latitudes, where day lengths are short. <sup>26</sup>

The developmental responses to temperature and photoperiod of five triticale cultivars and one wheat cultivar were examined in the field at Werribee, Victoria, in 1974. Researchers created a range of different photoperiod and temperature treatments by using six times of sowing and supplemental illumination to provide an 18-hour day length at one of the two sites. The order in which the varieties reached the various developmental stages changed very little with the successive times of sowing, but differed when the natural day length was compared with the 18-hour regime. When the duration of each phase was shortened by a longer mean daily photoperiod or a higher mean daily temperature, they observed that, in this instance, photoperiod had a greater effect than the temperature. <sup>27</sup>



<sup>22</sup> NSW DPI District Agronomists (2007) Wheat growth and development. Procrop Series. NSW DPI, <a href="http://www.dpi.nsw.gov.au/agriculture/">http://www.dpi.nsw.gov.au/agriculture/</a> broadacre-crops/winter-crops/wheat,-barley-and-other-winter-cereals/growth-and-development

<sup>23</sup> C Ugarte, DF Calderini, GA Slafer (2007) Grain weight and grain number responsiveness to pre-anthesis temperature in wheat, barley and triticale. Field Crops Research, 100 (2), 240–248.

<sup>24</sup> M Winzeler, DE McCullough, LA Hunt (1989) Leaf gas exchange and plant growth of winter rye, triticale, and wheat under contrasting temperature regimes. Crop Science, 29 (5), 1256–1260.

<sup>25</sup> CM McGoverin, F Snyders, N Muller, W Botes, G Fox, M Manley (2011) A review of triticale uses and the effect of growth environment on grain quality. Journal of the Science of Food and Agriculture, 91 (7), 1155–1165.

<sup>26</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>27</sup> JB Brouwer (1977) Developmental responses of different hexaploid triticales to temperature and photoperiod. Animal Production Science, 17 (88), 826–831.



**TABLE OF CONTENTS** 





#### 4.3.3 Salinity

Triticale has been found to be a salt tolerant crop. <sup>28</sup> Triticale is thought to be less salt tolerant that barley, but more salt tolerant than wheat. Studies in the US found that relative grain yield for triticale cultivars was unaffected by soil salinity up to 7.3 dS/m (electrical conductivity of the saturated-soil extracts in the root zone). Each unit increase in salinity above this reduced grain yield by 2.8%. These results place triticale in the salt-tolerant category. Yield reduction was primarily from a reduction in spike number rather than from lower weight per spike or lower weight per individual seed. These cultivars were slightly less salt tolerant at germination than they were after the three-leaf stage of growth. <sup>29</sup>

### **IN FOCUS**

## The affect of salt stress on photosynthetic characteristics and growth of triticale

Researchers treated six triticale cultivars with sodium chloride (NaCl) in concentrations of 0.5, 100, 200, 300 mmol/L. After 15 days, they measured the photosynthetic rate, transpiration rate, stomatal conductance, intercellular carbon dioxide (CO $_{\!2}$ ) concentration, root length, seedling height and fresh weight. They found that the 50 mmol/L NaCl process promoted the photosynthetic rate and the growth of the seedlings. However, as the concentration of NaCl increased, the net photosynthetic rate, transpiration rate and stomatal conductance of the seedlings decreased, the intercellular CO $_{\!2}$  concentration showed regular changes, and the growth of seedlings impeded.  $^{30}$ 

One study found that the germination of triticale under saline soil conditions could be improved by applying salicylic acid.  $^{31}$ 

#### 4.3.4 Drought

Triticale shows some drought tolerance due to its early vigour stemming from its cereal rye heritage. In Australia, triticale has often been more adaptable to drought conditions than wheat and barley. In triticale, tolerance to drought stress has increased with breeding compared to other cereals. <sup>32</sup>

A wide range of genotypic variability exists within triticale strains and cultivars show a wide range of tolerances to drought.  $^{\rm 33}$ 



<sup>28</sup> RM Koebner, PK Martin (1996) High levels of salt tolerance revealed in triticale. In H Guedes-Pinto, N Darvey, V Carnide (eds) Triticale: Today and Tomorrow. Springer Netherlands, pp. 429–436.

<sup>29</sup> LE Francois, TJ Donovan, EV Maas, GL Rubenthaler (1988) Effect of salinity on grain yield and quality, vegetative growth, and germination of triticale. Agronomy Journal, 80 (4), 642–647.

<sup>30</sup> LR Shi, XG Cui, YX Zhu (2009) The effect of salt stress on photosynthetic characteristics and growth of various triticale. Journal of Hengshui University 2009–04, <a href="http://en.cnki.com.cn/Article\_en/CJFDTOTAL-HSSZ200904022.htm">http://en.cnki.com.cn/Article\_en/CJFDTOTAL-HSSZ200904022.htm</a>

<sup>31</sup> V Ghodrat, MJ Rousta, N Zare (2013) Improving germination and growth of Triticale (x Triticosecale Wittmack) by priming with salicylic acid (SA) under saline conditions. International Journal of Agriculture and Crop Sciences, 5 (16), 1832.

<sup>32</sup> RS Jessop (1996) Stress tolerance in newer triticales compared to other cereals. In H Guedes-Pinto, N Darvey, V Carnide (eds) Triticale: Today and Tomorrow. Springer Netherlands, pp. 419–427.

<sup>33</sup> CM McGoverin, F Snyders, N Muller, W Botes, G Fox, M Manley (2011) A review of triticale uses and the effect of growth environment on grain quality. Journal of the Science of Food and Agriculture, 91 (7), 1155–1165.









SOUTHERN

## The role of stomatal conductance for water and radiation use efficiency of durum wheat and triticale in a Mediterranean environment

Stomatal conductance is important in crop water-use and ultimately affects crop productivity. Researchers in the Mediterranean-type climate of Italy tested the stomatal conductance of durum wheat and triticale in different environments. They compared leaf-transpiration efficiency and water- and radiation-use efficiency between the two species, giving an indication of crop productivity in different environments.

A large variation in stomatal conductance was observed between species. The greater stomatal conductance of triticale before anthesis did not deplete soil water as there was adequate water available for the development of dense canopies. The greater radiation-use efficiency of triticale associated with greater stomatal conductance in pre-anthesis resulted in greater biomass than durum wheat. Transpiration efficiency of triticale was also higher at the crop level, in spite of similar transpiration efficiency at the leaf level.

The greater stomatal conductance of triticale means an advantage in terms of both water and radiation use efficiency despite typical terminal drought affecting winter cereal crops in a Mediterranean-type environment. <sup>34</sup>

In one experiment, triticale cultivars were subjected to drought during the tillering phase and the heading phase. The cultivars were able to maintain better leaf hydration and, therefore, maintain photosynthesis. It is suggested that these are adaptation mechanisms, acting during drought, which can inhibit the use of carbohydrates in leaf growth and maintain high osmotic potential of cell sap. <sup>35</sup>



<sup>34</sup> R Motzo, G Pruneddu, F Giunta (2013) The role of stomatal conductance for water and radiation use efficiency of durum wheat and triticale in a Mediterranean environment. European Journal of Agronomy, 44, 87–97.

<sup>35</sup> T Hura, K Hura, M Grzesiak (2011) Soil drought applied during the vegetative growth of triticale modifies the physiological and biochemical adaptation to drought during the generative development. Journal of Agronomy and Crop Science, 197 (2), 113–123.







#### Water stress

## **IN FOCUS**

SOUTHERN

## Triticale grain yield and physiological response to water stress

Water availability in semi-arid regions is becoming increasingly threatened as rains become more erratic and droughts more frequent. This has led to over-reliance on irrigation in order to meet food demand. Improving crop Water Use Efficiency (WUE) has become a priority. A two-year study was carried out four commercial triticale genotypes that were subjected to four moisture levels, ranging from well-watered (430–450 mm) to severely stressed (220–250 mm). The triticales were grown under field conditions in a hot, arid, steppe climate in South Africa. The results showed that moisture level significantly influenced grain yield and intrinsic WUE in triticale. Well-watered conditions increased grain yield, which ranged from 3.5–0.8 t/ha–1 in 2013 and 4.9–1.8 t/ha–1 in 2014. Intrinsic WUE increased with decreasing moisture level. The researchers found that flag-leaf photosynthesis and pre-anthesis assimilates contribute much less carbon to grainfilling under water stress than previously thought. <sup>36</sup>

#### 4.4 Plant growth stages

Plant development is divided into several stages: germination and early seedling growth, tillering and vegetative growth, elongation and heading, flowering, and kernel development. Numerical scales have been developed for quantifying growth stages of small-grain crops. A growth stage key provides farmers, advisers and researchers with a common reference for describing the crop's development. Management by growth stage is critical to optimise returns from inputs such as N, herbicides, plant growth regulators and fungicides.

#### 4.4.1 Zadoks scale of cereal growth stages

The Zadoks scale marks the growth stages of cereals according to 10 distinct developmental phases (Figure 2).  $^{37}$  Table 2 relates the main features of the earlier stages of growth with the Zadoks scale.  $^{38}$ 

The Zadoks system uses a 2-digit code to refer to the principal stages of growth from germination (stage 0) through kernel ripening (stage 9). The second digit represents a subdivision of the principal growth stages. For instance, 13 indicates that in principal stage 1 (seedling growth) subdivision 3, when leaves are at least 50% emerged from the main stem; 75 indicates that in principal stage 7 (kernel development) subdivision 5, the grain is at the medium milk stage.

The principal Zadoks growth stages used in relation to disease control and nitrogen management are those from the start of stem elongation through to early flowering, GS30–GS61.



<sup>36</sup> L Munjonji, KK Ayisi, B Vandewalle, G Haesaert, P Boeckx (2016) Combining carbon-13 and oxygen-18 to unravel triticale grain yield and physiological response to water stress. Field Crops Research, 195, 36–49.

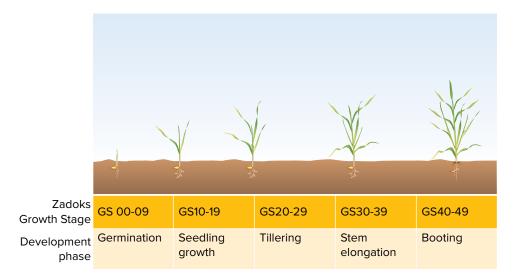
<sup>37</sup> N Poole (2005) Cereal Growth Stages. GRDC, <a href="https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20">https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20</a> Guidel.pdf

<sup>38</sup> P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

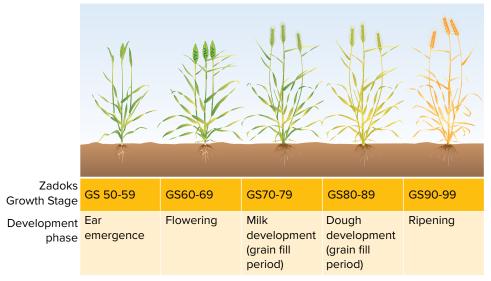








SOUTHERN
JANUARY 2018



**Figure 2:** The Zadoks cereal-growth stages.

Source: GRDC







Table 2: Cereal growth stages.

Crop growth stage				<u> </u>
	n stade	ırowtr	rop a	∪r

2-leaf stage

Two leaves (L) have unfolded; third leaf present, yet to fully expand Start of tillering
First tiller (T1)
appears from
between a lower
leaf and the main
shoot. Usually 3 or 4
leaves on the main
tiller.

Tillering stage

Tillers come from the base where leaves join the stem and continue forming, usually until there are 5 leaves on the main shoot. Secondary roots developing. Fully tillered stage

Usually no more tillers form after the very young head starts forming in the main tiller. Tillering completed when first node detected at base of main stem.

Start of jointing

Jointing or node formation starts at the end of tillering. Small swellings (joints) form at the bottom of the main tiller. Heads continue developing and can be seen by dissecting a stem.

Early boot stage

The last leaf to form, the flag leaf, appears on top of the extended stem. The developing head can be felt as a swelling in the stem.

#### Zadoks decimal code

2 leaves unfolded (Z12)

4 leaves unfolded (Z14)

Main shoot and 1 tiller (Z21)

5 leaves on main shoot or stem (Z15)

Main shoot and 1 tiller (Z21)

6 leaves on the main shoot or stem (Z16)

Main shoot and three tillers (Z23)

First node formed at base of main tiller (Z31)

Z35-Z45

Source: NSW DPI

#### Zadoks growth key

The main points to understanding the use of the Zadoks scale (see Photo 6) <sup>39</sup> are:

- The Zadoks growth stage (GS) key does not run chronologically from GS00 to GS99. For example, when the crop reaches the stage of three fully unfolded leaves (GS13) it begins to tiller (GS20)—before it has completed the stages of four, five or six fully unfolded leaves (GS14, GS15, GS16).
- During tillering, it is easier to assess the main stem and the number of tillers than it is the number of leaves (due to leaf senescence). The growth stage is determined by the main stem and number of tillers per plant, e.g. GS22 is main stem plus two tillers up to GS29, the main stem plus nine or more tillers.
- In Australian cereal crops, plants rarely reach GS29 before the main stem starts to stem elongate (GS30).
- As a consequence of growth stages overlapping it is possible to describe a
  plant with several growth stages at the same time. For example, a cereal plant
  at GS32 (second node on the main stem) with three tillers and seven leaves
  on the main stem would be at GS32, GS23 and GS17 at the same time, yet for
  practical purposes would be regarded as at GS32, since this describes the most
  advanced stage of development.
- After stem elongation (GS30) the growth stage describes the stage of the main stem, not an average of all the tillers. This is particularly important when timing the application of fungicides, e.g. GS39 is full flag leaf on the main stem, meaning that not all flag leaves in the crop will be fully emerged, and therefore may harbour infection but not receive spray coverage. 40



<sup>39</sup> C Royo, D Villegas (2011) Field measurements of canopy spectra for biomass assessment of small-grain cereals. InTechOpen. DOI 10.5772/I/7745, http://www.intechopen.com/books/biomass-detection-production-and-usage/field-measurements-of-canopy-spectra-for biomass-assessment-of-small-grain-cereals

<sup>40</sup> N Poole (2005) Cereal Growth Stages. GRDC, <a href="https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf">https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf</a>









#### 4.4.2 Germination and early seedling growth

The kernel (seed, or caryopsis), consists of a seed coat surrounding an embryo and endosperm. The embryo contains the seedling root (radicle), stem, and growing points of the new grain plant. The endosperm provides nutrients for growth until the first true leaves emerge and the root system is established. When moisture conditions are favourable, the seed germinates with the emergence of the radicle and the coleoptile, the first shoot, which forms a protective sheath around the first four leaves.

The primary root system includes the radicle and roots that develop from stem tissue near the kernel. It may penetrate the soil up to 30 cm, and provides the developing seedling with water and nutrients. The primary root system supports plant growth until tillering, when the secondary root system becomes the main root system of the plant. The primary roots may persist for the life of the plant and can support some plant growth through the heading stage. The first secondary roots appear at the tillering node about 2.5 cm below the soil line at the two- or three-leaf stage. These roots are always produced at about the same distance below the soil's surface, regardless of the depth at which the seed is planted. The secondary root system makes up the major part of the fully developed plant's root system.

Root development approaches its maximum at about the boot stage. The 'boot' is the swollen flag-leaf sheath, within which the developing spike is located after being pushed up as the stem has elongated.

As the seedling's root system is forming, the coleoptile grows upward and ruptures, allowing the first leaf to begin unfolding as soon as the coleoptile tip breaks the soil surface. Emergence usually occurs six to 20 days after sowing, depending on temperature and moisture. Emergence may be later than 20 days after sowing under prolonged cold or dry conditions. Initial formation of leaves and stems occurs at the shoot apex, which is located just below the soil surface.

#### 4.4.3 Tillering and vegetative growth

Branching in small-grain cereals is called tillering (or stooling). Individual branches are called tillers, and the mass of tillers is the stool. Two to four primary tillers develop from buds in the crown area of the main stem. Secondary tillers develop from buds in the axils of leaves at the base of the primary tillers. Tertiary tillers may develop from buds in the axils of leaves at the base of the secondary tillers.

The number of tillers that form is influenced by plant density (more with low plant density), soil moisture and nutrient supply (more with high supply), sowing date (more with early sowing), temperature (more under cooler temperatures), and cultivar. Water stress, nutrient deficiency, low temperatures, weed competition, and pest damage during early development reduce the number of tillers.

The emergence of primary tillers is synchronous with the emergence of leaves on the main stem of the plant (Photo 6). <sup>41</sup> The first primary tiller begins developing as leaf four of the main stem emerges; the second primary tiller begins developing as leaf five emerges. Subsequent primary tillers begin developing when subsequent leaves emerge.

Successive tillers develop fewer leaves; flowering and grain development is delayed, but only slightly, on later-developing tillers. Before the main stem and tillers begin to elongate, the spikes differentiate. The precursors (primordia) of all florets (flowers with lemma and palea, the outer bracts) or spikelets (units consisting of several florets on a thin axis, subtended at the base by two bracts, or glumes) develop at this time.

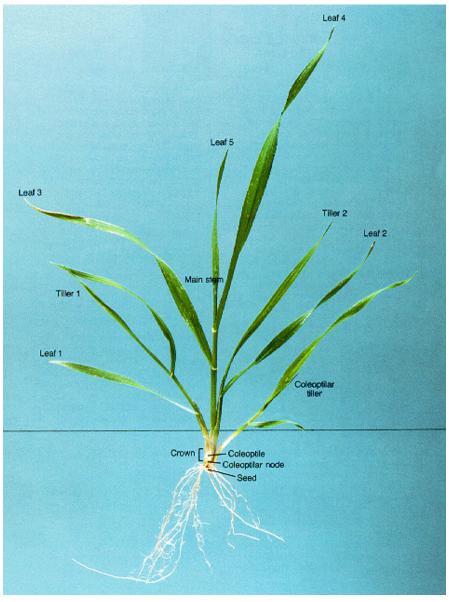


<sup>41</sup> University of Wisconsin (2013) Wheat growth and development. University of Wisconsin, <a href="http://corn.agronomy.wisc.edu/Crops/Wheat/L007.aspx">http://corn.agronomy.wisc.edu/Crops/Wheat/L007.aspx</a>



**TABLE OF CONTENTS** 





SOUTHERN

Photo 6: Plant parts in relation to growth stage.

Source: University of Wisconsin

#### 4.4.4 Stem elongation and heading

Stem elongation, or jointing, occurs when stem internodes increase in length and bring the nodes above ground. The uppermost five or six internodes elongate, the lowest ones beginning first. The appearance of the first node above ground marks the beginning of jointing. Jointing begins about the time all spikelet primordia have formed. The flowering structure (inflorescence) of wheat, triticale, and barley is called a spike. Inflorescences are composed of spikelets, each consisting of one or more flowers, called florets, at nodes along the spike or panicle.

During stem elongation, the spike increases in length from about 3 mm to its final size, and individual florets mature. All stages of spikelet development in wheat, triticale, and barley begin near the middle of the spike and proceed toward the base and tip.

The last leaf of the small-grain plant to emerge is called the flag leaf. When the flag leaf blade has completely emerged, the appearance of its ligule (a short membrane on the inside of the leaf at the junction of the blade and sheath) marks the beginning





**TABLE OF CONTENTS** 



of the boot stage. During this stage, the enlarging spike swells and splits the sheath of the flag leaf. Heading begins when the spike begins emerging through the collar of the flag leaf and is complete when the base of the spike is visible.

SOUTHERN

#### 4.4.5 Flowering and grainfilling

The flowers of wheat, triticale, barley, and oat are self-pollinated; most of the pollen is shed before the anthers emerge from the florets. Flowering (anthesis, or pollen shed) usually occurs within two to four days of the spikes completely emerging from the boot. If emergence occurs during hot weather, flowering may occur while the spikes are still in the boot. Most cells of the grain endosperm are formed during a period of rapid cell division following pollination. These cells enlarge and accumulate starch during grainfilling. Most of the carbohydrate used for grainfilling comes from the photosynthetic output of the flag leaf. Developing spikelets compete for limited supplies of photosynthate and nitrogen. The smallest, slowest-growing florets, which occur at the tip of the spikelet, are often unable to obtain enough nutrients to keep growing. Some spikelets at the base of the wheat or barley spike also may fail to develop.

The stages of grain ripening are called milk, soft dough, hard dough, hard kernel, and harvest ripe (Photo 7). Dry matter begins accumulating in the kernel during the milk stage. During the early milk stage, a clear fluid can be squeezed from the kernel. By the time the grains reach the late milk stage, the fluid has turned milky (and can still be squeezed from the kernel). Most of the dry matter accumulates during the soft-dough stage. Loss of water gives the kernel a doughy or mealy consistency. At the end of the hard-dough stage, the kernel reaches physiological maturity, water content drops to about 30%, and the plant loses most of its green colour. The kernel contents can be divided with a thumbnail. At the hard-kernel stage, the plant is completely yellow and water content of the kernel is 20–25%. The contents of the kernel are difficult to divide with a thumbnail, but its surface can be dented. When kernel moisture content has dropped to 13–14%, the grain is harvest ripe. The surface cannot be dented with a thumbnail. <sup>42</sup>



<sup>42</sup> Jackson L, Williams J (2006) Small grain production part 2: Growth and developments of small grains. University of California, <a href="http://manrcatalog.ucanr.edu/pdf/8165.pdf">http://manrcatalog.ucanr.edu/pdf/8165.pdf</a>

TABLE OF CONTENTS

FEEDBACK



**Photo 7:** Stages of cereal-grain ripening from the milk stage (top) to the harvest-ripe stage (bottom).

Source: Jackson and Williams 2006

#### 4.4.6 Growth of triticale compared to other cereals

Key points:

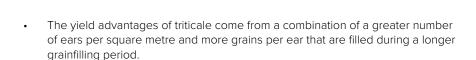
Early stages of growth have been found to be shorter in triticale than wheat.
 However, the period from grainfilling to harvest in triticale has been found to be considerably longer than wheat, without leading to a greater 1,000 grain weight.





**TABLE OF CONTENTS** 





SOUTHERN

- Triticale seed is generally bigger than wheat seed. Consequently, triticale can
  be seeded deeper than other small cereals and benefit from stored moisture in
  the soil, leading to better crop establishment early in the season, particularly in
  drought-prone areas.
- Differences in tillering between triticale and wheat influences management practices, such as seed rate or amount of fertiliser applied.

One of the advantages of triticale over wheat and barley is its early vigour, which enables fast crop growth during the first stages of development and a rapid cover of the soil by the canopy (Photo 8).



**Photo 8:** Triticale 50 days after emergence.

Source: Midwest Cover Crops Council

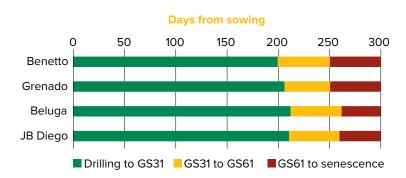
Trials in the UK were used to compare triticale and wheat growth. Researchers found a noticeable difference between the crops in the length of key growth phases. The growth phase from drilling to GS31 (first node detectable) was, on average, 8.5 days shorter for the triticale, and from GS31 to GS61 (flowering) 1.75 days shorter for triticale than for wheat. However, from GS61 (grainfilling) to harvest was 10.6 days longer in the triticale (Figure 3). <sup>43</sup> The longer grainfilling phase did not confer a greater 1,000-grain weight (TGW) to the triticale varieties. Instead, this extra time was needed to fill the greater number of grains per ear that triticale has.

Despite the shorter duration to flowering, triticale formed more biomass during this phase than wheat. Both triticale varieties formed more biomass than both wheats, but only for Benetto triticale were the increases significant. This was associated with both a greater number of stems and greater biomass per stem. The relative differences between the biomass of the different species at GS61 translated into differences at harvest, where triticale produced a greater yield. It can be seen that the yield advantages of triticale come from a combination of a greater number of ears per square metre and more grains per ear that are filled during a longer grainfilling period. These are supported by greater biomass that is evident throughout the season. 44



<sup>43</sup> S Clarke, S Roques, R Weightman, D Kindred (2016) Understanding triticale. AHDB, <a href="https://cereals.ahdb.org.uk/media/897536/pr556-understanding-triticale.pdf">https://cereals.ahdb.org.uk/media/897536/pr556-understanding-triticale.pdf</a>

<sup>44</sup> S Clarke, S Roques, R Weightman, D Kindred (2016) Understanding triticale. AHDB, https://cereals.ahdb.org.uk/media/897536/pr556-understanding-triticale.pdf



**OUTHERN** 

**Figure 3:** Length of key growth phases of two triticale varieties (Benetto and Grenado) and two wheat varieties (Beluga and JB Diego). Results are an average of two experiments. Plots grown at 180 kg N/ha.

Although triticale has a very large seed, in cooler climates it has been observed in the early stages of development to be slow-growing compared to other cereal species. This may be due to the early development of a massive root system at the expense of early top growth, which is in contrast to the general perception that triticale as a species is a very robust and competitive crop during its growth in many of its adapted growing zones. Triticale seed is generally bigger than that of commonly grown wheat varieties. Consequently, spring triticale can be seeded deeper than other small cereals and can therefore benefit from stored moisture in the soil, which translates into better crop establishment early in the season, particularly in drought-prone areas. Seeding equipment needs to be seed to account for a seed that may be 10–20% larger than wheat. 45

Spring triticale does not require vernalisation to go from vegetative to reproductive stages. These types exhibit upright growth and produce much more forage early in their growth. They are insensitive to photoperiod and have limited tillering. <sup>46</sup>

Triticale is thought to tiller less profusely than wheat. There are many differences between the tillering capacity between varieties of the same cereal type. However, in general (and assuming a May sowing) barley tillers better than oats, which in turn tillers better than wheat and this in turn tillers better than triticale. Generally, the earlier you sow and the higher the nitrogen fertility, the more tillering and tiller survival to harvest. Varieties with winter habit tend to tiller more, while there are some early maturing types (wheats in particular) which have limited tillering bred into them. Tillering can relate to DM yield; sow low tillering varieties at a higher seeding rate for hay and high tillering types at a lower rate. Similarly, higher sowing rates should be used when sowing late as tillering is reduced by late sowing. 47

Significant differences in tillering abilities between triticale and wheat influences management practices, such as seed rate or amount of fertiliser applied. In early research, adding nitrogen (N) increased tiller and ear numbers in three cereals (triticale, wheat and rye), although triticale produced fewer tillers and its response to N was significantly greater than wheat and rye. Triticale compensated for having fewer tillers by producing more spikelets per ear and setting more grains per spikelet, thereby producing more grains per pot than the other two cereals. The average kernel weights of triticale were also greater than those of wheat and rye. Total wateruse of triticale was less than that of the other cereals, particularly at the higher rates



<sup>45</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/v5553e00.pdf">http://www.fao.org/3/a-y5553e/v5553e00.pdf</a>

<sup>46</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>47</sup> AgVic. Sowing options for autumn: cereal varieties and other alternatives. <a href="http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/forage-cereals/sowing-options-for-autumn-cereal-varities-and-other-alternatives">http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/forage-cereals/sowing-options-for-autumn-cereal-varities-and-other-alternatives</a>



**TABLE OF CONTENTS** 





of N. The experiment showed that the yield of triticale was not restricted by less profuse tillering, and that it was able to compensate for this by producing more grains per ear and heavier kernels. Restricted tiller production of the cultivar Currency was associated with lower water use and higher Water Use Efficiency. 48

Triticale flowers earlier than most wheats, but matures at about the same time.

## **IN FOCUS**

#### Variation in temperate cereals in rain-fed environments

Barley yields more grain and total biomass than does triticale, which in turn yields more biomass than do bread wheat, durum wheat and oats when sown at the same time in rain-fed environments in southern Australia. Researchers wanted to determine reasons for these differences. They grew cultivars of each species at five field sites, and measured variation in their phenology and both pre- and post-anthesis growth.

Barley achieved a higher yield of grain and biomass in a shorter time than the other species. It reached physiological maturity about 10 days (180 thermal units) before the other species, and also reached double ridge and anthesis earlier. Triticale was also earlier to reach double ridge and terminal spikelet than the mean for the other species, although it had a similar physiological maturity to the wheats. Barley and triticale developed a greater leaf area and dry mass faster than the wheats and oats. The differences in leaf area was established from the time the first leaf had fully expanded. Barley also developed main-stem leaves and tillers faster than the other species, whereas triticale was slower in this respect. The rate of crop growth was greatest in barley and triticale up to anthesis, but no differences between species were found in their relative growth rates. The growth rate of individual grains and of total grain per unit of ground area were substantially greater in barley than the other species; oats and durum wheat were the slowest. Grain growth rate per unit of ground area was significantly associated with grain yield at one site where this was examined. The change in stem mass between anthesis and physiological maturity, which was determined to assess the possible contribution of stem reserves to grain, was also positively associated with grain yield at the two sites where it was determined, and more so at the drier site. The change in stem mass averaged 76 g/m-2 at the two sites, and this represented 25% of the total grain yield. However, the range varied from 13–39% of grain yield (corrected for husk mass in barley and oats). The loss in leaf sheath mass averaged 68 g/m-2 at both sites; this was not associated with grain yield. 49

Anthesis generally occurs 14 days after apical spikelet emergence for triticale. 50

Early triticale researchers explored the physiological maturity in seeds of two cultivars. Maximum germination, dry weight, and seedling vigour were attained 24 to 26 days after anthesis. Some seeds were capable of germinating eight days after anthesis. Moisture content decreased slowly from over 78% to 41%, at which time



<sup>48</sup> JB Golding (1989) Restricted tillering in triticale cv. currency: an impediment to grain yield? 5th Australian Agronomy Conference, <a href="http://www.regional.org.au/au/asa/1989/contributed/crop/pt-20.htm">http://www.regional.org.au/au/asa/1989/contributed/crop/pt-20.htm</a>

<sup>49</sup> C López-Castañeda, RA Richards (1994) Variation in temperate cereals in rainfed environments II. Phasic development and growth. Field Crops Research, 37 (1), 63–75.

S Tshewang (2011) Frost tolerance in Triticale and other winter cereals at flowering, Master's thesis. University of New England, <a href="https://e-publications.une.edu.au/vitid/access/manager/Repository/une.8821;isessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%25.</a>







functional maturity was attained. After this stage, the loss of moisture was accelerated and the seed entered into the ripening phase. 51

SOUTHERN

In dry springs, triticale yields are 10–15% below wheat, due to triticale's longer grainfilling period. Because of this, grain size may suffer in a hot, dry finish (Photo 9). 52



Photo 9: Triticale flowering (left) before grainfill (right).

Sources: left, KT Farmlife; right, Living Crop Museum



<sup>51</sup> UR Bishnoi (1974) Physiological maturity of seeds in triticale hexaploid L. Crop Science, 14 (6), 819–821.

<sup>52</sup> Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, <a href="http://www.farmtrials.com.au/trial/13801">http://www.farmtrials.com.au/trial/13801</a>



**TABLE OF CONTENTS** 





## **Nutrition and fertiliser**

#### Key messages

- In nutrient deficient soils, triticale appears to respond better to applied fertilisers
  than other cereals. Triticale has the capacity to survive, utilising trace elements
  in soils which would be considered nutrient deficient for any other type of
  crop. However, growth and yield of triticale is very responsive to phosphorus
  and nitrogen.
- Triticale has higher nutrient uptake efficiency than other crops.
- The nutrition requirements of triticale are similar to wheat. Triticale is very responsive to high inputs of seed and fertiliser. Adequate fertiliser is needed to achieve protein levels above 10%.
- Triticale has similar phosphorus and nitrogen requirements as wheat and responds to most compound fertilisers.
- In South Australia, high rates of fertiliser applied to triticale on sandy country have resulted in increased yields.
- Southern Australian cropping soils are more likely to be deficient in zinc (Zn), copper (Cu), and manganese (Mn) than the other trace elements.
- Triticale grows productively on alkaline soils where certain trace elements are deficient for other cereals.

Triticale has a very extensive root system (Photo 1) and can mine the soil more efficiently than other cereals where fertility is poor. <sup>1</sup> In general, triticale will respond favourably to cultural practices commonly used for the parental species wheat. However, it has been found that grain biomass and yield response of triticale are substantially higher than wheat when given larger increments of nitrogen and phosphorus inputs. <sup>2</sup>



Mergoum et al. (2004) In S Tshewang (2011) Frost tolerance in triticale and other winter cereals at flowering. Master's thesis. University of New England, <a href="https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22">https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22</a>

<sup>2</sup> S Tshewang (2011) Frost tolerance in triticale and other winter cereals at flowering. Master's thesis. University of New England, <a href="https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22">https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22</a>



**Photo 1:** Above- and below-ground growth, showing extensive root system.

Photo: Osborne Seed Company Variety Trials

#### **5.1.1** Declining soil fertility

The natural fertility of cropped agricultural soils in Australia is declining over time. Grain growers must continually review their soil-management programs to ensure the long-term sustainability of high-quality grain production (see Photo 2). <sup>3</sup> Pasture leys, legume rotations and fertilisers all play an important role in maintaining the chemical, biological and physical fertility of soils.

Although crop rotations with grain legumes and ley pastures help maintain and improve soil fertility, fertilisers remain the major source of nutrients to replace those removed by grain production. Fertiliser programs must supply a balance of the required nutrients in amounts needed to achieve a crop's yield potential. The higher yielding the crop, the greater the amount of nutrient removed.



SOUTHERN

JANUARY 2018

<sup>3</sup> Joint FAO-IAEA Programme (n.d.) Crop nutrition: resilience to harsh environments. Joint FAO-IAEA Programme, <a href="http://www-naweb.iaea.org/nafa/swmn/topic-crop-nutrition.html">http://www-naweb.iaea.org/nafa/swmn/topic-crop-nutrition.html</a>



**TABLE OF CONTENTS** 





SOUTHERN

JANUARY 2018

**Photo 2:** Without adequate effort to maintain the fertility of the soil, cereal plants will struggle, such as these in an infertile paddock.

Source: Joint FAO-IAEA Programme

#### Balancing sources of nutrition

The yield of a crop will be limited by any nutrient the soil cannot adequately supply. Poor crop response to one nutrient is often linked to a deficiency in another nutrient. Sometimes, poor crop response can also be linked to acidity, sodicity or salinity, pathogens, or a lack of beneficial soil microorganisms. <sup>4</sup>

To obtain the maximum benefit from investment, fertiliser programs must provide a balance of required nutrients. For example, here is little point in applying enough nitrogen (N) if phosphorous (P) or zinc (Zn) deficiency is limiting yield. To make better crop-nutrition decisions, growers need to consider the use of paddock records, soil tests and test strips. This helps to build an understanding of which nutrients the crop removes at a range of yield and protein levels.

Monitoring of crop growth during the season will assist in identifying factors such as water stress, P or Zn deficiency, disease, or other management practices responsible for reducing yield.  $^{5}$ 

#### 5.1.2 Fertilisers

Successful fertiliser decisions require robust information about a crop's likely yield response to that nutrient in a specific soil type, also taking into account the paddock history and season. As with most crops, rates of fertiliser application should be based on soil testing and other historical response information as well as anticipated costs and returns.

It is also valuable to know the anticipated market for the grain and whether price gradients may reward higher protein levels. This may warrant extra nitrogen usage. <sup>6</sup>



<sup>4</sup> DAF QId (2010) Nutrition management. Overview [of nutrition management]. Department of Agriculture and Fisheries DAF QId, <a href="http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview">http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview</a>

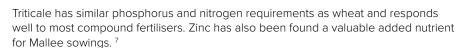
<sup>5</sup> DAF QId (2010) Overview [of nutrition management]. DAF QId, <a href="http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview">http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview</a>

<sup>6</sup> Agriculture Victoria (2012) Growing triticale. Note AG0497. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>



**TABLE OF CONTENTS** 





OUTHERN

 In South Australia, high rates of fertiliser applied to triticale on sandy country have resulted in increased yields.

In trials in NSW, researchers tested the response of triticale varieties to N and P application. Soil tests indicated marked differences between the years in N and P status. In 2002, the site had a very low soil N level (2 µg/g nitrate) and a low/medium level of P (16 µg/g available P). The data from the 2004 site indicated much higher levels of nutrients, 64 µg/g nitrate and 46 µg/g phosphorus. Although 2004 experiment used varieties that have now been largely superseded, the major findings remain relevant: that, in a high-rainfall region with yield potential levels above average, the yield responses to N fertiliser of a range of triticale varieties is at least equal to those for wheat (Table 1). With high yield potential (up to 8 t/ha) triticale varieties showed up to four times the yield response of the wheat variety Janz. At lower yields levels (2 t/ha) there were no differences in response between wheat and triticale varieties.

Table 1: Response of triticale (t/ha) to nitrogen fertiliser. 9

Variety	0 nitrogen	50 kg/ha nitrogen	100 kg/ha nitrogen	Response 100 kg/ha nitrogen
Everest	6.85	7.96	7.98	1.13
Kosciusko	7.37	7.48	8.34	0.97
Tahara	7.96	8.22	8.52	0.56
Janz wheat	6.73	6.99	7.00	0.27

These results indicated that, with low—medium yield expectations, wheat and triticale appear to show similar responses to additional N fertiliser. In locations with greater yield potential there is a suggestion that N requirements of triticale varieties exceed those of bread wheat varieties. The exact amounts of additional N fertiliser applied will depend on expected grain yields, soil N status, availability of water to the crop, and the current ratio of N fertiliser prices and crop returns.

Growers need to aim for sufficient soil N to obtain 11.5% protein in triticale, as below this level both grain yield and protein will be reduced. This aspect of triticale has been overlooked in the past and often triticale yields have been severely reduced compared with those in wheat as a result of inadequate N fertiliser application. <sup>10</sup>

A productive triticale will require application of P and N at sowing. Additional nitrogen is likely to be required for maximum dry-matter production for grazing and grain yield, particularly if the crop has been grazed. Consider applying 15–20 kg P/ha at sowing. This is equivalent to 75–100 kg MAP per ha which will also include 7.5–10 kg N/ha. A triticale used for grazing as well as grain production will require significant N. If targeting 3 t/ha then a minimum of 69 kg N/ha should be applied just to cover removal. If grazing is also included or soil nitrogen levels are low, additional N should be applied. Application can be split between sowing and top-dressing after grazing or during the stem-elongation stage (soon after the Zadoks growth stage 31).



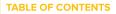
<sup>7</sup> Agriculture Victoria (2012) Growing triticale. Note AG0497. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

<sup>8</sup> Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, <a href="http://www.farmtrials.com.au/trial/13801">http://www.farmtrials.com.au/trial/13801</a>

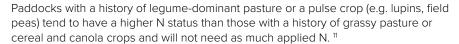
<sup>9</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/IA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/IA-102\_Final\_Research\_Report\_pdf</a>

<sup>10</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/iA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/iA-102\_Final\_Research\_Report\_pdf</a>









SOUTHERN

Table 2  $^{12}$  lists the concentrations of nitrogen and phosphorous in common fertilisers. Use this to calculate total quantity of fertiliser to apply. In the example with a requirement of 69 kg N/ha this could be achieved by applying:

- 100 kg MAP per ha or 10 kg N per ha, plus
- 130 kg urea per ha or 59.8 kg N per ha supplying a total of 69 kg N per ha for the season.

Table 2: Nitrogen and phosphorous content of common high-analysis fertilisers.

Product	Phosphorus		Nitrogen	
	Kg/kg product	Kg/100 kg product	Kg/kg product	Kg/100 kg product
MAP	2.2	22	1.0	10
DAP	2.0	20	1.8	18
Urea	0	0	4.6	46

Source: Waratah Seed Company

In a field experiment conducted in India, nine combinations of N and P were factorially randomised with four triticales and one check each of wheat and rye, to investigate the effect of progressive rates of application (180–300 kg N+P ha 1) of combined N+P fertiliser on grain yield and quality. Grain yield, protein content, and values for yield components significantly increased with increasing combined N+P fertiliser rates up to 240 kg N+P ha 1 (200 kg N+40 kg P ha 1). The response of further increases in N+P rates gradually diminished, thereafter, despite increasing N and/or P in the fertiliser combinations. This research revealed the harmful effects of over-fertilisation. This was thought to be due to a decrease in the activity of the enzyme despite increasing N and/or P in the fertiliser combinations. <sup>13</sup>

#### **Application**

#### Application method

Apply by using either gravity feed openers or air drills to the bury the fertiliser in a sub-surface band 5 cm below or to the side of the seed.

#### Application considerations

Use higher rates where nitrogen is known to be deficient, when double cropping or with large amounts of undecomposed stubble.

Rates should be reduced by 50% for very sandy soils and may be increased by 30% for heavy-textured soils or where soil moisture conditions at planting are excellent.

Rates should be reduced by 50% when planting equipment with narrow slit openers is used, as the concentration of fertiliser around the seed is increased.

Rates may be increased by 50% when using air seeders operating at high pressures with wide openers. Air seeders spread the fertiliser bands when operating at high pressures, reducing the fertiliser concentration around the seed. <sup>14</sup>



Crop nutrition: region by region



<sup>11</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>

<sup>12</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>

<sup>3</sup> S Moinuddin, MMRK Afridi (1997) Grain yield and quality of triticale as affected by progressive application rates of nitrogen and phosphorus fertiliser. Journal of Plant Nutrition, 20 (4–5), 593–600.

<sup>4</sup> DinoFert (2016) Triticale. DinoFert, <a href="http://www.dinofert.com.au/technical-information/plant-nutrition-guide/item/149-triticale">http://www.dinofert.com.au/technical-information/plant-nutrition-guide/item/149-triticale</a>



**TABLE OF CONTENTS** 





#### 5.1.3 Fungi and soil health

Arbuscular mycorrhiza (AMF, previously known as VAM) is a fungus that penetrates the roots of a vascular plant in order to help them to capture nutrients from the soil. These fungi are scientifically well known for their ability to take up and transport mineral nutrients from the soil directly into host plant roots. Approximately 80% of known plant species, including most economically important crops, have a known symbiosis with them.

The microscopic fungal fibres vastly extend the root system. They extract water and nutrients from a large volume of surrounding soil, and bring them to the plant, improving nutrition intake and growth. A plant's root system, however big, can never be as extensive as the network of fungal fibres.

In cropping systems, most plants depend, to varying degrees, on mycorrhizal fungi to supply them with nutrients such as phosphorus and zinc. (By comparison, saprobic soil fungi, which colonise and break down organic matter, and do not require a host plant to complete their lifecycle.) In return, the plant hosts the fungus and supplies it with carbohydrates. AMF is therefore known as an obligate symbiont. It produces spores as a means of survival in soil during the absence of a host (e.g. during a clean fallow) and then germinates and colonise host roots once plants grow again.

This mutually beneficial partnership has existed as long as there have been plants growing in soil. Unfortunately, these beneficial mycorrhizal fungi are destroyed in the development of human-made landscapes, resulting vegetation in these environments to struggle.

AMF levels can be severely reduced by long periods of fallow, such as those induced by drought. The longer the fallow, the less chance of survival of these spores and this is the cause of the syndrome that is called long fallow disorder (LFD). Hyphae in soil or in roots in the soil may also grow to new roots; however, they survive for less time in the soil than the spores. AMF levels can also be reduced by the growth of non-host crops.

Primarily, LFD leads to a phosphorus or zinc deficiency of the plant; this can be overcome by the application of P and/or Zn fertilisers. Having adequate populations of mycorrhizal fungi present in soils therefore can be beneficial; and in some cases it is essential for crop growth. Without mycorrhizae, much higher amounts of P and/or Zn fertiliser are required to attain the same level of productivity as when plants are supported by AMF.

When reintroduced to the soil, the arbuscular mycorrhiza colonizes the root system, forming a vast network of filaments. This fungal system retains moisture while producing powerful enzymes that naturally unlock mineral nutrients in the soil for natural root absorption.

Maintaining high mycorrhizal populations promotes good crop growth and the efficient use of P and Zn fertilisers. Many crop species require only half the phosphate concentration in soil when they are colonised by AMF. <sup>15</sup>

In one study, the colonisation of rye roots with arbuscular mycorrhizal fungi was investigated at two sites, cultivated using conventional or biological-dynamic farming methods. The AMF infection rate and infected root length were significantly higher at the biologically-dynamic cultivated site. It was suggested that these differences are due to several factors, such as the use of fertilisers and agro-chemicals, and the influence of crop rotation. <sup>16</sup>



N B (2009) Mycorrhizae and their influence on P nutrition. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2009/09/Mycorrhizae-and-their-influence-on-P-nutrition">https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2009/09/Mycorrhizae-and-their-influence-on-P-nutrition</a>

B Sattelmacher, S Reinhard, A Pomikalko (1991) Differences in Mycorrhizal colonization of rye (Secale cereale L.) grown in conventional or organic (biological-dynamic) farming systems. Journal of Agronomy and Crop Science, 167 (5), 350–355.





If you suspect low numbers of AMF in your paddock:

 Grow crops with low or very low mycorrhizal dependency, e.g. wheat or barley, as they won't suffer much yield loss but will still increase the AMF inoculum for following crops.

SOUTHERN

- Avoid non-mycorrhizal crops, as they will not increase AMF inoculum status.
- If you wish to grow a crop that is highly dependent on AMF (e.g. to get a good price for your grain), apply high rates of P and Zn fertilisers.
- Adopt zero- or reduced-tillage practices during fallow periods, as this is less harmful to AMF than frequent tillage.  $^{17}$

#### 5.2 Crop removal rates

Each tonne of triticale harvested will remove approximately 23 kg N/ha from the paddock (Table 3). So, if targeting 3 t/ha then a minimum of 69 kg N/ha should be applied just to cover removal. If grazing is also included or soil nitrogen levels are low, additional N should be applied (Table 3).  $^{18}$ 

**Table 3:** Nutrients removed (kg) per tonne of grain production.

Crop type	Nitrogen	Phosphorus	Potassium	Sulfur
Wheat	21	3.0	5	1.5
Triticale	21	3.0	5	1.5
Barley	20	2.7	5	1.5
Oats	17	2.5	4	1.5

Source: Agriculture Victoria

#### 5.3 Soil testing

Key points:

- The range of soil test values used to determine if a nutrient is deficient or adequate is termed a critical range.
- Revised critical soil test values and ranges have been established for nutrients, crops and soil class.
- A soil test value indicates if there is sufficient nutrient supply to meet the crop's demand.
- Results from more than 2,200 trials in south-east Australia have been compiled into a database that can be used to estimate soil test critical values and ranges.
- A value above the critical range indicates there is not likely to be a crop yield response to added nutrients.
- A value below the critical range indicates there is likely to be a crop yield response to added nutrients.
- Critical ranges for particular crops and soils have been established for a depth of 0–10 cm.
- Soil sampling to greater depth (0–60 cm) is considered important for more mobile nutrients (N, K and S) as well as for pH, salinity and sodicity.
- Use local data and support services to help integrate soil test data into making profitable fertiliser decisions.



<sup>17</sup> N Seymour (2009) Mycorrhizae and their influence on P nutrition. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2009/09/Mycorrhizae-and-their-influence-on-P-nutrition">https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2009/09/Mycorrhizae-and-their-influence-on-P-nutrition</a>

<sup>18</sup> Agriculture Victoria (2008) Establishing forage cereals. Note AG1269. Revised. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/dairy/pastures-management/forage-cereals/establishing-forage-cereals/">http://agriculturevic.gov.au/agriculture/dairy/pastures-management/forage-cereals/</a>



**TABLE OF CONTENTS** 



In south-eastern Australia profitable grain production depends on applied fertilisers, particularly nitrogen (N) and phosphorus (P), and to a lesser extent, potassium (K), sulfur (S), zinc (Zn), manganese (Mn) and copper (Cu).

SOUTHERN

Fertiliser is a major cost for grain growers, so making careful selections of crop nutrients is a major determinant of profit. Both under-fertilisation and over-fertilisation can lead to economic losses, due to unrealised crop potential or wasted inputs.

Before deciding on how much fertiliser to apply, it is important to understand the quantities of available nutrients in the soil, where they are located in the soil profile and the likely demand for nutrients in that season.

The values from appropriate soil tests can be compared against critical nutrient values and ranges; these indicate which nutrients are limiting and which are adequate.

Soil test critical values advise growers if a crop is likely to respond to added fertiliser, but without further information, they do not predict optimum fertiliser rates. When considered in combination with information about target yield, available soil moisture, last year's nutrient removal and soil type, soil tests can help in making fertiliser decisions.

#### 5.3.1 Why test soil?

Soils are tested for several reasons, but the principal ones are:

- to estimate how much water can be stored;
- · monitoring soil fertility levels;
- · estimating which nutrients are likely to limit yield;
- measuring properties such as pH, sodium (sodicity) and salinity, acidity, or high levels of boron or aluminium which affect the crop demand as well as the ability to access nutrients;
- the occurrence of soil-borne diseases;
- zoning paddocks for variable application rates; and
- as a diagnostic tool, to identify reasons for poor plant performance. Soil test results are part of the information that support decisions about fertiliser rate, timing and placement.

To determine micronutrient status, plant tissue testing is usually more reliable. <sup>19</sup>

#### **5.3.2 Basic requirements**

There are three basic steps that must be followed if meaningful results are to be obtained from soil testing. These are:

- 1. To use a representative sample of soil.
- 2. To analyse the soil using the accepted procedures that have been calibrated against fertiliser experiments in that region.
- 3. To interpret the results using criteria derived from those calibration experiments.

As each of these steps may be under the control of a different person or entity, it is important to use standardised procedures to that results are accurate. For example, the sample may be taken by the farmer manager or by a consultant agronomist; it is then sent to an analytical laboratory; and finally the soil test results are interpreted by an agronomist to develop recommendations for the farmer. <sup>20</sup>

#### 5.3.3 Types of test

Appropriate soil tests for measuring soil extractable or plant available nutrients are:

- bicarbonate extractable P (Colwell-P);
- 9 GRDC (2014) Soil testing for crop nutrition, southern region. Factsheet. GRDC, www.grdc.com.au/GRDC-FS-SoilTestingS
- 20 D Loch (n.d.) Soil nutrient testing: how to get meaningful results, <a href="https://www.daf.qld.gov.au/">https://www.daf.qld.gov.au/</a> data/assets/pdf\_file/0006/65985/Soil-Nutrient-Testing.pdf



Soil nutrient testing: How to get meaningful results











#### **MORE INFORMATION**

<u>Soil testing for crop nutrition—</u> <u>southern region</u>



WATCH: Over the Fence: Raised beds boost crops in Victoria's high rainfall zone



- · diffusive gradients in thin-films (DGT);
- bicarbonate extractable K (Colwell-K);
- KCI-40 extractable S; and
- 2M KCl extractable inorganic N, which provides measurement of nitrate-N and ammonium-N.

For determining crop N requirement, soil testing can be unreliable. This is because soil nitrogen availability and crop demand for nitrogen are both highly influenced by seasonal conditions. Ideally, soil testing for N should be carried out as close to sowing as possible, allowing for results to be returned.

SOUTHERN
JANUARY 2018

Other measurements that aid the interpretation of soil nutrient tests include soil pH, percentage of gravel in the soil, soil carbon/organic matter content, P sorption capacity (currently measured as phosphorus buffering index, or PBI), electrical conductivity (EC), and chloride and exchangeable cations (CEC) including aluminium. <sup>21</sup>

#### 5.4 Plant-tissue testing for nutrition levels

Plant-tissue testing can also be used to diagnose a deficiency or monitor the general health of the pulse crop.

Of the many factors affecting crop quality and yield, soil fertility is one of the most important. It is fortunate that producers can manage fertility by measuring the plant's nutritional status. This is an unseen factor in plant growth—until imbalances become so severe that visual symptoms appear on the plant. The only way to know whether a crop is adequately nourished before this stage is to have the plant tissue analysed during the growing season.

#### **5.4.1 Plant tissue analysis**

Plant-tissue analysis shows the nutrient status of plants at the time of sampling. This, in turn, shows whether soil nutrient supplies are adequate. In addition, plant-tissue analysis will detect unseen deficiencies and may confirm visual symptoms of deficiencies. Toxic levels of nutrients may also be detected. Though usually used as a diagnostic tool for future correction of nutrient problems, plant-tissue analysis from young plants will allow a corrective fertiliser application that same season.

Although a plant-tissue analysis can pinpoint the cause of nutritional imbalances, there is little point in using it if the plants come from fields that are infested with weeds, insects, or disease organisms, if they are stressed for moisture, or if they have some physical injury.

Sampling a crop periodically during the season or once a year provides a record of its nutrient content that can be used through the growing season or from year to year. Armed with soil-test information and a plant-analysis report, a producer can closely tailor fertiliser practices to specific soil and plant needs.

Things to do when sampling:

- Sample the correct plant part at the specified time or growth stage.
- Use clean plastic disposable gloves to sample to avoid contamination.
- Sample tissue (e.g. entire leaves) from vigorously growing plants unless otherwise specified in the sampling strategy.
- Take a sufficiently large sample quantity (adhere to guidelines for each species provided).
- When troubleshooting, take separate samples from good and poor growth areas.
- · When necessary, wash samples while fresh to remove dust and foliar sprays.
- Keep samples cool after collection.



<sup>21</sup> GRDC (2014) Soil testing for crop nutrition, southern region. Factsheet. GRDC, <u>www.grdc.com.au/GRDC-FS-SoilTestingS</u>



**TABLE OF CONTENTS** 



 Refrigerate or dry if samples can't be despatched to the laboratory immediately, to arrive before the weekend.

SOUTHERN

Generally sample in the morning while plants are actively transpiring.

#### Things to avoid when sampling:

- Avoid spoiled, damaged, dead or dying plant tissue.
- Don't sample plants stressed by environmental conditions.
- Don't sample plants affected by disease, insects or other organisms.
- Don't sample soon after applying fertiliser to the soil or foliage.
- Avoid sample contamination by dust, fertilisers, chemical sprays, perspiration and sunscreen.
- Avoid atypical areas of the paddock, e.g. poorly drained areas.
- Do not sample plants of different vigour, size and age.
- Do not collect from different cultivars (varieties) to make one sample.
- Don't collect samples into plastic bags as this will cause the sample to sweat and hasten its decomposition.
- Don't sample in the heat of the day, i.e. when plants are moisture stressed.
- Don't mix leaves of different ages. <sup>22</sup>

**Table 4:** Plant tissue requirements for nutrient testing of triticale.

Growth stage to sample	Plant part	Number required
Seedling to early tillering (GS 14–21)	Whole tops cut off 1 cm above ground	40
Early tillering to 1st node (GS 23–31)	Whole tops cut off 1 cm above ground	25
Flag leaf ligule just visible to boots swollen (GS 39–45)	Whole tops cut off 1 cm above ground	25
Early tillering to 1st node (GS 2131)	Youngest expanded blade (YEB) plus next 2 lower blades	40

Source: Back Paddock Company

#### 5.5 Nitrogen

#### Key points:

- Nitrogen (N) is needed for crop growth in larger quantities than any other nutrient.
- Nitrate (NO3-) is the highly mobile form of inorganic nitrogen in both the soil and the plant.
- Sandy soils in high-rainfall areas are most susceptible to nitrate loss through leaching.
- Soil testing and nitrogen models will help determine seasonal nitrogen requirements.
- Some farmers believe that triticale produces more grain under the same amount of applied nitrogen as wheat and barley.

The two forms of soil mineral N absorbed by most plants are nitrate (NO3N) and ammonium (NHp4N) (Figure 1). <sup>24</sup> In well-aerated soils during the growing season nitrate becomes the main form of N available for crops as microbial activity quickly



<sup>22</sup> Back Paddock Company (n.d.) Back Paddock SoilMate: Guidelines for sampling plant tissue for annual cereal, oilseed and grain legume crops. Back Paddock Company, <a href="https://www.backpaddock.com.au/assetts/Product-Information/Back-Paddock-Sampling-Plant-Tissue-Broadacre-V2\_odf?phpMyAdmin=c592\_o6580c88b2776783fdb796fb36f3">https://www.backpaddock.com.au/assetts/Product-Information/Back-Paddock-Sampling-Plant-Tissue-Broadacre-V2\_odf?phpMyAdmin=c592\_o6580c88b2776783fdb796fb36f3</a>

<sup>23</sup> GRDC (2006) Triticale. Ground Cover. No. 59, 1 January 2006. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover/Issue-59/Triticale">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover/Ground-Cover/Issue-59/Triticale</a>

<sup>24</sup> Soilquality.org. Nitrogen: NSW. Factsheet. Soilquality.org, <a href="http://www.soilquality.org.au/factsheets/nitrogen-nsw">http://www.soilquality.org.au/factsheets/nitrogen-nsw</a>

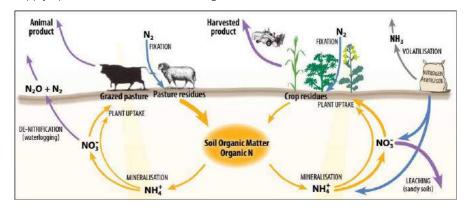


**TABLE OF CONTENTS** 



transforms ammonium into nitrate. It is crucial to keep nitrate at an adequate level because, on one hand, if they are too low crop production will be limited and, on the other hand, if they are too high environmental pollution can result. The levels of soil nitrate vary across space and over time. Proper agricultural management needs to consider both site-specific variations as well as temporal patterns in soil nitrate to supply optimum amounts from both organic and mineral sources. <sup>25</sup>

SOUTHERN



**Figure 1:** Principle nitrogen cycling pathways in a mixed cropping/pasture system (adapted from Peverill et al. 1995).

Source: Soilquality.org

Give particular attention to nitrogen supply. Triticale used for grazing and grain could use up to 100 kg/ha of N. Consider applying 60–100 kg/ha of N as a topdressing if soil nitrogen levels are low. Long fallow paddocks following good legume pastures generally have satisfactory nitrogen levels. They also have the highest yield potential because of stored moisture and have the greatest potential to respond to soil nitrogen. Yield increases are likely when nitrogen is applied to paddocks with low nitrogen status. The contribution of pulse crops and pastures to soil nitrogen depends on the amount of plant material produced and/or the subsequent grain yield. The actual amount of soil nitrogen accumulated is highly variable. <sup>26</sup>

Triticale has been found to response well to nitrogen application under drought conditions (Figure 2).  $^{27}$ 



<sup>25</sup> M. Ladoni, AN Kravchenko, GP Robertson (2015) Topography mediates the influence of cover crops on soil nitrate levels in row crop agricultural systems. PLOS ONE, 10 (11), e0143358.

<sup>26</sup> P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI, http://www.dpi.nsw.gov.au/\_\_data/assets/pdf\_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

<sup>27</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>



**TABLE OF CONTENTS** 

FEEDBACK



SOUTHERN

**Figure 2:** Triticale grain yield and straw dry-matter response to nitrogen levels under drought conditions in Morocco.

60

Nitrogen level (kg/ha)

90

120

30

Source: Mergoum and Gómez-Macpherson 2004

10

8

6

2

0

Grain yield and dry matter

In trials in Europe, researchers found an N rate of 90–120 kg/ha to be economically and ecologically optimal for spring triticale. It resulted in the highest (4.81-4.92 Mg/ha-1) grain yield.  $^{28}$ 

Additional nitrogen is likely to be required for maximum grain yield, particularly if the crop has been grazed.

Pre-plant N has been found to increase forage production and produce more bootstage triticale biomass. It also tended to increase P uptake, but in some cases, can reduce P and forage protein concentrations, likely due to plant dilution.  $^{29}$ 

Trials outside Canberra exploring crop management of dual-purpose cereals suggest that N should be applied at sowing to ensure good early plant growth and to build up a feedbank. Post-sowing nitrogen application should be left until after grazing: it should not be applied just before grazing due to the risk of high forage nitrate levels. High nitrate in forage can lead to nitrite toxicity in grazing livestock, especially under cool, cloudy conditions. Immediately after grazing finishes, growers may safely apply 50 kg/ha of nitrogen as urea to boost plant recovery. <sup>30</sup>

The main commercial triticale varieties are relatively tall compared with newer wheat varieties, increasing the likelihood of lodging. However, in most of the newer varieties lodging is not considered a problem. The likelihood of lodging is increased by high rates of nitrogen fertiliser and under irrigated conditions. <sup>31</sup>

# IN FOCUS

# Responses of triticale, wheat, rye and barley to nitrogen fertiliser

Researchers conducted a field experiment at Mintaro, South Australia, on triticale and three other grains to learn more about how they respond to N fertiliser. They planted a hexaploid triticale from Mexico and local cultivars



<sup>28</sup> D Janušauskaitė (2013) Spring triticale yield formation and nitrogen use efficiency as affected by nitrogen rate and its splitting. Zemdirbyste-Agriculture, 100 (4), 383–392.

<sup>29</sup> B Brown (2011) Nitrogen timing for boot stage triticale forage yield and phosphorus uptake. Forage and Grazinglands, 9 (1), 62–67.

<sup>30</sup> D Lush (2014) Rules of thumb for grazing cereals. Ground Cover. No. 109, March—April 2014. GRDC, https://grdc.com.au/Media-Centre/ Ground-Cover/Ground-Cover-Issue-109-Mar-Apr-2014/Rules-of-thumb-for-grazing-cereals

<sup>31</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/iA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/iA-102\_Final\_Research\_Report\_pdf</a>



TABLE OF CONTENTS



of wheat, rye and barley. To each they applied five levels of fertiliser nitrogen (0, 35, 70, 105 and 140 kg/ha) with four replications.

SOUTHERN

JANUARY 2018

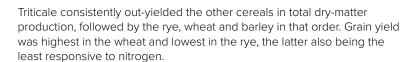
There was a visually discernible response to nitrogen fertiliser by all four genotypes from an early stage, and this confirmed by quantitative sampling at the stages of tillering, anthesis and maturity. Responses in plant dry weight to 105 kg N/ha were maintained until anthesis, but grain yield only improved significantly at 35 kg N/ha. Total dry-matter production responses at maturity to more than 35 kg N/ha were small. The numbers of tillers and heads were increased by adding nitrogen up to 140 kg/ha for tillering, and 105 kg/ha for heads. Plant height increased with the application of up to 70 kg/ha, but greater amounts of N than this resulted in significant lodging in both and triticale. For all genotypes, thousand-grain weight decreased with increasing level of nitrogen supply, while grain and straw nitrogen increased up to levels of 140 and 105 kg/ha, respectively. Nitrogen supply had little effect on maturity: plants at 0 kg/ha and 140 kg/ha of N reached anthesis less than a day apart. The lack of a significant nitrogen × genotype interaction in nearly all the data suggests that the triticale is the same as the traditional cereals in it nitrogen needs.





**TABLE OF CONTENTS** 





SOUTHERN

The advantage of the triticale lay in its high grain protein and lysine content, combined with good yield.  $^{\rm 32}$ 

# 5.5.1 Symptoms of deficiency

Most of the deficiency symptoms listed are based on observations in wheat and other cereals. Specific information for triticale is limited. Observing these symptoms should prompt growers to investigate further.

#### What to look for in the paddock

- Light green to yellow plants particularly on sandy soils or unburnt header or swathe rows (Photo 3). 33
- Double-sown areas have less symptoms if nitrogen fertiliser was applied at seeding.

#### What to look for in the plant

- Plants are pale green with reduced bulk and fewer tillers.
- Symptoms first occur on the oldest leaf, which becomes paler than the others and shows marked yellowing starting at the tip and gradually merging into light green (Photo 4).
- Other leaves start to yellow, and the oldest leaves change from yellow to almost white.
- Leaves may not die for some time.
- Stems may be pale pink.
- Plants develop more slowly than healthy plants, but maturity is not greatly delayed.
- Reduced grain yield and protein levels.



<sup>32</sup> RD Graham, PE Geytenbeek, BC Radcliffe (1983) Responses of triticale, wheat, rye and barley to nitrogen fertiliser. Animal Production Science, 23 (120), 73–79.

<sup>33</sup> DAFWA (2015) Diagnosing nitrogen deficiency in wheat. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-wheat">https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-wheat</a>



SOUTHERN JANUARY 2018

**Photo 3:** Nitrogen deficiency on unburnt header row.

Source: DAFWA



**Photo 4:** Deficient plants are smaller with yellow leaves and fewer tillers.











#### What else it could be

Before assuming nitrogen deficiency, eliminate other possible causes of symptoms (Table 5).

**Table 5:** Other possible problems of triticale that could be confused for nitrogen deficiency.

SOUTHERN

Condition	Similarities	Differences
Waterlogging	Pale plants with oldest leaves most affected	Root browning or lack of feeder roots and wet soil
Potassium deficiency	Pale plants with oldest leaves most affected	Differences include more marked leaf-tip death and contrast between yellow and green sections in potassium-deficient plants. Tillering is less affected.
Molybdenum deficiency	Pale, poorly tillered plants	Molybdenum deficiency affects the middle leaves first and causes white heads, shrivelled grain and delayed maturity

Source: DAFWA

# 5.5.2 Managing nitrogen

Key points:

- In environments where yields are consistently greater than 2.5 t/ha, N
  applications can be delayed until stem elongation without any loss in yield. In
  lower-yielding environments, the chances of achieving a yield response similar
  to that achieved with an application at sowing is less.
- There is no consistent difference in the response to N between different forms of N fertiliser.
- In general, increases in grain protein concentration are greater with N
  applications between flag-leaf emergence and flowering.
- Volatilisation losses can be significant in some cases: the greatest risk is with urea, and lower, but still significant, with a solution of urea and ammonium nitrate (UAN) and ammonium sulphate. 34

Nitrogen fertilisers are a significant expense for broadacre farmers, so optimising the use of fertiliser will reduce this cost. There are four main sources of nitrogen available to crops: stable organic nitrogen, rotational nitrogen, ammonium and nitrate. To optimise plants' ability to use soil nitrogen, growers should first be aware of how much of each source there is. The best method of measuring these nitrogen sources is soil testing.

Deficiency symptoms can be treated with N fertiliser or foliar spray. Note that, when topdressing on dry, alkaline soils in dewy conditions, there is a risk of volatilisation loss from urea or ammonium sources of nitrogen. Losses rarely exceed 3% per day. <sup>35</sup>

#### Timing of application

Grain-yield improvements are mainly caused by increased tiller numbers and grains per ear, both of which are determined early in the life of a cereal plant. A sufficient supply of nitrogen during crop emergence and establishment is critical. Nitrogen-use efficiency can be improved by delaying fertiliser application until the crop's roots system is adequately developed, around 3–4 weeks after germination.

Later nitrogen applications can also have yield benefits by aiding increased tiller survival, leaf duration and photosynthetic area. However, delaying application reduces the chance that economic gain from the response to nitrogen will be



<sup>34</sup> G McDonald, P Hooper (2013) Nitrogen decision: Guidelines and rules of thumb. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Nitrogen-decision-Guidelines-and-rules-of-thumb">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Nitrogen-decision-Guidelines-and-rules-of-thumb</a>

<sup>35</sup> DAFWA (2015) Diagnosing nitrogen deficiency in wheat. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-wheat">https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-wheat</a>



**TABLE OF CONTENTS** 



achieved. An advantage of late applications (once the first node is visible) is that growers have a better idea of what the yield might be before applying the nitrogen. <sup>36</sup>

SOUTHERN

#### **Budgeting**

The critical factor in budgeting is the target yield and protein, as crop yield potential is the major driver of N requirement. As a guide, Table 6 shows the N required for different yield and protein combinations at maturity and anthesis.  $^{37}$  For example, if you are targeting a 3 t/ha crop at 11% protein, you would need to have about 62 kg N/ ha taken up by the crop by flowering. The amount of fertiliser N required will depend on your estimate of fertiliser recovery, but if you work on a 50% recovery, you would need to supply 134 kg N/ha.

Clearly predicting yield during the growing season is crucial to allow growers to make tactical decisions on N management. Recent experience has shown that <u>Yield Prophet®</u> can predict yields accurately in mid-August and can assist with N decisions. <sup>38</sup>

**Table 6:** Nitrogen requirements for cereal crops at different combinations of yield and grain protein at maturity, and the corresponding N required at anthesis.

Grain Growth		Grain protein (%)					
yield (t/ ha)	stage	9	10	11	12	13	
		kg N/ha					
1	Maturity	21	23	26	28	30	
	Anthesis	17	19	21	22	24	
2	Maturity	42	47	51	56	61	
	Anthesis	34	37	41	45	49	
3	Maturity	63	70	77	84	91	
	Anthesis	51	56	62	67	73	
4	Maturity	84	94	103	112	122	
	Anthesis	67	75	82	90	97	
5	Maturity	105	117	129	140	152	
	Anthesis	84	94	103	112	122	
6	Maturity	126	140	154	168	182	
	Anthesis	101	112	124	135	146	

Source: GRDC

The estimates are based on the assumption that 75% of the total crop N is in the grain at maturity and that 80% of the total N is taken up by anthesis.

# 5.6 Phosphorus

Key points:

- Phosphorus (P) is one of the most critical and limiting nutrients in agriculture in Australia.
- Phosphorous cycling in soils is complex.
- Only 5–30% of phosphorus applied as fertiliser is taken up by the plant in the year of application.
- Phosphorus fertiliser is best applied at seeding.





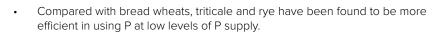
<sup>36</sup> R Quinlan, A Wherrett (2013) Nitrogen: NSW. Soilquality.org.au

<sup>37</sup> G McDonald, P Hooper (2013) Nitrogen decision: Guidelines and rules of thumb. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Nitrogen-decision-Guidelines-and-rules-of-thumb">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Nitrogen-decision-Guidelines-and-rules-of-thumb</a>

<sup>38</sup> G McDonald, P Hooper (2013) Nitrogen decision: Guidelines and rules of thumb. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/">https://grdc.com.au/</a> Research-and-Development/GRDC-Update-Papers/2013/02/Nitrogen-decision-Guidelines-and-rules-of-thumb

**TABLE OF CONTENTS** 

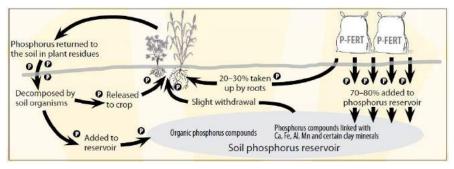
FEEDBACK



Triticale has been classified as phosphorus-efficient; i.e., it is higher yielding than
other cultivars under low P supply. It has also been classified as phosphorusresponsive; i.e. it is higher yielding than other cultivars under high P supply).

SOUTHERN

After nitrogen stress, phosphorus is the second most widely occurring nutrient deficiency in cereal systems around the world. <sup>40</sup> Phosphorus is essential for plant growth, but few Australian soils have enough P for sustained crop and pasture production. Many soils have large reserves of total phosphorus, but low levels of available phosphorus. Complex soil processes influence the availability of P applied to the soil, with many soils able to adsorb or 'fix' phosphorus, making it less available to plants (Figure 3). <sup>41</sup> A soil's ability to fix phosphorus must be measured when determining requirements for crops and pastures. <sup>42</sup>



**Figure 3:** The phosphorus cycle in a typical cropping system is particularly complex, because movement through the soil is minimal and availability to crops is severely limited.

Source: Soilquality.org

# **IN FOCUS**

# Cereal types and phosphorus use in Waikerie, Murray Mallee

Crop growth on the flats is typically thicker than on sand hills, but in most years grain yields are less. Soil P levels (0–10 cm) do not vary markedly across the different soil types: 19 ppm for soil in the flats, 17 ppm on the slopes and 11 ppm in the sand hills.

Researchers wanted to test the concept of reducing rates where the crop is likely to yield lower, and possibly increasing them where the crop is likely to yield more. GRDC funded a project to investigate this. The researchers applied different P treatments in 2005 and 2006 to crops on the flats and in the sand hills. As well, in 2005, thy also tested the value of growing a different cereal crop on the flats (triticale) compared with the sand hill (barley).

In 2005, grain yield responses to applied P were greater in the lighter soil zone (sand hills) than in the heavier soil zone (flats). The most economic rate for both zones was 3 kg/ha. A higher rate of P (11 kg/ha) increased grain yield on the lighter soil (Zone 2) more than on the heavier shallow



<sup>39</sup> JI Ortiz-Monasterio, RJ Pena, WH Pfeiffer, AH Hede (2002) Phosphorus use efficiency, grain yield, and quality of triticale and durum wheat under irrigated conditions. In Proceedings of the 5th International Triticale Symposium, Annex, 30 June–5 July. Vol. 30.

<sup>40</sup> JI Ortiz-Monasterio, RJ Pena, WH Pfeiffer, AH Hede (2002) Phosphorus use efficiency, grain yield, and quality of triticale and durum wheat under irrigated conditions. In Proceedings of the 5th International Triticale Symposium, Annex, 30 June–5 July. Vol. 30.

 $Soil quality.org.\ Phosphorus:\ Queensland.\ Factsheet.\ Soil quality.org,\ \underline{http://www.soil quality.org.aw/factsheets/phosphorus-queensland}$ 

<sup>42</sup> Soilquality.org. Phosphorus: NSW. Soilquality.org.au.

**TABLE OF CONTENTS** 



soil (Zone 1). This is consistent with lower leaf tissue P from the crop on the sand hill (3,000 mg/kg) than on the flat (3,700 mg/kg).

SOUTHERN

In this trial the grain yield of triticale was the same on the flats (1.3 t/ha) as on the sand hill, while the barley grain yield was similar on the flats (1.47 t/ ha) and the sand hill (1.48 t/ha).

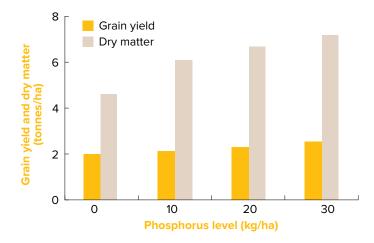
In 2006, grain-yield responses of barley and triticale to different rates of P and N fertiliser were compared for three different zones (flat, slope and hill) in this paddock. In each zone, two rates were compared, one rate for an average year and a lower rate.  $^{43}$ 

As in 2005, grain yields were lower on the flats than on the sand hills. However, in these lower-yielding crops grain yield responses to P and N were relatively small. In only two cases for triticale (on the flats and in the hills) did yield increases cover the cost of the extra fertiliser (0.07 t/ha) within a zone, and in one case (on the slopes) for the barley (0.06 t/ha).

While there has been substantial improvement (e.g. through genetic gains) in terms of P responsiveness in triticale, there has been little improvement in terms of phosphorus-use efficiency, i.e. performance in low-phosphorus conditions. Researchers in Mexico found that triticale was responsive to P applications, with grain yields in some genotypes almost three times higher in the application of P formulated as P2O5 applied at a rate of 80 kg.  $^{44}$ 

Phosphorus application has also been found to influence triticale growth stages. One study found that plots treated with phosphorus (90 kg/ha-1) produced more days to anthesis (126), plant height (114 cm) and leaf area cm $^2$  (21) while more days to physiological maturity (167) was formed by 60 kg P/ha-1.  $^{45}$ 

Triticale responds well to phosphorus application under drought conditions (Figure 4).  $^{46}$ 



**Figure 4:** Triticale grain yield and straw dry-matter response to phosphorus levels under drought conditions in Morocco.

Source: Mergoum and Gómez-Macpherson 2004



<sup>43</sup> A Mayfield (n.d.) SPA00003: Improvement of nutrient management through effective use of precision agriculture technologies in the southern Australian grains industry. Final reports. GRDC, <a href="https://finalreports.grdc.com.au/SPA00003">https://finalreports.grdc.com.au/SPA00003</a>

<sup>44</sup> JI Ortiz-Monasterio, RJ Pena, WH Pfeiffer, AH Hede (2002) Phosphorus use efficiency, grain yield, and quality of triticale and durum wheat under irrigated conditions. In Proceedings of the 5th International Triticale Symposium, Annex, 30 June–5 July. Vol. 30.

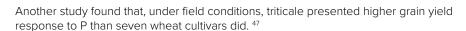
<sup>45</sup> B Iqbal, B Ahmad, I Ullah, AA Khan, S Anwar, A Ali, K Shahzad, S Khan (2016) Effect of phosphorus, sulfur and different irrigation levels on phenological traits of Triticale. Pure and Applied Biology, 5 (2), 303–310.

<sup>46</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/v5553e00.pdf">http://www.fao.org/3/a-y5553e/v5553e00.pdf</a>



**TABLE OF CONTENTS** 





SOUTHERN

A study in south-western Australia found that on an acidic soil, triticale required from 50-70% less P than wheat, but on less acidic soil it required 100% more P.  $^{48}$ 

In many soils of south-eastern Australia, P application has good residual value. However, if not applied for five to 10 years, even those soils with excellent fertiliser history are likely to develop a P deficiency.

In sandy soils P has a tendency to leach out of the soil. Sandy soils have been measured to lose up to 100% of applied phosphorus to leaching in the first season. Certainly 50% losses are common. However, soils with sufficient levels of 'reactive' iron (Fe) and aluminium (Al) will tend to resist phosphorus leaching. If you have sandy soils with low 'reactive' levels of Fe and Al then you should test your P levels and apply less phosphorus more often, so that you don't lose your expensive phosphorus dollar to leaching. In soils with high free lime (10–20%), phosphorus will react with calcium carbonate in the soil to create insoluble calcium phosphates. Lock-up of phosphorus occurs on these soils at high pH and more sophisticated methods of applying phosphorus may be needed.

Phosphorus deficiency is thought to be responsible for biomass reduction of triticale in nutrient solution with aluminium. One study suggests that in previous experiments, P deficiency was probably the most important limiting factor in acid nutrient solutions with aluminium. <sup>49</sup>

# **5.6.1** Symptoms of deficiency

#### What to look for in the paddock

- Smaller, lighter green plants with necrotic leaf tips, generally on sandier parts of the paddock or between header or swathe rows.
- Plants look unusually water-stressed despite adequate environmental conditions (Photo 5). <sup>50</sup>
- Affected areas are more susceptible to leaf diseases.

#### What to look for in the plant

- In early development, usually in cases of induced phosphorus deficiency, seedlings appear to be pale olive green and wilted (Photos 6 and 7).
- On older leaves, chlorosis starts at the tip and moves down the leaf on a front, while the base of the leaf and the rest of the plant remains dark green. Unlike with nitrogen deficiency, necrosis (death) of these chlorotic (pale) areas is fairly rapid, with the tip becoming orange to dark brown and shrivelling, while the remainder turns yellow. By this stage, the second leaf has taken on the early symptoms of phosphorus deficiency.
- By tillering, uncommon symptoms of severe deficiency are dull, dark green leaves with slight mottling of the oldest leaf.



<sup>47</sup> JR Ben (1991) Response of triticale, wheat, rapeseed and lupine to phosphorus in soil. In 2. Proceedings of the International Triticale Symposium. Passo Fundo (Brazil) 1–5 October 1990.

<sup>48</sup> MDA Bolland (1992) The phosphorus requirement of different crop species compared with wheat on lateritic soils. Fertilizer Research,

<sup>49</sup> VL Quartin, HG Azinheira, MA Nunes (2001) Phosphorus deficiency is responsible for biomass reduction of triticale in nutrient solution with aluminum. Journal of Plant Nutrition, 24 (12), 1901–1911.

<sup>50</sup> DAFWA (2015) Diagnosing phosphorous deficiency in wheat. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-wheat">https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-wheat</a>

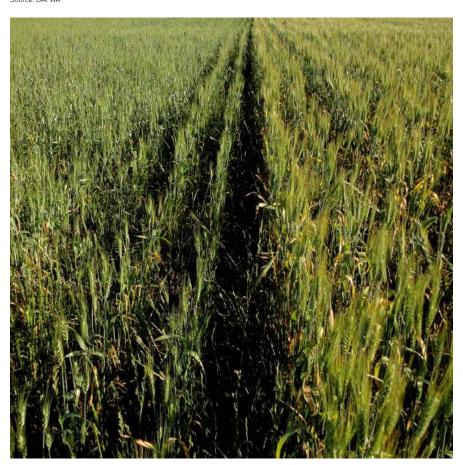
TABLE OF CONTENTS





**Photo 5:** Stunted early growth with reduced tillers in P deficient crop on the left.

Source: DAFWA



**Photo 6:** *P-deficient plants on the left are later maturing with fewer and smaller heads.* 





**SOUTHERN** 

**Photo 7:** Dark leaves with necrosis moving down from the tip of the oldest leaf is symptom of P deficiency.

Source: DAFWA

# What else it could be

Before assuming phosphorous deficiency, eliminate other possible causes of symptoms (Table 7).

**Table 7:** Other possible problems of triticale that could be confused for phosphorous deficiency.

Condition	Similarities	Differences
Nitrogen deficiency	Small, less tillered and light green plants	Phosphorus-deficient plants are thinner with darker leaves and older leaf tip death without leaf yellowing
Molybdenum deficiency	Small, less tillered and light green plants	Phosphorus-deficient plants are thinner with darker leaves and older leaf tip death without leaf yellowing
Potassium deficiency	Small, less tillered and light green plants	Phosphorus-deficient plants are thinner with darker leaves and older leaf tip death without leaf yellowing

Plants have a high requirement for P during early growth. As P is relatively immobile in the soil, topdressed or sprayed fertiliser cannot supply enough to correct a deficiency.









Phosphorus does leach on sands with a very low PBI (a measure of phosphorus retention), particularly on coastal plains. Topdressing is effective on these soils. <sup>51</sup>

SOUTHERN

#### Soil testing

Testing the phosphorus levels in your soil is important and will help in the budgeting of your phosphorus dollar. The release of phosphorus is related to:

- The total amount of phosphorus in the soil.
- The abundance of iron and aluminium oxides.
- · Organic carbon content.
- Free lime or soluble calcium carbonate.
- Phosphorus buffer index (PBI).

Available phosphorus tests like the Colwell and Olsen's phosphorus test don't measure available phosphorus. Rather they express an indication of the rate at which P may be extracted from the soils. This rate is calibrated with field trials. There is a relationship between total soil phosphorus and Colwell phosphorus, and this can enable you to predict when a given level of phosphorus input (fertiliser) or output (product removal) will result in a risk of phosphorus rate of supply becoming a limiting factor. <sup>52</sup>

# 5.6.2 Managing phosphorus

Key points:

- After decades of consistent P application, many soils now have adequate P status.
- Before deciding on a fertiliser strategy, use soil testing to gain a thorough understanding of the nutrient status across the farm.
- If the soil P status is sufficient, there may be an opportunity for growers to save money on P fertiliser by cutting back to a maintenance rate.
- Consider other factors: if pH (CaCl<sub>2</sub>) is less than 4.5; the soil is water repellent or root-disease levels are high, then the availability of soil test P is reduced and a yield increase to fertiliser P can occur even when the soil test P results show that levels are adequate.
- Work with an adviser to refine your fertiliser strategy.
- Adding fertiliser to the topsoil in systems that rely on stored moisture does not always place nutrients where crop needs them.
- Testing subsoil (10–30 cm) P levels using both Colwell-P and BSES-P soil tests is important in developing a fertiliser strategy.
- Applying P at depth (15–20 cm deep on 50 cm bands) can improve yields over a number of cropping seasons (if other nutrients are not limiting).
- Addressing low P levels will usually increase potential crop yields, so match the application of other essential nutrients, particularly N, to this adjusted yield potential.

Place phosphorous with or near the seed at seeding time, or band prior to seeding. High application rates can lead to both salt burning of the seedlings and a thin plant stand, and potentially reduce yield. <sup>54</sup>

Phosphorus fertiliser and, where necessary, nitrogen fertiliser are recommended in the same amounts as recommended for wheat. The current recommendations for the Mallee are:

• Phosphorus at 10–15 kg/ha and 10–20 kg/ha of nitrogen applied at sowing.

- 51 DAFWA (2015) Diagnosing phosphorus deficiency in wheat. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-wheat">https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-wheat</a>
- 2 G Bailey, T Brooksby (n.d.) Managing phosphorous in south-east soils. South East Soil Issues, <a href="http://www.naturalresources.sa.gov.au/south-east/land/soil-management/South-East-Soil-Issues">http://www.naturalresources.sa.gov.au/south-east/land/soil-management/South-East-Soil-Issues</a>
- 3 GRDC (2012) Phosphorus management, southern region. Factsheet. GRDC, <u>www.grdc.com.au/GRDC-FS-PhosphorusManagement</u>
- 4 Alberta Agriculture and Forestry (2016) Fall rye production. Agdex 117/20-1. Revised. Alberta Government, <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/agdex1269/\$file/117\_20-1.pdf">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/agdex1269/\$file/117\_20-1.pdf</a>



Phosphorus in the southeast soils

<u>Crop nutrition: Phosphorus</u> management—southern region





TABLE OF CONTENTS





WATCH: GCTV13: Phosphorus uptake



WATCH: <u>Improving phosphate use</u> efficiency



Occasionally nitrogen may need to be broadcast after sowing if the crop appears deficient.  $^{55}$ 

Arbuscular mycorrhizae fungi play an important role in plant uptake of P. The uptake of this nutrient by wheat, rye, and triticale was, respectively, 10%, 64%, and 35% higher with AMF infection than without. Triticale followed wheat, with similar mycorrhizal dependency. <sup>56</sup>

SOUTHERN

JANUARY 2018

#### 5.7 Sulfur

Key points:

- In cereals, lower sulfur levels lead to lower protein and because this affects the quality of the flour, the price received for this grain will be reduced.
- The leaves on deficient plants leaves turn pale with no stripes or green veins, but generally do not die although growth is retarded and maturity delayed
- Top-dressing 10–15 kilograms per hectare of sulfur as gypsum or ammonium sulphate will overcome deficiency symptoms.
- Comprehensive research in terms of triticale and sulfur are limited.

Sulfur is a major plant element. It is an essential plant nutrient (along with N) required for the production of amino acids, which in turn make up proteins. In cereals, lower sulfur levels lead to lower protein and because this affects the quality of the flour, the price received for this grain will be reduced. A lack of sulfur will also affect the oil content and hence the price received for canola.

Yield losses also occur in low-sulfur situations, especially with canola. Ideally, plants will take up sulfur at the same levels as phosphorus.

Sulfur is present to varying degrees in nearly all soils. Soils with clay and gravel have generally more sulfur present than sandier soils from high-rainfall areas. This is due in part to the composition of the original parent rock. Organic sulfur, which is mineralised into plant-available sulfate, is more prevalent in soils with high clay and gravel content. The sandier soils from higher-rainfall areas do not have any ability to restrict the leaching of water-soluble sulfate. Sulfur remaining in plant residues is readily recycled into the soil. <sup>57</sup>

Historically, S has been adequate for crop growth because S is supplied in superphosphate, in rainfall in coastal areas and some from gypsum. In the southern region, sulfur-responsive soils are uncommon in cereals, but can be seen in canola. Sulfur inputs to cropping systems have declined with the use of triple superphosphate (TSP), mono-ammonium phosphate (MAP) and diammonium phosphate (DAP), which are low in S. Sulfur, like Nitrogen, is also subject to leaching and in wet seasons may move beyond the root zone.

The occurrence of S deficiency appears to be a complex interaction between the mineralisation of S from soil organic matter, seasonal conditions, crop species and plant availability of subsoil S. Similar to N, these factors impact on the ability of the soil S test to predict plant-available S .  $^{58}$ 

The forage production of triticale and wheat is essential to many livestock producers. Very little data is available concerning the effects of sulfur fertilisation on production and quality of triticale or wheat forage. However, research conducted in a greenhouse may give clues to the use of S in the paddock. The greenhouse research was conducted to evaluate the addition of S as either ammonium thiosulfate (ATS) or ammonium sulfate (AS) on production and quality of triticale and wheat forage on four different soils. Sulfur fertilisation increased forage yields and S concentrations of both crops on all soils, and in many cases, resulted in higher N concentrations in



<sup>55</sup> Agriculture Victoria (2012) Growing triticale. Note AG0497. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

<sup>56</sup> R Pandey, B Singh, TVR Nair (2005) Impact of arbuscular-mycorrhizal fungi on phosphorus efficiency of wheat, rye, and triticale. Journal of Plant Nutrition, 28 (10), 1867–1876.

 $<sup>57 \</sup>quad \text{Summit Fertilizers (n.d.) Sulfur (S). Summit Fertilizers, \\ \underline{\text{http://www.summitfertz.com.au/research-and-agronomy/sulfur.html}}$ 

<sup>58</sup> GRDC (2014) Soil testing for crop nutrition, southern region. Factsheet. GRDC, www.grdc.com.au/GRDC-FS-SoilTestingS



**TABLE OF CONTENTS** 



the forage. Sulfur fertilisation also increased the *in vitro* digestibility of wheat, but had little effect on triticale digestibility. Both S sources performed similarly. Application of S after the first clipping was effective in increasing second-clipping forage production on three of the four soils, and forage S concentrations were dramatically increased for both crops on all soils. Although the magnitude of response varied, S fertilisation was effective in increasing production and quality of triticale and wheat forage grown in the greenhouse.  $^{59}$ 

SOUTHERN

Treatments of nitrogen and phosphorous fertilisers have been found to significantly increase the dry matter, sulfur concentrations and sulfur uptake of triticale compared to unfertilised treatments. <sup>60</sup>

One study found that sulfur (20 kg/ha-1) applied to plots of triticale produced a greater number of days to anthesis (126).  $^{61}$ 

# **5.7.1** Symptoms of deficiency

#### What to look for in the paddock

Areas of pale plants (Photo 8). 62

#### What to look for in the plant

- Plants grow poorly and lack vigour, and have reduced tillering, delayed maturity and lower yields and protein levels.
- · The youngest leaves are affected first and most severely.
- The leaves on deficient plants leaves turn pale with no stripes or green veins, but generally do not die although growth is retarded and maturity delayed (Photo 9).
- With extended deficiency the entire plant becomes lemon yellow and stems may become red.
- Additional applied N can exacerbate the yellowing.



<sup>59</sup> RL Feyh, RE Lamond, DA Whitney, RG Sears (1993) Sulfur fertilisation of wheat and triticale for forage production 1. Communications in Soil Science & Plant Analysis, 24 (5–6), 443–455.

<sup>60</sup> B Lasztity (1993) The variation of sulfur contents and uptakes in triticale during growth [in Hungary]. Agrochimica (Italy).

<sup>61</sup> B Iqbal, B Ahmad, I Ullah, AA Khan, S Anwar, A Ali, K Shahzad, S Khan (2016) Effect of phosphorus, sulfur and different irrigation levels on phenological traits of Triticale. Pure and Applied Biology, 5 (2), 303–310.sulfur

<sup>62</sup> DAFWA (2015) Diagnosing sulfur deficiency in cereals. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-sulfur-deficiency-cereals">https://www.agric.wa.gov.au/mycrop/diagnosing-sulfur-deficiency-cereals</a>









SOUTHERN JANUARY 2018

Photo 8: Areas of pale plants characterise sulfur deficiency.

Source: DAFWA



**Photo 9:** Leaves showing some yellowing.







#### What else it could be

Before assuming sulfur deficiency, eliminate other possible causes of symptoms (Table 8).

**Table 8:** Other possible problems of triticale that could be confused for sulfur deficiency.

SOUTHERN

Condition	Similarities	Differences
Iron deficiency	Pale new growth	Iron-deficient plants have interveinal chlorosis
Group B herbicide damage	Seedlings with pale new leaves	Plants generally recover from Group B herbicide damage; and leaves often have interveinal chlorosis.
Waterlogging, or nitrogen, molybdenum or manganese deficiency	Pale growth	The youngest leaves of sulfur- deficient plants are affected first while the middle or older leaves are affected first with waterlogging, and manganese, nitrogen and molybdenum deficiency

Source: DAFWA

# **5.7.2** Managing sulfur

Top-dressing 10-15 kilograms per hectare of sulfur as gypsum or ammonium sulphate will overcome deficiency symptoms.

Foliar sprays generally cannot supply enough sulfur for plant needs. 63

Modern high-analysis fertilisers will usually contain enough S to supply sufficient levels to cereal crops. Canola, however, will require more than can be safely or conveniently applied using a seeding fertiliser and so extra sulfur must be applied, either before seeding as gypsum, or after seeding as amsul (sulphate of ammonia).

If a deficiency manifests in an established crop, it can be easily corrected with an application of sulphate of ammonia.

#### Supplies of sulfur (elemental or sulphate)

Plants take up sulfur in the sulphate (SO4) form. The sulfate form is water-soluble, and being an anion, readily leaches. The elemental form of sulfur needs to be broken down into the sulfate form before becoming available to the plant. This is achieved by bacteria (Thiobacillus spp.) which digest the sulfur and excrete sulfate. All soils contain these bacteria. It takes about a fortnight for elemental sulfur to start breaking down, so it should be used before a plant deficiency can be seen. In waterlogged conditions, where sulfate will be lost by leaching or run-off, the bacteria will become dormant, so sulfur will not be lost.

#### Pros and cons of the two sulfur sources

Sulfate sulfur is:

- immediately available to the plant
- water-soluble
- quick acting
- leachable
- easily lost with one heavy rainfall

Elemental sulfur is:

- released slowly
- not lost by leaching



 $<sup>{\</sup>sf DAFWA}\ (2015)\ {\sf Diagnosing}\ s {\sf Sulfur}\ deficiency\ in\ cereals.\ {\sf DAFWA}\ , \\ \underline{{\sf https://www.agric.wa.gov.au/mycrop/diagnosing-sulfur-deficiency-relations}\ (2015)\ {\sf Diagnosing}\ s {\sf Sulfur}\ deficiency\ in\ cereals.\ DAFWA\ , \\ \underline{{\sf https://www.agric.wa.gov.au/mycrop/diagnosing-sulfur-deficiency-relations}\ (2015)\ {\sf Diagnosing}\ s {\sf Sulfur}\ deficiency\ in\ cereals.$ cereals



**TABLE OF CONTENTS** 





- will build up a sulfur 'bank'
- · slow to break down
- not suitable to correct a visible deficiency in plants 64

#### 5.8 Potassium

Key points:

- Triticale can be sensitive to potassium deficiency and responses to its application.
- Soil testing combined with plant-tissue testing is the most effective means of determining potassium requirements.

SOUTHERN

 Banding away from the seed, at sowing or within four weeks of sowing, is the most effective way to apply potassium when the requirement is less than 15 kg/ha.

Potassium (K) is an essential plant nutrient. It has many functions, including the regulation of the opening and closing of stomata, the breathing holes on plant leaves that control moisture loss from the plant. Adequate potassium increases vigour and disease resistance of plants, and helps to form and move starches, sugars and oils. Available potassium exists as an exchangeable cation associated with clay particles and humus. <sup>65</sup>

A study in Europe found that triticale is more sensitive to potassium deficiency than to phosphorus deficiency. <sup>66</sup>

Other research showed that the highest rate of grain yield for triticale (6.1 t/ha–1) was obtained by application of 160 kg/ha-1 of nitrogen and 90 kg/ha-1 of potassium. The application of different levels of nitrogen affected grain protein of triticale, but using different amounts of potassium did not.  $^{67}$ 

Generally, in the southern region, cropping soils are unresponsive to additions of K. However, as crops continue to mine K from soils, this may change in the future.

Potassium deficiency is more likely to occur on light soils and with high rainfall, especially where hay is cut and removed regularly.

Factors such as soil acidity, soil compaction and waterlogging will modify root growth and the ability of crops to extract subsoil K. <sup>68</sup>

High potassium:sodium (Na) ratios in wheat and some triticale varieties can induce magnesium (Mg) deficiency in grazing stock, which may show up as tetany. Surveys in southern Australia showed that all varieties of cereals tested had a K:Na ratio that could cause magnesium deficiency in livestock.

One contributing factor to the variation in animal gains is the mineral nutrition provided by cereals to grazing livestock. The Mg content of cereal is typically satisfactory for stock, but the high K content and very low Na content of forage result in a high rumen K:Na ratio, which impedes magnesium absorption in the rumen.

Sheep and cattle grazing cereals can therefore have a sodium deficiency and a magnesium deficiency.  $^{69}$ 



Mineral supplements needed when grazing cereals



<sup>64</sup> Summit Fertilisers (n.d.) Sulfur (S). Summit Fertilizers, http://www.summitfertz.com.au/research-and-agronomy/sulfur.html

 $<sup>65 \</sup>quad Soil quality.org \, (n.d.) \, Potassium: \, NSW. \, Soil quality.org.au, \, \underline{http://www.soil quality.org.au/factsheets/potassium-nsw.} \, A to the property of the property$ 

<sup>66</sup> R Gaj (2012) The effect of different phosphorus and potassium fertilisation on plant nutrition in critical stage and yield of winter triticale. Journal of Central European Agriculture, 13 (4).

<sup>67</sup> SA Tababtabaei, GH Ranjbar (2012) Effect of different levels of nitrogen and potassium on grain yield and protein of triticale International Research Journal of Applied and Basic Sciences, 3 (2), 390–393.

<sup>68</sup> GRDC (2014) Soil testing for crop nutrition, southern region. Factsheet. GRDC, www.grdc.com.au/GRDC-FS-SoilTestingS

<sup>69</sup> L Bell, H Dove (2012) Mineral supplements needed when grazing cereals. Ground Cover. No. 98, May—June 2012. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-98-May-June-2012/Mineral-supplements-needed-when-grazing-cereals">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-98-May-June-2012/Mineral-supplements-needed-when-grazing-cereals</a>





# 5.8.1 Symptoms of deficiency

#### What to look for in the paddock

- Smaller, lighter green plants with necrotic leaf tips, generally on sandier parts of the paddock or between header or swathe rows (Photo 10).
- Plants look unusually water-stressed despite adequate environmental conditions.
- Affected areas are more susceptible to leaf disease.

#### What to look for in the plant

- Plants appear paler, and weak and floppy (Photo 11).
- Older leaves are affected first, with leaf tip death and progressive yellowing and death down from the leaf tip and edges. There is a marked contrast in colour between yellow leaf margins and the green centre.
- Yellowing leaf tip and leaf margins sometimes generates a characteristic green 'arrow' shape towards leaf tip.



**Photo 10:** There are fewer symptoms in header rows.



<sup>70</sup> DAFWA (2015) Diagnosing potassium deficiency in wheat. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-potassium-deficiency-wheat">https://www.agric.wa.gov.au/mycrop/diagnosing-potassium-deficiency-wheat</a>



SOUTHERN JANUARY 2018

**Photo 11:** Potassium-deficient plants may display floppy older leaves and furled flag leaf from water stress.

Source: DAFWA

#### What else it could be

Before assuming potassium deficiency, eliminate other possible causes of symptoms (Table 9).

 
 Table 9: Other possible problems of triticale that could be confused for potassium
 deficiency.

Condition	Similarities	Differences
Molybdenum deficiency	Pale plants with leaf tip death	Potassium-deficient plants do not have white or rat-tail heads, and have more marked contrast between yellow and green sections of affected leaves
Nitrogen deficiency	Pale plants with oldest leaves most affected	Potassium-deficient plants have more marked leaf-tip death and contrast between yellow and green sections of affected leaves, and tillering is less affected
Spring drought	Water-stressed plants with older leaves dying back from the tip, yellowing progressing down from tip and edges and often leaf death occurs	The main difference is that potassium deficiency is more marked in high-growth plants in good seasons
Root lesion nematodes	Smaller, water- stressed, pale plants	Root-lesion-nematode affected plants have 'spaghetti' roots with few feeder roots







FEEDBACK



<u>Potassium responses observed in</u> South Australian cereals Topdressing potassium will generally correct the deficiency. Foliar sprays generally cannot supply enough potassium to overcome a severe deficiency and can also scorch crops.  $^{71}$ 

SOUTHERN

# 5.8.2 Managing potassium

Soil and plant-tissue analysis together give insight into the availability of potassium in the soil. Growers should not rely on soil testing alone, as results are subject to many potential sources of error.

Tissue analysis of whole tops of crop plants will determine whether a deficiency exists, but won't define a potassium requirement. These results are generally too late to be useful in the current season, but inform the need to assess K requirements for the next crop.

Potassium available in the soil is measured by the Colwell-K or Exchangeable K soil tests. The amount of potassium needed for plant nutrition depends on soil texture (Table 10).

Table 10: Critical (Colwell) soil test thresholds for potassium (in ppm).

	Deficient	Moderate	Sufficient
Cereals, canola, lupins, etc. (Brennan and Bell 2013)	<50	50–70	>70
Pasture legumes (Gourley et al. 2007)	<100 (sand) <150 (clay loam)	100–140 (sand) 150–180 (clay loam)	>140 (sand) >180 (clay loam)

Source: Soilquality.org

Sandy soils require less potassium to be present, but are more likely to show deficiencies. Clay soils require more potassium to be present, but are more capable of supplying replacement potassium through the weathering of clay minerals.

Potassium lost through product removal should be replaced once paddocks fall below sufficient K levels, rather than waiting for deficiency symptoms to appear. Replacement requirements for each crop differ, and this must be accounted for when budgeting K requirements for the coming season.

#### Fertiliser types

Sulphate of potash (SOP), or potassium sulphate, is usually recommended if soils are deficient in K. Applying the cheaper muriate of potash (MOP), or potassium chloride, also corrects potassium deficiency, but it also adds chloride to the soil, which contributes to overall salinity and can decrease the establishment of seedlings.

Potassium magnesium sulphate can also be used where magnesium and sulphate are also required. This form is often used in 'complete' fertiliser blends. Potassium nitrate supplies nitrogen and potassium in a highly water-soluble (and available) form, but is rarely used in broadacre farming because of its cost.

#### Fertiliser placement and timing

Potassium generally stays very close to where it is placed in the soil. Banded potassium has been shown to be twice as accessible to the crop as topdressed potassium. This is thought to be related to improved availability for the emerging crop, and decreased availability for weeds. Seed must be sown within 50 mm of the potassium drill row or seedlings may miss the higher levels of potassium. High band rates (>15 kg/ha) of potassium can inhibit sensitive crops (e.g. lupins, canola). If a paddock is severely deficient then potassium needs to be applied early in the season, at seeding or up to four weeks after.  $^{72}$ 



<sup>71</sup> DAFWA (2015) Diagnosing potassium deficiency in wheat. DAFWA, <a href="https://www.agric.wa.qov.au/mycrop/diagnosing-potassium-deficiency-wheat">https://www.agric.wa.qov.au/mycrop/diagnosing-potassium-deficiency-wheat</a>

<sup>72</sup> Soilquality.org (n.d.) Potassium: NSW. Soilquality.org.au









#### 5.9 Micronutrients

Key points:

- Trace elements are important in particular situations but are not miracle workers.
- Deficiencies are not uncommon, but when they occur can result in large yield penalties.
- Diagnosis by soil tests and tissue tests is difficult, but in most cases the potential for deficiencies can be assessed by reviewing soil types, crop type and seasonal conditions.
- Products vary in their efficiency and growers should look for evidence of the efficacy of products in their region.

Most growers and agronomists are fully aware of the nitrogen and phosphorus demands of crops, and meeting those demands is a major investment in crop production. Sulfur and potassium are also important in some regions, as are calcium and magnesium. These six nutrients, the macronutrients, are complemented by a set of nutrients required in smaller amounts; the micronutrients or trace elements. Even though needed in tiny quantities, copper (Cu), manganese (Mn), iron (Fe), zinc (Zn), boron (B) and molybdenum (Mo) are all essential for plant growth. Essential trace elements are nutrients which are required by plants and animals to survive, grow, and reproduce, but are needed in only minute amounts. Southern Australian cropping soils are more likely to be deficient in zinc (Zn), copper (Cu), and manganese (Mn) than the other trace elements.

Of these three, Zn deficiency is probably the most important because it occurs over the widest area. Zn deficiency can severely limit annual pasture-legume production and reduce cereal-grain yields by up to 30%. Cu deficiency is also important because it may result in total crop failure.

If Zn, Cu and Mn are not managed well, the drop in productivity of crops and pastures can leave the farmer suffering expensive losses, and further production can also be lost through secondary effects such as increased disease damage and susceptibility to frost.

Adequate trace-element nutrition is just as important for vigorous and profitable crops and pastures as adequate major element (such as nitrogen or phosphorus) nutrition.

Many soils in the cropping zone of southern Australia are deficient in trace elements in their native condition. Despite many decades of research into trace-element management, crops can still be found to be deficient in one or more of these elements. It is important to keep an eye on trace-element levels as part of regular farm management: just because trace element deficiencies have not been prevalent in recent years, does not mean they will not return. There is increasing concern in some districts that trace-element deficiencies may be the next nutritional barrier to improving productivity. This is because current cropping systems are exporting more nutrients to the grain terminal than ever before. <sup>73</sup>

Triticale grows productively on alkaline soils where certain trace elements are deficient enough that they will not be suitable for other cereals. <sup>74</sup>

South Australia has a long and proud history of micronutrient research, and in the early 1960s it was found that foliar sprays of Mn onto barley gave a 20-fold response in the southern Yorke Peninsula. This was the first time foliar trace elements had been applied to agricultural crops in Australia. Similarly, with copper, South Australian scientists have led the way with diagnosis and remediation, as well as developing a deep understanding of cultivar differences in copper (and manganese) responses. Even so, between farms and within farms, the response to micronutrients will differ. <sup>75</sup>



<sup>73</sup> N Wilhelm, S Davey (2016) Detecting and managing trace element deficiencies in crops. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops</a>

<sup>74</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>75</sup> R Norton (2014) Trace elements; copper and manganese: their role, requirements and options. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Trace-elements-copper-and-manganese-their-role-requirements-and-options">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Trace-elements-copper-and-manganese-their-role-requirements-and-options</a>



**TABLE OF CONTENTS** 

FEEDBACK



# **MORE INFORMATION**

Detecting and managing trace element deficiencies in crops

Trace elements: copper and manganese—their role, requirements and options

Trace element disorders in South Australian agriculture

In early trials, it has been reported that triticale has the Cu, Zn and Mn efficiency traits derived from its cereal rye parent. Triticale usually performs remarkably well on highly calcareous soils which are often deficient in Mn and Zn and sometimes in Cu. 76

SOUTHERN

One study from Europe suggests that calcium, magnesium and potassium are the mineral nutrients most likely to limit triticale yield. 77

# 5.9.1 Manganese

Many triticale cultivars carry tolerance to soils high in manganese, which is typical of some soils of Australia. 78

# Symptoms of deficiency

#### What to look for in the paddock

Manganese deficiency often appears as patches of pale, floppy plants in an otherwise green, healthy crop (Photo 12). 79

#### What to look for in the plant

- Plants are frequently stunted and occur in distinct patches.
- The middle leaves are affected first, but it can be difficult to determine which leaves are the most affected as symptoms rapidly spread to other leaves and the growing point (Photo 13).
- Leaves develop interveinal chlorosis and/or white necrotic flecks and blotches.
- Leaves often kink, collapse, and eventually die.
- Tillering is reduced, with extensive leaf and tiller death. With extended deficiency, the plant may die.
- Surviving plants produce fewer and smaller heads.



<sup>76</sup> D Reuter (2007) Trace element disorders in South Australian agriculture. http://www.pir.sa.gov.au/\_\_data/assets/pdf\_file/0011/49619/

R Gaj (2012) The effect of different phosphorus and potassium fertilisation on plant nutrition in critical stage and yield of winter triticale. Journal of Central European Agriculture, 13 (4).

DAFWA (2015) Diagnosing manganese deficiency in wheat. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-manganesedeficiency-wheat











SOUTHERN JANUARY 2018

**Photo 12:** Patches of pale, floppy plants in otherwise healthy crop. Source: DAFWA



TABLE OF CONTENTS





SOUTHERN

**Photo 13:** Middle leaves are affected first, and show yellowing and necrosis. Source: DAFWA

#### What else it could be

Before assuming potassium deficiency, eliminate other possible causes of symptoms (Table 11).

**Table 11:** Other possible problems of triticale that could be confused for potassium deficiency.

Condition	Similarities	Differences
Zinc deficiency	Pale plants with interveinal chlorosis and kinked leaves	Differences include linear 'tramline' necrosis on zinc-deficient plants.  Manganese-deficient plants are more yellow and wilted.
Nitrogen deficiency	Pale plants	Nitrogen-deficient plants do not show wilting, interveinal chlorosis, leaf kinking and death
Waterlogging	Pale plants	Waterlogged plants do not show wilting, interveinal chlorosis, leaf kinking and death
Iron deficiency	Pale plants	New leaves are affected first, and plants do not die
Sulfur deficiency	Pale plants	New leaves are affected first, and plants do not die





**TABLE OF CONTENTS** 





#### Managing manganese deficiency

- Use a foliar spray.
- Acidifying ammonium nitrogen fertilisers can reduce manganese deficiency by lowering pH and making manganese more available to growing crops.
- Manganese fertiliser is effective but expensive, as high rates and several applications are required to generate residual value.
- Seed manganese-coating treatments have little effect in correcting the deficiency. 80

Due to the detrimental effect of high soil pH on Mn availability, correction of severe Mn deficiency on highly calcareous soils can require the use of Mn-enriched fertilisers banded with the seed (3–5 kg Mn/ha) as well as one to two follow-up foliar sprays (1.1 kg Mn/ha). In the current economic climate, growers on Mn-deficient country have tended not to use Mn-enriched fertilisers due to their cost, and have relied solely on a foliar spray. This is probably not the best or most reliable strategy for long-term management of the problem.

Neither soil nor foliar Mn applications have any residual benefits and must be reapplied every year. Another approach is to coat the seed with Mn. This technique is cheap and will probably be the most effective in conjunction with foliar sprays and/or Mn-enriched fertilisers. Mn deficiency in lupins must be treated with a foliar spray at mid-flowering on the primary laterals. The use of acid fertilisers (e.g. nitrogen in the ammonium form) may partially correct Mn deficiency on highly alkaline soils, but will not overcome a severe deficiency.

Mn deficiency in crops can also be corrected by fluid application at seeding. 81

# **5.9.2** Copper

Triticale is tolerant to low concentrations of available copper in soil, a condition widely associated with poor sandy soils in Australia. Such soils may contain enough total copper for tens of thousands of crops but it is relatively unavailable to widely grown cultivars of wheat, oats and barley. 82

# IN FOCUS

# Tolerance of triticale, wheat and rye to copper deficiency in low and high soil pH

Researchers investigated the tolerance of triticale to low copper in a soil adjusted to extremes of pH, and compared it with the tolerance of its parent species, wheat and rye. The experiment was conducted using plants in pots of soil in a glasshouse. The wheat plants were extremely sensitive to copper deficiency at all soil pH values and failed to produce heads or grain, whereas rye produced maximum yield irrespective of copper status or soil pH. Triticale demonstrated intermediate tolerance by virtue of the copper–pH–genotype interaction: it was tolerant (like rye) at pH 5.0, but sensitive (like wheat) at pH 8.4.

Concentrations of copper were highest in rye and lowest in wheat, and decreased with increasing pH. The uptake of copper into grain and shoot was also lowest in wheat, and showed the same pH dependence as concentration. The appearance of symptoms of copper deficiency in all plants that had low yields suggests that the major effect of pH in this system was on copper availability; the change in availability was, however,



<sup>80</sup> DAFWA (2015) Diagnosing manganese deficiency in wheat. DAFWA, <a href="https://www.agric.wa.qov.au/mycrop/diagnosing-manganese-deficiency-wheat">https://www.agric.wa.qov.au/mycrop/diagnosing-manganese-deficiency-wheat</a>

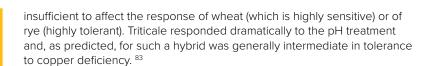
<sup>81</sup> N Wilhelm, S Davey (2016) Detecting and managing trace element deficiencies in crops. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops</a>

<sup>82</sup> RD Graham (1978) Tolerance of triticale, wheat and rye to copper deficiency. Letters. Nature, 271, 542–543.



**TABLE OF CONTENTS** 





SOUTHERN

#### Symptoms of deficiency

#### What to look for in the paddock

- Before head emergence, deficiency shows as areas of pale, wilted plants with dying new leaves in an otherwise green, healthy crop (Photo 14). 84
- After head emergence, mildly affected areas have disorganised, wavy heads. Severe patches have white heads and discoloured late maturing plants.
- Symptoms are often worse on sandy or gravelly soils, where root-pruning herbicides have been applied, and in recently limed paddocks.

#### What to look for in the plant

- The youngest growth is affected first.
- The first sign of copper deficiency before flowering is growing-point death and tip withering, and/or bleaching and twisting up to half the length of young leaves (Photo 15).
- The base of the leaf can remain green.
- Old leaves remain green, but are paler than normal.
- Tiller production may increase, but tillers die prematurely.
- Mature plants are dull grey-black in colour, with white or stained empty or 'rat-
- Grain in less severely affected plants may be shrivelled. Heads with full grain droop due to weak stems.



SP Harry, RD Graham (1981) Tolerance of triticale, wheat and rye to copper deficiency and low and high soil pH. Journal of Plant Nutrition, 3 (1–4), 721–730.

 $<sup>{\</sup>sf DAFWA}\ (2015)\ {\sf Diagnosing}\ copper\ deficiency\ in\ wheat.\ {\sf DAFWA}\ , \underline{{\sf https://www.agric.wa.gov.au/mycrop/diagnosing-copper-deficiency-particles}\ (2015)\ {\sf Diagnosing}\ copper\ deficiency\ in\ wheat.\ {\sf DAFWA}\ , \underline{{\sf https://www.agric.wa.gov.au/mycrop/diagnosing-copper-deficiency-particles}\ (2015)\ {\sf Diagnosing}\ copper\ deficiency\ in\ wheat.\ {\sf DAFWA}\ , \underline{{\sf https://www.agric.wa.gov.au/mycrop/diagnosing-copper-deficiency-particles}\ (2015)\ {\sf Diagnosing}\ copper\ deficiency\ in\ wheat.\ DAFWA\ , \underline{{\sf https://www.agric.wa.gov.au/mycrop/diagnosing-copper-deficiency-particles}\ (2015)\ {\sf Diagnosing}\ copper\ deficiency\ d$ wheat



TABLE OF CONTENTS





SOUTHERN JANUARY 2018

**Photo 14:** Pale, necrotic flag leaf at head emergence.

Source: DAFWA



Photo 15: Partly sterile head and twisted flag leaf.







#### What else it could be

Before assuming copper deficiency, eliminate other possible causes of symptoms (Table 12).

**Table 12:** Other possible problems of triticale that could be confused for copper deficiency.

SOUTHERN

Condition	Similarities	Differences
False black chaff	Discoloration on the upper stem and glumes	False black chaff does not affect yield or grain quality
Molybdenum deficiency	White heads and shrivelled grain	Molybdenum deficiency affects middle leaves first rather than the youngest leaf
Boron deficiency	Youngest leaf death	Boron-deficient plants are dark rather than light green, and affected leaves have marginal notches and split near the base
Stem and head frost damage	White heads, shrivelled grain, late tillers and delayed maturity	Spring frost does not cause death or twisting of the flag leaf, and is location specific (frost-prone areas)
<u>Take-all</u>	White heads and shrivelled grain	Take-all causes blackened roots and crowns and often kills the plant

Source: DAFWA

#### Managing copper deficiency

- Use foliar spray (only effective in the current season) or drilled soil fertiliser.
- Copper foliar sprays are not effective after flowering, as sufficient copper is required pre-flowering for pollen development.
- Mixing copper throughout the topsoil improves availability due to more uniform nutrient distribution.
- As copper is immobile in the soil, topdressing is ineffective, being available to the plant only when the topsoil is wet.
- In long-term no-till paddocks, frequent, small applications of copper via drilled or in-furrow application reduces the risk of plant roots not being able to obtain the nutrient in dry seasons.
- Copper drilled in deep increases the chances of roots being able to obtain enough copper when the topsoil is dry.
- Copper seed treatment is insufficient for the requirements of actively growing plants. <sup>85</sup>

Traditionally, Cu deficiency has been corrected by applying Cu-enriched fertilisers and incorporating them into the soil. Most soils require 2 kg Cu/ha to fully correct a deficiency, and this application may be effective for many years. Due to the excellent residual benefits of soil-applied Cu, deficiency of this element in crops and pastures has been largely overcome in most areas following the use of 'blue stone' mixes in the 1950s and 1960s. However, Cu deficiency may be re-surfacing as a problem due to a number of reasons:

- The applications of Cu made 20–40 years ago may be running out.
- The use of nitrogen fertilisers is increasing, and they will increase the severity of Cu deficiency.
- Cu deficiency is affected by seasonal conditions and farming practices (e.g. lupins in a lupin—wheat rotation make Cu deficiency worse in succeeding wheat crops).

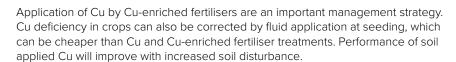


<sup>85</sup> DAFWA (2015) Diagnosing copper deficiency in wheat. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-copper-deficiency-wheat">https://www.agric.wa.gov.au/mycrop/diagnosing-copper-deficiency-wheat</a>



**TABLE OF CONTENTS** 





OUTHERN

Although Cu deficiency is best corrected with soil applications, foliar sprays will also overcome the problem in the short term. A foliar spray of Cu (75–100 g Cu/ha) is very cheap (approximately 90 c/ha for the ingredient) but a second spray immediately before pollen formation may be necessary in severe situations. This was the case in a trial conducted on lower Eyre Peninsula in 2015, where a late foliar spray was needed to completely eliminate Cu deficiency in an area that was extremely deficient in the trace element and the problem had been exacerbated by a dry spring when wheat was forming pollen and setting grains. <sup>86</sup>

Although plants do have a requirement for copper, the main reason copper is applied is for the benefit of grazing stock. Copper deficiency is more common on light-textured soils such as sands or sandy loams. Where required, copper is normally applied with the fertiliser at 1–2 kg/ha every 3–6 years. Including copper in the fertiliser will provide a long-term supply to pasture and grazing stock. Where copper deficiency has been diagnosed in stock, more direct supplementation such as copper drenches are recommended. Copper is commonly applied in southern Victoria and on lighter soil types in western Victoria and parts of Gippsland whenever molybdenum is applied. Copper is not normally applied in northern Victoria. 87

#### 5.9.3 Zinc

Deficiencies of zinc (Zn) are well known in all cereals and cereal-growing countries. Physiological evidence suggests that a critical level of zinc must be present in the soil before roots will grow and function effectively; it is likely the requirement is frequently not met in deep sandy, infertile profiles widespread in southern Australia.

Triticale is thought to have a high tolerance to Zn deficiency compared to wheat. The resistance index for Zn in triticale has been estimated at 75%, second only to rye, which is a very resistant crop to Zn deficiency. 88

In one experiment, Zn deficiency symptoms were either absent or only slightly apparent in triticale and rye, and occurred more rapidly and severely in wheats, particularly in durum wheats. In field experiments at the milk stage, decreases in shoot dry-matter production due to Zn deficiency were absent in rye, and were on average 5% visible in triticale, 34% in bread wheats and 70% in durum wheats. Zinc fertilisation had no effect on grain yield in rye, but enhanced grain yield of the other cereals. Zinc efficiency of cereals, expressed as the ratio of yield (shoot dry matter or grain) produced under Zn deficiency compared to Zn fertilisation were, on average, 99% for rye, 74% for triticale, 59% for bread wheats and 25% for durum wheats. <sup>89</sup>

#### Symptoms of deficiency

#### What to look for in the paddock

- Patchy growth of stunted plants with short, thin stems and usually pale green leaves.
- Heavily limed soils, sands and gravels or alkaline grey clays tend to be most affected.
- Zinc-deficiency symptoms are usually seen on young seedlings early during the growing season.



<sup>86</sup> N Wilhelm, S Davey (2016) Detecting and managing trace element deficiencies in crops. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops</a>

<sup>87</sup> Agriculture Victoria (2008) Trace elements for dryland pastures. Note AG0265. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/trace-elements-for-dryland-pastures">http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/trace-elements-for-dryland-pastures</a>

<sup>88</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>99</sup> I Cakmak, H Ekiz, A Yilmaz, B Torun, N Köleli, I Gültekin, A Alkan, S Eker (1997) Differential response of rye, triticale, bread and durum wheats to zinc deficiency in calcareous soils. Plant and Soil, 188 (1), 1–10.

TABLE OF CONTENTS



#### What to look for in the plant

Young to middle leaves develop yellow patches between the mid-vein and edge of the leaf and extend lengthways towards the tip and base of the leaf. This stripe may occur only on one side of the mid-vein.

SOUTHERN

- The areas eventually die turning pale grey or brown
- The leaf changes from green to a muddy greyish-green in the central areas of middle leaves.
- Stunted plants often have 'diesel-soaked' leaves, showing dead areas about halfway along the leaves, causing them to bend and collapse in the middle section (Photo 16). 90
- Maturity is delayed. 91



**Photo 16:** Leaves yellow and die and can have tramline effect on leaves. Necrosis halfway along middle and older leaves causes them to droop.

Source: DAFWA

#### What else it could be

Before assuming zinc deficiency, eliminate other possible causes of symptoms (Table 11).



<sup>90</sup> DAFWA (2015) Diagnosing zinc deficiency in wheat. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-zinc-deficiency-wheat

<sup>91</sup> DAFWA (2015) Diagnosing zinc deficiency in wheat. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-zinc-deficiency-wheat



**Table 13:** Other possible problems of triticale that could be confused for zinc deficiency.

Condition	Similarities	Differences
Manganese deficiency	Leaf kinking, pale lesions, streaks and wilted plants	Manganese-deficient plants are very pale, are more common as patches of limp, dying plants, and lack the parallel necrotic tramlines adjoining the midrib
Wheat streak mosaic virus	Stunted plants with many tillers and striped leaf lesions	Zinc-deficient plants have pale, linear spots or lesions that can develop into parallel 'tramlines', and lack vivid yellow streaks towards the leaf tip
Yellow dwarf virus	Stunted plants with many tillers and striped leaf lesions	Zinc-deficient plants have pale linear spots or lesions that can develop into parallel 'tramlines', and lack vivid yellow streaks towards the leaf tip

Source: DAFWA

#### Managing zinc deficiency

- Use a foliar spray (effective only in current season) or drilled soil fertiliser.
- Zinc foliar sprays need to be applied as soon as deficiency is detected to avoid irreversible damage.
- As zinc is immobile in the soil topdressing is ineffective, being available to the plant only when the topsoil is wet.
- Mixing zinc through the topsoil improves availability due to more uniform nutrient distribution.
- Zinc drilled in deep increases the chances of roots being able to obtain enough
  of the element when the topsoil is dry.
- Zinc seed treatment is used to promote early growth where root disease
  is a problem, but the level will be lower than a growing plant needs in a
  given season.
- Zinc present in compound fertilisers often meets the current requirements of the crop. 92

Zinc may be required on light-textured soils such as sands or sandy loams, and particularly those that are alkaline, as the more alkaline the soil, the lower the availability of zinc for plant uptake. Most of the alkaline soils in Victoria occur in the Wimmera and Mallee, but there are a few pockets of alkaline soils in the higher-rainfall areas of the state. Plant responses to Zn on pasture are rare, but where required zinc should be applied at about 1–2 kg/ha, every 5–6 years. <sup>93</sup>

Correction of Zn deficiency in a way that provides benefits after the year of treatment is possible through the use of Zn-enriched fertilisers, or with a pre-sowing spray of Zn onto the soil, which will be incorporated with subsequent cultivation. There is also the option of a Zn-coated urea product which can be used to supply Zn to the crop, and is most useful when pre-drilling urea before the crop.

Another option that will also provide long-term benefits but has become available only recently is the application of fluid zinc at seeding. The advantage of this approach is that it will provide residual benefits for subsequent crops and pastures and has a low up-front application cost (providing you ignore the capital investment in a fluid-delivery system).

Only Zn-enriched fertilisers of the homogenous type (i.e. fertiliser manufactured so that all granules contain some Zn) are effective at correcting Zn deficiency in the first year of application. A rate of 2 kg of elemental Zn per hectare applied to the soil is necessary to overcome a severe Zn deficiency; it should persist for three to 10 years,



<sup>92</sup> DAFWA (2015) Diagnosing zinc deficiency in wheat. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-zinc-deficiency-wheat">https://www.agric.wa.gov.au/mycrop/diagnosing-zinc-deficiency-wheat</a>

<sup>93</sup> Agriculture Victoria (2008) Trace elements for dryland pastures. Note AG0265. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/dairv/pastures-management/trace-elements-for-dryland-pastures">http://agriculture.vic.gov.au/agriculture/dairv/pastures-management/trace-elements-for-dryland-pastures</a>



**TABLE OF CONTENTS** 



depending on the soil type. Short intervals between repeat applications of Zn will be necessary on heavy and calcareous soils in the high-rainfall areas, while seven to 10 year intervals will be acceptable in the low-rainfall areas. Following an initial soil application of 2 kg Zn/ha repeat applications of 1 kg/ha will probably be sufficient to avoid the reappearance of Zn deficiency in crops and pastures. Few zinc-enriched fertilisers are now sold as homogeneous types, but providing a homogeneous fertiliser is used as part of the mix the final product is still satisfactory for correcting Zn deficiency. For example, the company may produce a diammonium phosphate (DAP) Zn 5% 'parent' product which has Zn on every granule which they will then blend with straight DAP to give 1% and 2.5% products for the retail market. This option will currently cost approximately \$17.00/ha.

OUTHERN JANUARY 2018

Zn deficiency can be corrected in the year that it is recognised with a foliar spray of 250–350 g Zn/ha, but it has no residual benefits and is therefore not the best approach for a long-term solution. Zinc can be mixed with many herbicides and pesticides, but not all, so check with your supplier for compatible tank mixes. Recent trials in eastern Australia suggest that chelated sources of trace elements are no more effective at correcting a deficiency than their sulphate forms.

Seed dressings of zinc are another option for managing Zn deficiency. These products are effective and will supply Zn to the young crop, but they will not completely overcome a severe deficiency. Nor will they increase soil reserves of Zn. Seed with high internal levels of Zn can also be used in a similar way. However, both approaches should be used in conjunction with soil applications to correct and manage Zn deficiency in the long term. 94

#### 5.9.4 Iron

Iron (Fe) is involved in the production of chlorophyll and is a component of many enzymes associated with energy transfer, nitrogen reduction and fixation, and lignin formation. Iron deficiencies are mainly manifested by yellow leaves, which are due to low levels of chlorophyll. Leaf yellowing first appears on the younger upper leaves in interveinal tissues. Severe iron deficiencies cause the leaves to turn completely yellow or almost white, and then brown as leaves die. Iron deficiencies are found mainly in alkaline soils, although some acidic, sandy soils, low in organic matter, may also be iron-deficient. Cool, wet weather enhances iron deficiencies, especially in soils with marginal levels of available iron. Poorly aerated or compacted soils also reduce iron uptake. High levels of available phosphorus, manganese and zinc in soils can also reduce iron uptake. 95

#### Symptoms of deficiency

#### What to look for in the paddock

Pale plants, particularly in waterlogged or limed areas (Photo 17). 96

#### What to look for in the plant

- The youngest growth is affected first and most severely.
- Symptoms begin with young leaves turning pale green or yellow.
- Interveinal areas become yellow and in severely deficient plants interveinal areas turns almost white (Photo 18).
- New growth remains yellow for some time before leaves start to die.
- Old leaves remain pale green and apparently healthy.
- Severely affected plants are stunted, with thin spindly stems.



N Wilhelm, S Davey (2016) Detecting and managing trace element deficiencies in crops. GRDC Update Paper. GRDC, https://grdc.com.  $\underline{au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops au/Research-and-Development/GRDC-Update-Papers/2016/02/Detecting-and-managing-trace-element-deficiencies-in-crops au/Research-and-Development-deficiencies-in-crops au/Resea$ 

<sup>95</sup> RHJ Schlegel (2013) Rve: Genetics, Breeding, and Cultivation, CRC Press.

DAFWA (2015) Diagnosing zinc deficiency in cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-iron-deficiency-cereals





TABLE OF CONTENTS





**Photo 17:** Pale green to yellow plants may be an indication of iron deficiency. Source: DAFWA

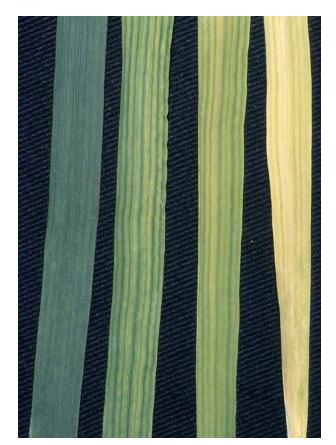
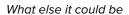


Photo 18: Pale yellow, iron-deficient leaves, most showing prominent green veins (the three on the right) compared with dark green healthy leaf (left).









Before assuming iron deficiency, eliminate other possible causes of symptoms (Table 12).

Table 14: Other possible problems of triticale that could be confused for iron deficiency.

SOUTHERN JANUARY 2018

Condition	Similarities	Differences
Sulfur deficiency	Pale plants with pale new growth	Sulfur-deficient plants do not have interveinal chlorosis
Group B herbicide	Pale seedlings with interveinal chlorosis on new leaves	Herbicide-damaged plants generally recover, and are not restricted to waterlogged areas
Waterlogging, or nitrogen, molybdenum and manganese deficiency	Pale growth	Middle or older leaves are affected first

Source: DAFWA

# Managing iron deficiency

- No yield responses to iron to justify soil application.
- Where symptoms occur, particularly in cold and wet conditions, they are frequently eliminated as soil and air temperatures rise.
- Foliar sprays will remove the symptoms where they occur in highly calcareous or limed soils. 97

#### 5.10 Nutritional deficiencies

Many soils in the cropping zone of southern Australia are deficient in macronutrients and micronutrients in their native condition. To help identify nutritional deficiencies, see the GRDC's Winter Cereal Nutrition: the Ute Guide.

# 5.10.1 Making use of the crop-nutrition information available to you

As part of the GRDC's More Profit from Crop Nutrition (MPCN) extension and training project for the southern region, The Birchip Cropping Group (BCG), in conjunction with other grower groups, has been hosting nutrition events across the southern region since 2012. The most important nutritional areas are being investigated through the MPCN initiative; however, there are a few immediate resources available to advisers to help with understanding nutrition and giving such advice.

#### Useful resources

- More Profit from Crop Nutrition (MPCN)—extension and training for the southern region.
- The Extension Hub on crop nutrition—connects the lab and the paddock, and provides updates on the latest research, and articles focussing on strategic management of crop nutrition in the current season.
- Better Fertiliser Decisions for Cropping (BFDC)—provides the fertiliser industry, agency staff and agribusiness advisors with knowledge and resources to improve nutrient recommendations for optimising crop production.
- The page Making Better Fertiliser Decisions for Cropping Systems in Australia on BFDC provides the fertiliser industry, agency staff and agribusiness advisers with knowledge and resources to improve nutrient recommendations for optimising crop production.



DAFWA (2015) Diagnosing iron deficiency in wheat. DAFWA, https://www.agric.wa.qov.au/mycrop/diagnosing-iron-deficiency-cereals





FEEDBACK



# **MORE INFORMATION**

MPCN extension and training project

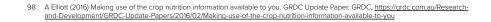
Better fertiliser decisions

Detecting and managing trace element deficiencies in crops

Nutrition technical workshops are being held by <u>AgCommunicators</u> as part of the GRDC's technical workshop projects. Multiple MPCN projects are presented at these workshops.

**SOUTHERN** 

Birchip Cropping Group—organises events and workshops, which are advertised on BCG's website, and often promoted in the area where an event will be held. This group expands the worth of its project by contributing data and results to crop-nutrition publications and to various other cropping publications in the region. 98











# Key messages

- Weed control in triticale is similar to that for wheat.
- There are mixed reviews on triticale's ability to compete with weeds. Triticale can be a poor competitor against weeds due to reduced tillering capacity.

SOUTHERN

JANUARY 2018

- In most cases, the herbicides that work on wheat and rye will work on triticale, however growers must check product labels for registration for use on triticale.
- Integrated weed management practices for becoming more common in Australian cropping systems, and show promising results that should also be employed with triticale.
- Good soil fertility along with vigorous germination and fast emergence may be one of the most efficient ways to reduce weeds through competition.

Weeds are estimated to cost Australian agriculture A\$2.5–4.5 billion per annum. For winter cropping systems alone the cost is \$1.3 billion, with annual rye grass being one of the biggest problems (Photo 1). ¹ Consequently, any practice that can sustainably reduce the weed burden is likely to generate substantial economic benefits to growers and the grains industry.



**Photo 1:** Annual ryegrass is one of the most problematic weeds in Australia and around the world (left). Here (right) it is heavily infesting a cereal paddock.

Source: Southwest Farm Press

In most cases, the herbicides that work on wheat and rye will work on triticale, however growers must check product labels for registration for use on triticale. Some studies indicate that triticale may be less tolerant of some herbicide cocktails than wheat. Newer herbicides as well as pesticides are now being released with recommendations for use on triticale. <sup>2</sup>

# 6.1 Weed competitiveness of triticale

Good soil fertility along with vigorous germination and fast emergence may be one of the most efficient ways to reduce weeds through competition. A vigorously growing crop is usually weed-free, and this is as true of triticale as it is of other grains.

The actual competitiveness of different cereals depends on growing conditions, management practices, weed load and relative growth stage of the weed and crop.



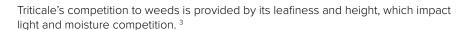
<sup>1</sup> R Smith (2014) Two-step program controls resistant ryegrass in wheat. 24 February. Southwest Farm Press, <a href="http://www.southwestfarmpress.com/wheat/two-step-program-controls-resistant-ryegrass-wheat">http://www.southwestfarmpress.com/wheat/two-step-program-controls-resistant-ryegrass-wheat</a>

<sup>2</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/05553e00.pdf">http://www.fao.org/3/a-y5553e/05553e00.pdf</a>



**TABLE OF CONTENTS** 





SOUTHERN

Triticale may have some allelopathic effect which can inhibit the germination and growth of weeds but this effect is not as high as one of its parent crops, cereal rye. 4

The grass weed annual ryegrass (*Lolium rigidum*) is one of the worst weeds of triticale (as well as other grains). Based on research in southern NSW the most competitive crops in the face of annual ryegrass (at 300 plants/m–2 are, in descending order, oats, cereal rye, triticale, oilseed rape, barley, wheat, field peas, and lupins. <sup>5</sup>

Suppression of annual ryegrass by wheat, triticale and rye was compared in field trials at Wagga Wagga in 1993. Triticale and cereal rye appeared to be more competitive than wheat: the biomass of mature ryegrass was 70 g/m² in triticale, compared to 170 g/m² in wheat. Triticale has large seeds which lead to rapid early growth and the capacity to suppress weeds because of a vigorous growth habit. Early seedling vigour, superior height and broad leaves appeared to influence the greater competitive ability of the triticale and cereal rye in this study. <sup>6</sup>

A general rule of thumb in cereals is that taller, leafier varieties are more competitive due to the ability to close the canopy quickly. Being somewhat weed competitive, triticale is sometimes used in a 'green' approach in crop rotations to reduce weed seedbanks. When seeded early and under good conditions, triticale will compete with many weed species. Although it is not as effective as rye, triticale can be very competitive with wild oats. <sup>7</sup>

To minimise weeds, prepare the seedbed so it is as clean as possible before planting, and be sure to practice crop rotation. Planting early will help with the quick establishment of a triticale stand and may stave off early weed pressure. Triticale can also be inter-seeded with another crop (including forage grasses or legumes) to aid in weed competition and nutrient management. <sup>8</sup>

## **6.1.1** Best management practices for weed control in triticale

Best management practices for weed control in triticale are similar to those for wheat. These include:

- Seed at higher rates and ensure proper crop nutrition, which can help control
  weeds in triticale.
- Plan ahead. Chemical weed control options in triticale are limited, making it more important to select relatively clean paddocks in which to seed triticale.
- In the case of perennial weed problems, apply pre-harvest glyphosate or use as a pre-seeding burn off when direct seeding. Use in-crop herbicides to control or suppress broadleaf weeds.
- Use certified or well-cleaned and graded seed as this ensures that only triticale, and not weeds, is seeded.
- Seed early within the recommended sowing window, as earlier sown triticale
  usually results in more competitive stand establishment, and provides a jumpstart on the woods
- Seed shallow at between 13–38 mm (optimum 25 mm). Shallow seeding generally results in uniform seedling emergence with plants quickly covering



<sup>3</sup> S Clarke, S Roques, R Weightman, D Kindred (2016) Understanding triticale. AHDB, <a href="https://cereals.ahdb.org.uk/media/897536/pr556-understanding-triticale.pdf">https://cereals.ahdb.org.uk/media/897536/pr556-understanding-triticale.pdf</a>

<sup>4</sup> Albert Lea Seed (2010) Triticale, <a href="http://www.alseed.com/UserFiles/Documents/Product%20Info%20Sheets-PDF/Basics%20Triticale-2010.pdf">http://www.alseed.com/UserFiles/Documents/Product%20Info%20Sheets-PDF/Basics%20Triticale-2010.pdf</a>

<sup>5</sup> D Lemerle, B Verbeek, N Coombes (1995) Losses in grain yield of winter crops from Lollium rigidum competition depend on crop species, cultivar and season. Weed Research, 35 (6), 503–509.

<sup>6</sup> D Lemerle, K Cooper (1996) Comparative weed suppression by triticale, cereal rye and wheat. In Triticale: Today and Tomorrow. Springer Netherlands, pp. 749–750.

Alberta Agriculture and Forestry (2016) Triticale Crop Protection. Alberta Agriculture and Forestry, <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10572">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10572</a>

<sup>8</sup> UVM Extension Crops and Soils Team (2011) Triticale. University of Vermont, <a href="http://northerngraingrowers.org/wp-content/uploads/TRITICALE.pdf">http://northerngraingrowers.org/wp-content/uploads/TRITICALE.pdf</a>

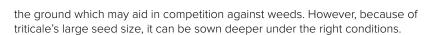








GRDC, <u>Integrated weed management</u> manual



SOUTHERN

 Use sanitary practices: clean machinery and seeding equipment before planting.<sup>9</sup>

## 6.2 Integrated weed management

The Grains Research and Development Corporation (GRDC) supports the practice of integrated weed management (IWM). This is a system for managing weeds over the long term, and particularly incudes the management of weeds so as to minimise the development of herbicide resistance. There is a need to combine herbicide and nonherbicide methods into an integrated control program. Given that there are additional costs associated with implementing IWM, the main issues for growers are whether it is cost-effective to adopt the system and whether the benefits are likely to be long term or short term in nature.

The GRDC manual, Integrated Weed Management in Australian Cropping Systems, looks at these issues and breaks them down into seven clear sections, to assist the reader to make the development of an IWM plan a simple process.

#### **6.2.1 IWM for triticale**

Although triticale has been shown to be more competitive against annual ryegrass than wheat, a sound weed-control program must still be implemented to avoid a blow-out in weed seed numbers and to optimise yields.

It is vital to control weeds early in the crop's growth to give the crop a chance to get ahead. Once the crop has grown it then becomes more competitive.

When sowing dual-purpose varieties early, choose a paddock with low weed numbers and control weeds prior to the first grazing. Strategic grazing can be used to help manage weeds. When planning to graze the crop, always check grazing withholding periods before you apply post-emergent herbicides. <sup>10</sup>

## **IN FOCUS**

## The effect of cultivation and row spacing on the competitiveness of triticale

Research in 2007 explored the effect of cultivation and row spacing on the competitiveness of triticale against weeds. The aim of this work was to identify agronomic practices that enable triticale to express its full genetic potential for competitive growth against the vigorous weedy competitor annual ryegrass (*Lolium rigidum*). Researchers assessed the effects on triticale of cultivation (disc ploughing), or lack thereof (zero tillage) before sowing, and row spacing (15 cm, 30 cm and 45 cm).

Most of the experiments evaluating the effect of row spacing and level of cultivation on cereals have been performed on wheat, so there is little data specifically on triticale. The researchers hoped to identify the optimal row spacing and level of cultivation that enhance the competitive ability of triticale, to help farmers secure more sustainable yields by increasing including triticale in their cropping rotations. They hoped the results would help farmers reduce the cost of weed control, reduce weed-induced losses of yield, and see greater fertiliser uptake and utilisation by the crop at the expense of weeds.



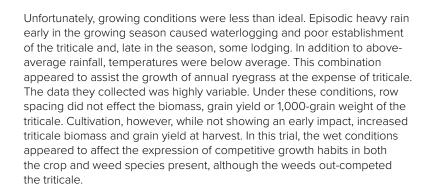
<sup>9</sup> Alberta Agriculture and Forestry (2016) Triticale Crop Protection. Alberta Agriculture and Forestry, <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10572">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10572</a>

Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/IA-102">http://www.porkcrc.com.au/IA-102</a> Triticale Guide Final Fact Sheets.pdf



**TABLE OF CONTENTS** 





SOUTHERN
JANUARY 2018

All was not lost. Several findings validated the value of the agro-ecological principles on which integrated weed management is based. They included:

- Weeds that emerge prior to or at the same time as the crop impose
  the greatest weed—crop interference, particularly in those weed
  species (e.g. L. rigidum) that share similar morphology and phenology
  to cereal crops.
- Strong selection pressure from a given agronomic practice will cause a shift in the composition of the weed flora and may contribute to the development of single species becoming a problem, e.g. *Fallopia convolvulus* under high crop densities.
- Early suppression of weeds, in terms of preventing germination or limiting biomass accumulation, is the most important aspect of crop competitive ability, as even the most tolerant crops will have lower yields if early weed—crop competition results in reduced crop tillering during early crop growth.
- The expression of competitive growth in cereal crops with strong genetic potential for competitive ability (e.g. triticale) is highly influenced by optimal plant densities and competition between individual plants in the crop. <sup>11</sup>

## 6.2.2 General IWM principles and tactics

There are very effective strategic and tactical options available to manage weed competition that will increase crop yields and profitability. Weeds with herbicide resistance are an increasing problem in grain-cropping enterprises. The industry and researchers advise that growers adopt integrated weed management to reduce the damage caused by herbicide-resistant weeds.

An <u>integrated weed management plan</u> should be developed for each paddock or management zone.

The following five-point plan will assist in developing a management plan in each paddock:

- Review past actions and history.
- 2. Assess current weed status.
- 3. Identify weed management opportunities.
- 4. Match opportunities and weeds with suitably effective management tactics.
- 5. Combine ideas into a management plan, and consider using a rotational plan.

In an IWM plan, each target weed is attacked using tactics from several tactical groups (see links below). Each tactic provides an opportunity for weed control. It is

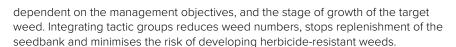


<sup>11</sup> B Sindel (2008) UHS127: The effect of cultivation and row spacing on the competitive ability of triticale against weeds. GRDC, <a href="http://finalreports.grdc.com.au/UHS127">http://finalreports.grdc.com.au/UHS127</a>



**TABLE OF CONTENTS** 





**OUTHERN** 

#### IWM tactics:

- Reduce weed seed numbers in the soil.
- Controlling small weeds.
- Stop weed seed set.
- Reduce weed seed numbers in the soil.
- Hygiene: prevent weed seed introduction.
- Agronomic practices and crop competition.

Successful weed management also relies on the implementation of the best agronomic practices to optimise crop growth. Basic agronomy and fine-tuning the crop system are the important steps in sustainably managing weeds.

There are several agronomic practices that improve crop environment and growth, along with the crop's inherent ability to out-compete weeds. These include crop choice and sequence, improving crop competition, planting herbicide-tolerant crops, improving pasture competition, using fallow phases, and using controlled traffic or tramlining. <sup>12</sup>

#### **Review past actions**

Knowing the historical level of selection pressure can be valuable information to give managers a 'heads up' as to which weed and herbicidal mode of action (MOA) groups are at greatest risk of developing resistance. Such knowledge can prompt more intensive monitoring for escapee weeds when a situation of higher risk exists. Noticing developing resistance while patches are still small and before they spread can make a big difference in the cost of management over time. If a population is suspected resistant, a herbicide resistance test should be conducted to confirm the resistance level and resistance group.

From all available paddock records, calculate or estimate the number of years in which different herbicide MOAs have been used. This is of far greater relevance than the number of applications in total. For most weeds, using a herbicide MOA in two consecutive years presents a far greater selection pressure for resistance than two applications of the same herbicide MOA in the one year. If the entire paddock history is unavailable to you, state what is known and estimate the rest. Collate separate data on MOA use for summer and winter weed spectrums. Further subdivide these into broadleaved and grass weeds.

Account for past double-knock practices. Where survivors of one tactic would have been controlled in large part by the use of another tactic, reduce the number of MOA uses accordingly. An example might be: Trifluralin (Group D) has been used 20 times, but there have been six years when in-crop Group A selectives were used and several more years where in-crop group B products that targeted the same weed as the trifluralin were used. These herbicides effectively double-knocked the trifluralin, thus somewhat reducing the effective selection pressure for resistance to trifluralin.

Review the data you have collected and identify which weed and MOA groups have been selected for at a frequency likely to lead to resistance in the absence of a double-knock. Trifluralin typically takes about 10–15 years of selection for resistance to occur (Table 1). Thus, using the above example, a watching brief would be in place for trifluralin and other Group D MOA herbicides.

Paddock history can also be useful information when evaluating the likely reasons for herbicide spray failures, in prioritising strategies for future use, and in deciding which paddocks receive extra time for scouting for patches of escaped weeds.

Information on the history of MOA use should be added to paddock records.



<sup>12</sup> DAFWA (2016) Crop weeds: Integrated weed management (IWM). DAFWA, <a href="https://www.agric.wa.gov.au/qrains-research-development/crop-weeds-integrated-weed-management-iwm">https://www.agric.wa.gov.au/qrains-research-development/crop-weeds-integrated-weed-management-iwm</a>









SOUTHERN

Herbicide group	Typical years of application	Resistance risk
A (fops, dims, dens)	6–8	High
B (SUs, IMIs)	4	High
C (triazines, subst. ureas)	10–15	Medium
D (trifluralin, Stomp)	10–15	Medium
F (diflufenican)	10	Medium
I (phenoxies)	>15	Medium
L (paraquat, diquat)	>15	Medium
M (glyphosate)	>12	Medium

#### Assess the current weed status

Record the key broadleaved and grass weed species for summer and winter, and include an assessment of weed density, with notes on weed distribution across the paddock. Include GPS locations or some other reference to spatial location of any key weed patches or areas tested for resistance.

Include any data, observations or information relating to the known or suspected herbicide resistance of weeds in this paddock.

Add this information to paddock records.

#### Identify weed management opportunities

Identify what different herbicide and non-herbicide tactics could be cost effectively added to the system and where in the crop sequence these can be added.

#### Fine-tune your list of options

Which are your preferred options to add to your existing weed-management tactics, so that you to add diversity and help drive down the weed seedbank?

#### Combine and test ideas

Computer simulation tools can be useful to run a number of 'what if' scenarios to investigate potential changes in management and the likely effect of weed numbers and crop yield. Two simulation tools being used are the <a href="Weed Seed Wizard">Weed Seed Wizard</a> and <a href="RIM">RIM</a> (Ryegrass Integrated Management).

Combine ideas using a rotational planner, or test them in using decision-support software such as RIM (see below) and/or Weed Seed Wizard.



Section 4: Tactics for managing weed populations











## **MORE INFORMATION**

Weed Seed Wizard

Weed Control Handbook for Declared Plants in South Australia

<u>Declared plants of South Australia:</u> Are they on your land?

SA weed risk management guide

#### Weed Seed Wizard

The Weed Seed Wizard helps growers understand and manage weed seedbanks on farms in Australia's grain growing regions.

It is a computer simulation tool that uses paddock-management information to predict weed emergence and crop losses. Different weed management scenarios can be compared to show how different crop rotations, weed control techniques, irrigation, grazing and harvest management tactics can affect weed numbers, the weed seedbank and crop yields.

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JANUARY 2018

The 'wizard' uses farm-specific information: users enter their own farm management records, their paddock soil type, local weather and one or more weed species. The wizard has numerous weed species to choose from, including annual ryegrass, barley grass, wild radish, wild oats, brome grass and silver grass in the southern states.

#### South Australian Weed Control App - SA Weed control

Biosecurity SA, in partnership with the eight natural resource management regions in South Australia, has developed a free weed-control app that provides essential information about the control of weeds declared in South Australia under the *Natural Resources Management Act 2004*. The app provides information from the Weed Control Handbook for Declared Plants in South Australia. The app includes:

- control recommendations for over 132 declared plants
- chemical and non-chemical treatments
- information on the safe use of herbicides
- colour photographs of each species for identification

In addition app users can:

- · record the location of weeds
- keep a personal log of control activities
- phone or email regional natural resource officers
- send photos and text of high-risk weeds

It is intended that the app will be updated annually as chemical uses and plant declarations change. Download the app from <u>Google Play (for Android devices)</u> or the iTunes App Store.

## 6.2.3 IWM in the southern region

Grain growers in Victoria, South Australia and Tasmania have the ability to beat costly weeds by driving down the weed seedbank through an aggressive 'stacked' approach.

By combining five essential measures and repeating the exercise year after year, growers can run down seedbanks even when there are high levels of herbicide resistance on their farms. Weed seedbanks can be eroded to near-zero levels by committing to a simple strategy, the five components of which are:

- 1. employing a double-knock of herbicides;
- 2. mixing and rotating chemicals;
- 3. planting competitive crops;
- 4. stopping seedset; and
- 5. harvest weed-seed control through crop topping or desiccation.





**TABLE OF CONTENTS** 



When you stack all these components together, you can drive down the weed seedbank.

Double-knock is not so much about the seedbank but preserving the usefulness of herbicides and glyphosate. If you double-knock every year glyphosate resistance shouldn't be an issue, but it's not a double-knock if you already have glyphosate resistance. If you have lot of glyphosate resistance and you start double-knocking, you are basically applying a single knock of paraquat, in which case paraquat resistance will develop. The best time to start using double-knock is before you have glyphosate resistance.

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JANUARY 2018

It's also important to mix herbicide use. By mixing two herbicides together at full rates, if a weed is resistant to one product the other will kill it before it sets seed. It is almost impossible for a weed to have two resistance mechanisms operating in the face of a mixed herbicide selection.

Crop competition involves four factors: seeding rate, row spacing, orientation and cultivars. Growers need to be employing at least one of these, and preferably two, to encourage crop competitiveness.

Another component is harvest weed-seed control (HWSC), which has been a focus of the research and development efforts of the Australian Herbicide Resistance Initiative (AHRI). In mixed-farming systems with sheep, using a chaff cart for HWSC is recommended. For continuous croppers in high-production areas, the Harrington Seed Destructor is recommended. Putting chaff on tramlines is cheap and there is nothing to do after harvest. Chaff lining, leaving chaff in the windrow to rot, is another option. Windrow burning is a popular option, with more people doing this than any other HWSC activity, but it does have its problems. With the other HWSC tools growers can do them in every crop every year, but that's not always the case with windrow burning.

Another tool is baling directly which involves towing a baler behind the harvester. This is a good option where a large market for straw bales exists close to the farm.

Competitive crops improve HWSC. Competitive crops hold ryegrass and other weeds up so that growers can catch them in the header. HWSC works better on low-density ryegrass.

A lot of weeds are becoming more dormant: they are adapting to germinate later to avoid knock-down and pre-emergent herbicides. Ryegrass, barley and brome grasses are among these. This can be turned to the grower's advantage because they can sow a competitive crop early and it will compete well against the weeds.

When all components of weed-seed management are stacked together and growers commit to the regime for at least six years, the outcome can be dramatic.  $^{13}$ 

#### 6.3 Key weeds of Australia's cropping systems

Section 8 of GRDC's *Profiles of common weeds* of cropping contains profiles of the common weeds of Australian crops: <sup>14</sup>

- annual ryegrass (Lolium rigidum)
- barley grass (Hordeum spp.)
- barnyard grasses (Echinochloa spp.)
- black bindweed (Fallopia convolvulus)
- bladder ketmia (Hibiscus trionum)
- brome grass (Bromus spp.)
- capeweed (Arctotheca calendula)
- doublegee (Emex australis)



S Watt (2016) Odds of beating weeds stacked in favour of grain growers. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2016/03/Odds-of-beating-weeds-stacked-in-favour-of-grain-growers">https://grdc.com.au/Media-Centre/Media-News/South/2016/03/Odds-of-beating-weeds-stacked-in-favour-of-grain-growers</a>

<sup>44</sup> GRDC (2014) Section 8. Profiles of common weeds of cropping. GRDC, <a href="https://grdc.com.au/Resources/IWMhub/Section-8-Profiles-of-common-weeds-of-cropping">https://grdc.com.au/Resources/IWMhub/Section-8-Profiles-of-common-weeds-of-cropping</a>



**TABLE OF CONTENTS** 





- fleabane (Conyza spp.)
- fumitory (Fumaria spp.)
- Indian hedge mustard (Sysimbrium orientale)
- liverseed grass (Urochloa panicoides)
- muskweed (Myagrum perfoliatum)
- paradoxa grass (*Phalaris paradoxa*)
- silver grass (Vulpia spp.)
- sweet summer grass (Brachiaria ericuformis)
- turnip weed (Rapistrum rugosum)
- wild oats (Avena fatua and Avena Iudoviciana)
- wild radish (Raphanus raphanistrum)
- windmill grass (Chloris truncata)
- wireweed (Polygonum aviculare and Polygonum arenastrum)

## IN FOCUS

#### **RIM (Ryegrass Integrated Management)**

RIM (Ryegrass Integrated Management) is software that provides insights into the long-term management of annual ryegrass in dryland broadacre crops where herbicide resistance is developing. RIM enables users to test different tactics for ryegrass management and observe their predicted impacts on ryegrass populations, crop yields and long-term economic outcomes. It can be used at paddock scale, and over short and long time scales. The underlying model of the software integrates biological, agronomic and economic considerations in a dynamic and user-friendly framework.

The tool tracks the changes through time on a 10-year crop cycle for ryegrass seed germination, seed production and competition with the crop. Financial returns are also estimated annually and as a 10-year average return.

A wide variety of chemical and non-chemical weed treatment options are included, so that as chemicals are lost to herbicide resistance, the next-best substitute can be identified.

To do this by trial and error in the real world, rather than in a computer simulation, would take many years and may leave farmers with a major weed problem they could have avoided. With RIM, farmers and others can conduct virtual experiments with a range of treatment options before they put real dollars at risk.

RIM can help farmers to tackle questions such as:

- How much income will I lose once resistance develops?
- Which combination of strategies provides the best overall system once resistance is present?
- Is it worth trying to delay the onset of resistance by using herbicides less frequently?
- Is it economically viable to maintain a continuous cropping rotation once resistance occurs?
- If a pasture phase is included, how long should it be?



**Ryegrass Integrated Management** 



WATCH: <u>Managing herbicide resistant</u> ryegrass with IWM





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#### 6.3.1 Ryegrass management in the southern region

Herbicide resistance is increasing, with higher levels of chemical tolerance recorded in south-east South Australia. In 2013, a study found that 16% of paddocks in the south-east contained glyphosate-resistant ryegrass (Photo 2).



Photo 2: Glyphosate-resistant ryegrass in crop paddock.

Source: Weekly Times

Although herbicide resistance is widespread across Australia, in a three-year trial by the University of Adelaide at Roseworthy, in SA's mid-north, researchers found that the strategic use of oaten hay was the best tool for rapidly reducing the seedbank of annual ryegrass. However, having done this, another year of seedset control is needed to keep weed populations low.

In this four-year trial for improving weed management, researchers used three different weed-management for ryegrass control . Cutting oaten hay in the first year reduced the seedbank of ryegrass by 86%, from 4,819 seeds/m² to 692 seeds/m². Field peas were sown in the following year and three spray options used across three sections.

- When trifluralin was used alone, seedbank levels increased from 692 seeds/m<sup>2</sup> to 8,319 seeds/m<sup>2</sup>.
- 2. When Select® was applied after trifluralin, the ryegrass seedbank slightly increased, from 692 seeds/m² to 806 seeds/m².
- When Select® was applied and the field peas crop-topped with Roundup® glyphosate, the seedbank declined to fewer than 500 seeds/m².

These results show that a second year of seedset control in managing annual ryegrass is important. Growers need to be cautious in using chemicals, as resistance to Select® is increasing in SA. This is a major concern as Select® is important for providing effective control of ryegrass. Crop-topping after Select® application, even if there are only a few weeds left in the paddock, decreased the risk of resistance emerging. Where two years of seedset control had been used, the annual ryegrass seedbank in the following crop continued to decline, even where Boxer Gold® was the only herbicide used. <sup>15</sup>

Another, long-term trial that began in 2012 at Southern Farming System's Lake Bolac site, in Victoria's high-rainfall zone (HRZ) has shown that adapting some farming practices can make a difference in the fight against weeds. The HRZ has a history of herbicide-resistant ryegrass. Researchers assessed the effectiveness and applicability of cultural control practices before seeding, in combination with preemergent herbicides, on management of herbicide-resistant annual ryegrass in the

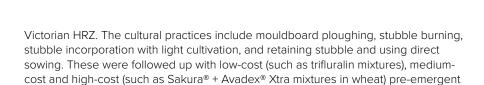


D Lush (2013) Consistent weed control needed to combat ryegrass. Ground Cover. No. 106. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-106-Sept-Oct-2013/Consistent-seed-control-needed-to-combat-ryegrass">https://grdc.com.au/Media-Centre/Ground-Cover-Issue-106-Sept-Oct-2013/Consistent-seed-control-needed-to-combat-ryegrass</a>



**TABLE OF CONTENTS** 





SOUTHERN

The following lessons have been gleaned from the work.

#### Mouldboard ploughing

herbicide treatments.

Although expensive, early results from mouldboard ploughing were promising despite some wild radish germinating in the area ploughed. In a long-season scenario where there is plenty of rain, any ryegrass that germinates late (after treatments have been applied) will produce a lot of seed. In the HRZ that is a problem. If growers are not stopping the seedset of ryegrass it will rebuild the seedbank quickly.

#### Pre-emergent herbicides

The biggest lesson learned from using pre-emergent herbicides was not to incorporate stubble. Farmers with too much stubble are advised to burn it instead. Incorporating stubble moves the ryegrass away from the range of herbicides, limiting their effectiveness.

Farmers with ryegrass that is resistant to post-emergent herbicides cannot manage outbreaks by growing wheat and barley. Even with our best treatments, numbers of resistant plants are still going up.

Unsurprisingly, the cheapest pre-emergent herbicide strategies were the least effective. The mid-cost strategy is better, but the expensive strategy is the best. Growers in the HRZ have few options but to use expensive herbicides it they want to control resistant ryegrass. This is because it is the costly ones, particularly the Sakura® + Avadex® Xtra mix, that provide the length of persistence needed.

#### Narrow windrow burning

When attempting to burn windrows of barley in the trials, the burn got too fast and didn't burn the windrows all the way down to the ground, which meant that streaks of ryegrass were left across the site. The lesson is to gain windrow-burning skills using a crop such as canola, that is easy to control, before moving on to barley, which is probably the hardest crop to do it in. <sup>16</sup>

# **6.3.2** Brome grass and barley grass in the southern region

Control of brome grass is becoming increasingly difficult throughout south-eastern Australia's cropping zone due to high herbicide resistance, increasing seed dormancy, and the spread of the weed from its traditional low-rainfall area to new regions (Photo 3).  $^{7}$ 

The increasing incidence of brome and barley grass in cropping paddocks in southern Australia is likely to be associated with selection of more dormant biotypes as a response to growers' weed-management practices.

At present brome-grass management in cereals is heavily reliant on Group B herbicides, especially the ClearfieldTM technology. Delaying onset of resistance to these herbicides would require the identification of effective alternative herbicides.



<sup>16</sup> A Lawson (2015) HRZ trial yields lessons in resistant ryegrass management. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2015/01/HRZ-trial-yields-lessons-in-resistant-ryegrass-management">https://grdc.com.au/Media-Centre/Media-News/South/2015/01/HRZ-trial-yields-lessons-in-resistant-ryegrass-management</a>

<sup>17</sup> R Barr (2014) Long-term strategy needed for brome grass control. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2014/10/Long-term-strategy-needed-for-brome-grass-control">https://grdc.com.au/Media-Centre/Media-News/South/2014/10/Long-term-strategy-needed-for-brome-grass-control</a>

TABLE OF CONTENTS

FEEDBACK



**Photo 3:** Brome grass growing in a cereal crop at a University of Adelaide trial in Balaklava.

Source: GRDC

Barley grasses (Hordeum spp.) are annual species renowned for rapidly germinating in autumn to provide valuable stockfeed soon after breaking rain (Photo 4). <sup>18</sup> This speedy establishment has traditionally been seen as a useful clue for early identification, but changes in seedbank dormancy now mean an increasing proportion of the seedbank is germinating later in the season.



Photo 4: Emerging flower-head of barley-grass.

Photo: AJ Brown



Barley-grass. Victorian Resources Online. Department of Economic Development, Jobs, Transport and Resources, <a href="http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/sip\_barley\_grass">http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/sip\_barley\_grass</a>



**TABLE OF CONTENTS** 



Barley grass is a problem for a number of reasons:

- They act as an alternate host for a number of cereal diseases.
- Seeds cause stock health problems where seed gets stuck in wool or eyes.

SOUTHERN

- Post-emergent herbicide control is limited in cereals.
- Barley grasses generally mature earlier than the crop and seeds are readily dispersed.
- Populations of barley grasses can develop resistance to herbicides.

#### Managing brome grass and barley grass

Field trials undertaken over four years have investigated various pre-emergence herbicides for brome-grass control in wheat. Even though Sakura® (pyroxasulfone) appears to be the most active pre-emergent herbicide against brome grass, it lacks the consistency required for long-term population management of brome grass.

Surveys by the University of Adelaide in a previous GRDC-funded project showed high levels of resistance to Group B herbicides, with 40–50% resistance to Atlantis® and CrusaderTM in the South Australian Mallee, and 40% resistance to Atlantis® in Victoria.

Field trials confirmed consistently high efficacy of Sakura® against barley grass, especially under situations with good soil moisture.

Barley-grass management is now being complicated by the evolution of Group A resistance in this weed species. However, there appear to be several effective alternatives (e.g. Sakura® and Raptor®) that could be used for barley-grass control in broadleaf crops. <sup>20</sup>

Pre-emergent control options are no more promising because most common options are ineffective. The most common practice in wheat is use of trifluralin, but GRDC trials showed trifluralin may only provide about 50% control in wheat. The combination of Sakura® and Avadex® has been shown to be more effective, but the high cost means it is often uneconomical.

With herbicide control providing no easy solutions, an integrated weed management strategy is needed to control the problem weed.

Where there are severe brome-grass patches in cereals, in the range of >50 plants per square metre, it is recommended that growers patch out the area with a knockdown herbicide such as glyphosate before it can set seed. Where the soil type permits, narrow-windrow burning can be a good control method, or else the use of chaff carts can help reduce the seedbank. Note though that windrow burning for Brome grass is problematic as it tends to drop seeds before the header goes through.

However, the most effective control will be to use rotations. For a severe infestation, use a pulse or break crop with a grass-selective herbicide and crop-topping, followed by a ClearfieldTM variety using IMI chemistry. If there are still some weeds after two years, go with a crop of barley with pre-emergent trifluralin and metribuzin for a third-step control. High brome grass populations will require at least three years of very good grass control.

Full results from the trials are expected 2017. 21



Brome and barley grass management in southern cropping systems

<u>Long-term strategy needed for brome</u> <u>grass control</u>



<sup>19</sup> GRDC. Barley grass. In Integrated Weed Management Hub. Section 8. Profiles of common weeds of cropping. GRDC, <a href="https://grdc.com.ai/Resqurces/IWMhub/Section-8-Profiles-of-common-weeds-of-cropping/Barley-grass">https://grdc.com.ai/Resqurces/IWMhub/Section-8-Profiles-of-common-weeds-of-cropping/Barley-grass</a>

<sup>20</sup> G Gill, L Shergill, B Fleet, P Boutsalis, C Preston (2013) Brome and barley grass management in cropping systems of southern Australia. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Brome-and-barley-grass-management-in-cropping-systems-of-southern-Australia">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Brome-and-barley-grass-management-in-cropping-systems-of-southern-Australia</a>

<sup>21</sup> R Barr (2014) Long-term strategy needed for brome grass control. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2014/10/Long-term-strategy-needed-for-brome-grass-control">https://grdc.com.au/Media-Centre/Media-News/South/2014/10/Long-term-strategy-needed-for-brome-grass-control</a>

**TABLE OF CONTENTS** 





Flaxleaf fleabane (Photo 5) is a major weed in dryland crops in southern Queensland and northern New South Wales, and is emerging as a problem across the entire cereal-cropping belt of southern Australia.  $^{22}$ 

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Photo 5: Flaxleaf fleabane.

Source: GRDC

Previously, fleabane was found mainly on roadsides, particularly where council use of glyphosate created bare ground on which the weed could flourish without competition. However, the weed is highly mobile and soon found its way into adjacent cropping systems. With the move to minimum tillage and the increasing use of glyphosate, the scene was set for an expansion of this troublesome weed. Wet summers in southern grain regions over recent years have aided the weed's spread.

Costs of fallow weed control have increased markedly because of fleabane, with some zero-till growers having to reintroduce cultivation as a control tactic. Disturbingly, populations of fleabane have recently been confirmed as resistant to eight times the normal rate of glyphosate, earning it the title of Australia's first glyphosate-resistant broadleaf weed.

#### Control strategy

While fleabane presents a serious and costly weed challenge, GRDC-funded research has shown that a strategic approach using IWM can significantly reduce the weed's impact on crop production. The key to getting on top of fleabane is to attack all parts of the weed's life cycle to keep the seedbank low. Adopting an IWM strategy will result in substantially fewer fleabane problems and fewer resistant populations in subsequent seasons.

Fleabane has the capacity to produce 110,000 seeds per plant and two or three generations each year, so it is easy to understanding that it is critical to control it before it sets seed.

In southern and western Australia, fleabane often germinates under crops during spring or at harvest. Following harvest, a lack of crop competition combined with summer rain can cause rapid growth. By the time there is a window for control, the



Managing flaxleaf fleabane

Flaxleaf fleabane a weed best management guide



WATCH: GCTV4: Flaxleaf fleabane



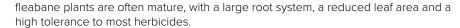
<sup>22</sup> GRDC (2012) Multi-pronged attack needed in fight against fleabane weed. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/Misc/2012/05/Multipronged-attack-needed-in-fight-against-fleabane-weed">https://grdc.com.au/Media-Centre/Media-News/Misc/2012/05/Multipronged-attack-needed-in-fight-against-fleabane-weed</a>











SOUTHERN

Research across Australia indicates that hitting the weed with herbicide while it is young and actively growing is the best approach. Delaying herbicide application until the weed is mature and water-stressed can result in poor control.

The double-knock approach, using glyphosate followed by paraquat 7-10 days later, has proved to be a valuable component of a fleabane IWM program. This, coupled with the use of competitive crops and pastures and strategic cultivations to bury 'blowouts' of seed production, can reduce the weed's seedbank to manageable levels within a few seasons. A complete IWM approach to controlling fleabane includes targeting fence lines and roadsides. <sup>23</sup>

## 6.3.4 Feathertop Rhodes grass heads south

A shift to minimum tillage and increasing glyphosate use across southern Queensland and northern New South Wales has created the perfect environment for feathertop Rhodes grass (FTR) to flourish (Photo 6). Already a problem weed in central Queensland for many years, where it is mostly a roadside weed, FTR has only recently become an issue further south. GRDC-funded research has shown that no single management strategy will effectively control FTR. A variety of tactics across rotations is required to keep on top of this troublesome weed.



Photo 6: Feathertop Rhodes grass.

Source: GRDC

As with all problem weeds, the aim is to deplete the seedbank, control seedlings and small plants, stop seedset, and prevent new seeds entering from outside the area. <sup>24</sup>

#### Fallow control

Annual grasses such as FTR can rapidly develop resistance to the 'fop' chemistry of Group A herbicides. To reduce the rate at which this occurs in FTR, the Australian Pesticides and Veterinary Medicines Authority (APVMA) issued permit PER12941 to limit the use of Verdict® 520 to one application per season in fallow, and this must be followed by a double-knock application of a paraquat product at 250 g/L at a rate of at least 1.6 L/ha.

Researchers have found that once FTR is past early tillering, a Group M (glycine) herbicide used alone becomes ineffective, but if a Group L bipyridyl herbicide (paraquat) is applied sequentially, FTR control approaches 100%. This double-knock

- 23 M Widderick (2013) Fleabane now a national challenge. In Emerging Issues with Diseases, Weeds and Pests: Ground Cover Supplement. January–February 2013. Ground Cover. No. 102. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/6CS102">https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/6CS102</a>
- 24 GRDC (2011) UQ00062: Improving IWM practice in the northern region. GRDC, <a href="http://projects.grdc.com.au/projects.php?action=view\_projects.php.action=view\_projects.php.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_projects.php.action=view\_



Managing Feathertop Rhodes grass.

Feathertop Rhodes grass integrated weed management manual



WATCH: <u>GCTV19</u>: <u>Feathertop Rhodes</u> <u>Grass</u>: <u>Important weed management</u> <u>recommendations</u>



WATCH: <u>Ecology and management of</u> feathertop Rhodes grass







**TABLE OF CONTENTS** 





WATCH: GCTV14: Early control wild radish



WATCH: GCTV Extension files: Wild Radish—1st spray



WATCH: GCTV Extension files: Wild radish—2nd spray



tactic has proved to be the most consistent and effective approach across a range of growth stages and plant-stress conditions. The same research shows that adding residual herbicides (particularly Group B) to the second knock enhances the effect of the Group L herbicide. The interval between knocks is important to overall efficacy. For many weeds, the interval required is short (three to four days), but FTR research by the GRDC-supported Northern Grower Alliance found that a minimum of seven days is necessary when using a Group M herbicide as the first knock. This is probably due to an antagonism that occurs inside the plant and is specific to FTR.

SOUTHERN

JANUARY 2018

The double-knock tactic works best when applied to small, actively growing weeds, and rates for both knocks are robust. Applying the second knock as a spot spray, or using optical weed-detection technology (if available), can cut herbicide costs. Spot tilling is also an option and, in some instances, the second knock can be a spot-tillage operation instead of herbicide.

#### In-crop control

In-crop control of FTR will be limited by the herbicides that can be safely used within the crop. For post-emergence control, shielded sprayers might be required; control will be with Group L and M herbicides in most crops, and Group A herbicides in some grass and cereal crops. Research has shown that several of the grass-selective Group A herbicides control FTR well; however, butroxydim and clethodim are the only Group A herbicides registered for in-crop FTR control.

Researchers are examining other Group A herbicides, which may perform better. Grass-selective knockdown herbicides are widely used in broadleaf crops such as mungbeans, chickpeas, cotton and sunflowers. Growing these crops in the rotation will help manage FTR. In addition, certain Group A herbicides used in wheat and barley provide effective post-emergence control of FTR, so winter cereals are a good option in an FTR integrated weed management plan.

Weed control tactics rarely achieve 100% control, so monitoring for and controlling survivors is important. Target survivors as soon as possible by using spot tillage, spot spraying (including weed-sensor spray technology) or manual removal to avoid further seedset and minimise future problems. <sup>25</sup>

#### 6.3.5 Wild radish resistance

Growers in the GRDC's southern cropping region should be able to draw on the experience of their western counterparts for developing and implementing proactive control strategies for herbicide-resistant wild radish (Photo 7). <sup>26</sup> This difficult weed is becoming a serious threat in the southern region, but western growers have considerable experience in keeping it in check.



M Widderick (2013) Feathertop heads south. In Emerging Issues with Diseases, Weeds and Pests: Ground Cover Supplement. January– February 2013. Ground Cover. No. 102. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102">https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102</a>

<sup>26</sup> DAFWA (2016) Wild radish. DAFWA, <a href="https://www.agric.wa.gov.au/grains-research-development/wild-radish">https://www.agric.wa.gov.au/grains-research-development/wild-radish</a>

**TABLE OF CONTENTS** 





Photo 7: Herbicide-resistant wild radish plant in cereal paddock.

Source: DAFWA

Although wild radish has been present in both regions, the use of a sheep–wheat rotation in the south—southern New South Wales, Victoria, South Australia and Tasmania—has helped keep the weed under control.

In contrast, Western Australia's intensive-cropping system has led to wild radish becoming the number-one weed issue, with 60% of wild radish populations having developed resistance to at least one herbicide. Some populations are now resistant to multiple herbicide groups.

While the level of resistant wild radish populations in the southern region is still significantly lower than in the west, with enterprise changes to more intensive cropping, characterised by fewer sheep and more herbicide use, southern farmers are beginning to replicate what has happened in WA.

According to University of Adelaide weed scientist Dr Christopher Preston, by 2013 there were more than 20 paddocks across Victoria and SA with wild radish that is resistant to herbicides. Of these, five wild radish populations were resistant to Group I herbicides (three in Victoria and two in SA) and one to Group B, Group I and Group F herbicides. Dr Peter Boutsalis, the director of Plant Science Consulting, reported that, between 2009 and 2013, half the 60 wild radish samples received from growers across south-eastern Australia have been verified as resistant to Group B and Group I herbicides. Plant Science Consulting carries out annual herbicide-resistance testing on wild radish from paddocks where herbicides have failed. <sup>27</sup>

When poor herbicide control of wild radish is identified, it is critical that the weed seed is tested for herbicide resistance. GRDC-funded research in the western and southern regions is quantifying the extent of the wild radish problem and developing management systems to lower the weed's on-farm seedbank.

An underlying principle of wild radish management is to keep the weed seedbank in check. More than 90% of seed can be captured at harvest. As long as this seed is destroyed or removed via chaff carts, baling systems, windrowing and burning, crushing (using the Harrington Seed Destructor), or feeding to livestock, then radish seedbank numbers can be reduced to manageable levels.



Weedsmart, <u>Herbicide resistant Wild</u> radish: take back control

Wild radish management and strategies to address herbicide resistance



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<sup>27</sup> J Paterson (2013) South faces wild radish resistance. In Emerging Issues with Diseases, Weeds and Pests: Ground Cover Supplement. January–February 2013. Ground Cover. No. 102. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102">https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102</a>









WATCH: GRDC Grains Research
Updates 6–7 February 2013,
Southern Region, Ballarat Vic: Bill
Campbell



WATCH: <a href="MM">IWM: Weed seedbank</a> destruction—wild radish seed

WEED SEED BANK DESTRUCTION



When weed seed is not destroyed it remains in the chaff to be spread back onto the paddock or, even worse still, to be transported to another paddock, where wild radish or herbicide-resistant wild radish may not be present. <sup>28</sup>

SOUTHERN

#### 6.4 Herbicides

Chemical weed-control options in triticale varieties are in general similar to those for wheat, although some differences in tolerances are important. In all states, the agriculture departments produce a publication giving recommended herbicide usage. This should be consulted before using herbicides with triticale.

It is important that care is taken to ensure crop and weed tolerances based on the label recommendations are adhered to. Additionally, weather conditions, herbicide rates, water-dilution rates, and the status of adjoining crops need to be assessed and managed correctly. A range of chemicals is registered for use in both wheat and triticale, but some other herbicides are only legal for use in wheat. And for triticale, some herbicides are only legal to use at specific crop stages. <sup>29</sup>

## 6.4.1 Herbicides explained

When selecting a herbicide, it is important to know crop growth stage, weeds present and plant-back period. For best results, spray weeds while they are small and actively growing. Herbicides must be applied at the correct stage of crop growth, or significant yield losses may occur. Check product labels for up-to-date registrations and application methods.

#### Residual and non-residual herbicides

Residual herbicides remain active in the soil for months, and can act on successive germinations of weeds. Residual herbicides are absorbed through the roots or shoots, or both. Examples of residual herbicides are imazapyr, chlorsulfuron, atrazine and simazine. The persistence of residual herbicides is determined by several factors, such as application rate, soil texture, organic matter levels, soil pH, rainfall and irrigation, temperature, and the characteristics of the herbicide. Persistence of herbicides will affect the cropping sequence in the enterprise (e.g. a rotation of wheat–barley–chickpeas–canola–wheat).

Non-residual herbicides, such as the non-selective paraquat and glyphosate, have little or no soil activity, and are quickly deactivated in the soil. They are either broken down or bound to soil particles, which make them less available to growing plants. They also may have little or no ability to be absorbed by roots.

#### Pre-emergent and post-emergent herbicides

Pre-emergent and post-emergent herbicides refer to chemicals utilised to fit in with the timing of plant growth. Pre-emergent refers to the application of the herbicide to the soil before the weeds have emerged, and post-emergent to foliar application of the herbicide after the target weeds have emerged from the soil. <sup>30</sup>

#### Herbicide groups

Herbicides have been classified into a number of groups that refer to the way a chemical works: their different chemical make-up and mode of action (Table 2). 31



<sup>28</sup> J Paterson (2013) South faces wild radish resistance. In Emerging Issues with Diseases, Weeds and Pests: Ground Cover Supplement. January–February 2013. Ground Cover. No. 102. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102

<sup>29</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Rethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/1A-102\_Final\_Research\_Report\_.pdf">http://www.apri.com.au/1A-102\_Final\_Research\_Report\_.pdf</a>

<sup>30</sup> GRDC Integrated weed management, Section 4: Tactics for managing weed populations. <a href="http://www.grdc.com.au/"/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf">http://www.grdc.com.au/"/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf</a>

<sup>31</sup> Agriculture Victoria. Monitoring tools. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/farm-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/herbicide-resistance">http://agriculture/iarm-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/herbicide-resistance</a>



**Table 2:** Herbicide groups and examples of chemical products in each group.

SOUTHERN

Group	Common chemicals in the group
Group A	Hoegrass®, Nugrass®, Digrass®, Verdict®, Targa®, Fusilade®, Puma S®, Tristar®, Correct®, Sertin® Grasp®, Select®, Achieve®, Gallant®, Topik®
Group B	Glean®, Chlorsulfuron, Siege®, Tackle®, Ally®, Associate®, Logran®, Nugran®, Amber Post® Londax®, Spinnaker®, Broadstrike®, Eclipse®, Renovate®
Group C	Simazine, Atrazine, Bladex®, Igran®, Metribuzin, Diuron, Linuron, Tribunil®, Bromoxynil, Jaguar®, Tough®
Group D	Trifluralin, Stomp®, Yield®, Surflan®
Group E	Avadex®, BW, EPTC, Chlorpropham
Group F	Brodal®, Tigrex®, Jaguar®
Group H	Saturn®
Group I	2,4-D, MCPA, 2,4-DB, Dicamba, Tordon®, Lontrel®, Starane®, Garlon®, Baton®, Butress®, Trifolamine®
Group K	Dual®, Kerb®, Mataven®
Group L	Regione®, Gramoxone®, Nuquat®, Spraytop®, Sprayseed®
Group M	Glyphosate, Glyphosate CT®, Sprayseed®, Roundup CT®, Touchdown®, Pacer®, Weedmaster®

Notes. List of commonly used products only. List of products does not necessarily imply state registration. Check that product is registered in your state before use. Groups G and J not included.

Source: Agriculture Victoria

## 6.5 Pre-emergent herbicides

Triticale is competitive against weeds once it is established. If needed, a preemergent knockdown should be applied, as there are limited options available postemergence. Ideally, a non-selective knockdown should be used when sowing main season varieties to reduce the reliance on post-emergent herbicides. <sup>32</sup> There are some herbicide options available against broadleaf weeds. <sup>33</sup>

For herbicides registered for use on triticale and for the recommended herbicide rate and time to apply, the Field Crop Herbicide Guide from the Kondinin Group is a good reference. Local agronomists and resellers are also a good source of advice on pesticide use.

Pre-emergent herbicides control weeds between radicle (root shoot) emergence from the seed and seedling emergence through the soil. Some may also provide post-emergent control.

#### 6.5.1 Benefits and concerns

- The residual activity of pre-emergent herbicides controls the first few flushes of germinating weeds while the crop or pasture is too small to compete.
- Good planning is needed to use pre-emergent herbicides as an effective tactic.
   It is necessary to consider weed species and density, crop or pasture type, soil condition, and the rotation of crop or pasture species.
- Soil activity and environmental conditions at the time of application play an important role in the availability, activity and persistence of preemergent herbicides.
- Both the positive and negative aspects of using pre-emergent herbicides should be considered in the planning phase. <sup>34</sup>



<sup>32</sup> Waratah see Co. Ltd. (2010). Triticale: planting guide. http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf

<sup>33</sup> AGF Seeds. Triticale.  $\underline{\text{https://agfseeds.com.au/triticale}}$ 

<sup>34</sup> DAFWA. (2016) Herbicides. <a href="https://www.agric.wa.gov.au/herbicides/herbicides?page=0%2C2">https://www.agric.wa.gov.au/herbicides/herbicides?page=0%2C2</a>







The important factors in getting pre-emergent herbicides to work effectively while minimising crop damage are:

- to understand the position of the weed seeds in the soil;
- the soil type (particularly amount of organic matter and crop residue on the surface);
- · the solubility of the herbicide; and
- its ability to be bound by the soil.

## 6.5.2 Understanding pre-emergent herbicides

With the increasing incidence of resistance to post-emergent herbicides across Australia, pre-emergent herbicides are becoming more important for weed control. There are typically more variables that can affect their efficacy than for post-emergent herbicides. Post-emergent herbicides are applied when weeds are present and usually the main considerations relate to application coverage, weed size and environmental conditions that impact on performance. Pre-emergent herbicides are applied before the weeds germinate and a number of other considerations come into play. The various pre-emergent herbicides behave differently in the soil, and may behave differently in different soil types. Therefore, it is essential to understand the behaviour of the herbicide, the soil type and the farming system in order to use pre-emergent herbicides in the most effective way.

Pre-emergent herbicides have to be absorbed from the soil by the germinating seedling. To do so, these herbicides need to be at least partly soluble in water and be in a position in the soil where the roots or emerging shoot can access them. The dinitroaniline herbicides, such as trifluralin, are an exception in that they are absorbed by the seedlings as a gas. These herbicides still require water in order to be activated as a gas. Therefore, weed control with pre-emergent herbicides will always be lower under dry conditions.

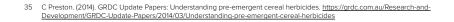
#### Behaviour of pre-emergent herbicides in the soil

The behaviour of pre-emergent herbicides in the soil is driven by three key factors:

- the solubility of the herbicide;
- how tightly the herbicide binds to soil components; and
- the rate of breakdown of the herbicide in the soil.

The characteristics of some common pre-emergent herbicides are given in Table 3. 35

The water solubility of herbicides ranges from very low values for trifluralin to very high values for chlorsulfuron. Water solubility influences how far the herbicide will move in the soil profile in response to rainfall events. Herbicides with high solubility are at greater risk of being moved into the crop seed row by rainfall and potentially causing crop damage. If the herbicides move too far through the soil profile they risk moving out of the weed root zone and failing to control the weed species at all. Herbicides with very low water solubility are unlikely to move far from where they are applied.

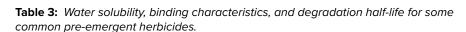












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Herbicide	Water solubility		Koc*		Degradation half-
	mg L <sup>-1</sup> (at 20 C and neutral pH)	Rating	mL g <sup>.1</sup> (in typical neutral soils)	Rating	life (days)
Trifluralin	0.22	Very low	15,800	Very high	181
Pendimethalin	0.33	Very low	17,800	Very high	90
Pyroxasulfone	3.9	Low	223	Medium	22
Triallate	4.1	Low	3000	High	82
Prosulfocarb	13	Low	2000	High	12
Atrazine	35	Medium	100	Medium	75
Diuron	36	Medium	813	High	75.5
S-metolachlor	480	High	200	Medium	15
Triasulfuron	815	High	60	Low	23
Chlorsulfuron	12,500	Very high	40	Low	160

<sup>\*</sup>Koc, = the soil organic carbon-water partitioning coefficient. High Koc values mean that more herbicide will be bound to organic matter and less herbicide will be available to move in the soil solution. Koc values for pre-emergent herbicides in Table above range from very high for trifluralin and pendimethalin to low for triasulfuron and chlorsulfuron.

#### Source: GRDC.

- Soils with low organic matter, especially sandy soils, are particularly prone to crop damage from pre-emergent herbicides, and rates should be reduced where necessary to lower the risk of crop damage.
- The more water-soluble herbicides will move more readily through the soil
  profile, and are better suited to post sowing pre-emergent applications than the
  less water-soluble herbicides. They are also more likely to produce crop damage
  after heavy rain.
- Pre-emergent herbicides need to be at sufficient concentration at or below the
  location of the weed seed (except for triallate which needs to be above the
  weed seed) to provide effective control. Keeping weed seeds on the soil surface
  will improve control by pre-emergent herbicides.
- High crop-residue loads on the soil surface will impair the effectiveness of preemergent herbicides as they keep the herbicide from contact with the seed.
   More water-soluble herbicides cope better with crop residue, but the solution is to manage crop residue so that at least 50% of the soil surface is exposed at the time of application.
- If the soil is dry on the surface but moist underneath there may be sufficient
  moisture to germinate the weed seeds, but not enough to activate the herbicide.
  Poor weed control is likely under these circumstances. The more water-soluble
  herbicides are less adversely affected under these conditions.
- Many pre-emergent herbicides can cause crop damage. Separation of the product from the crop seed is essential. In particular, care needs to be taken with disc seeding equipment in choice of product and maintaining an adequate seeding depth. <sup>36</sup>

#### 6.5.3 Top tips for using pre-emergent herbicides

- Only use pre-emergent herbicides as part of an integrated weed control plan that includes both chemical and non-chemical practices.
- Preparation starts at harvest. Minimise compaction and maximise trash spreading from the header.



<sup>36</sup> C Preston (2014) Understanding pre-emergent cereal herbicides. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-bevelopment/GRDC-Update-Papers/2014/03/Understanding-pre-emergent-cereal-herbicides">https://grdc.com.au/Research-and-bevelopment/GRDC-Update-Papers/2014/03/Understanding-pre-emergent-cereal-herbicides</a>



**TABLE OF CONTENTS** 

FEEDBACK



## **MORE INFORMATION**

<u>Understanding pre-emergent cereal</u> herbicides

<u>Using pre-emergent herbicides in</u> <u>conservation farming systems</u>

Gearing up to use pre-emergent herbicides

GRDC, Pre-emergent herbicide use

How pre-emergent herbicides work

Kondinin Group, <u>Field Crop Herbicide</u> Guide

Weed control in winter crops 2016, <u>Table 12. Herbicides for pre-emergent</u> <u>and post-sowing pre-emergent weed</u> <u>control</u>  Minimise soil disturbance so that weed seeds are more likely to remain on the soil surface.

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- Leave stubble standing rather than laying it over.
- Knife points and press wheels allow greatest crop safety. Avoid harrows.
- If using a disc seeder understand the mechanics of your machine and the its limitations compared to a knife point and press wheel.
- Pay attention to detail in your sowing operation and ensure soil throw on the inter-row while maintaining a seed furrow free of herbicide.
- Ensure the seed furrow is closed to prevent herbicide washing onto the crop seed.
- Ensure even seed placement, typically 3–5 cm of loose soil on top of seed in cereals, for best crop safety.
- Use incorporate by sowing (IBS) rather than post-sow per-emergent (PSPE) cropping for crop safety.
- Understand herbicide chemistry. Choose the right herbicide in the right paddock at the right rate. <sup>37</sup>

## 6.6 Post-planting pre-emergent herbicides

Post-sowing pre-emergent (PSPE) herbicides are, as the name implies, applied to the seedbed after sowing and before the crop emerges. Post-sown pre-emergent herbicides are absorbed primarily through the roots, but there may also be some foliar absorption (e.g. with Terbyne®). When applied to soil, best control is achieved when the soil is flat and relatively free of clods and trash. Sufficient rainfall (20–30 mm) to wet the soil through the weed root zone is necessary within two or three weeks of application. The best weed control is achieved from PSPE application because rainfall improves incorporation. Mechanical incorporation pre-sowing is less uniform, and so weed control may be less effective. If applied pre-sowing and sown with minimal disturbance, incorporation will essentially be by rainfall after application. Weed control in the sowing row may be less effective because a certain amount of herbicide will be removed from the crop row.

#### 6.6.1 Incorporation by sowing

Incorporation by sowing (IBS) is when a herbicide is applied just before sowing (usually in conjunction with a knockdown herbicide such as glyphosate and soil throw from the sowing operation incorporates the herbicide into the seedbed.

This is the preferred method of applying pre-emergent herbicides in conservation farming systems, as crop safety is maximised, stubble remains standing to protect the seedbed, and soil disturbance is minimised.

Applying pre-emergent herbicides before sowing and then incorporating them into the seedbed during the sowing process usually increases safety to the crops because the sowing operation moves a certain amount of herbicide away from the seed row. This can reduce weed control for the same reason. In this case it is wise to include a water-soluble herbicide into the mix aiming to have some herbicide wash into the seed furrow.

Two trials were conducted in 2013 to evaluate the crop safety and efficacy of registered residual herbicides for the control of annual ryegrass in wheat. This work was conducted due to concerns about commercial crop safety. The majority of treatments were managed by using IBS, which specifies the use of narrow-point tynes on the planting equipment. This approach helps to ensure sufficient soil is thrown across the inter-row space to effectively incorporate the herbicide, add it removes most of the herbicide-treated soil from the planting furrow, thus improving crop safety. The negative consequence is that IBS generally provides poor weed control in the



<sup>37</sup> B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW DPI, http://www.dpi.nsw.gov.au/\_\_data/assets/ pdf\_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf



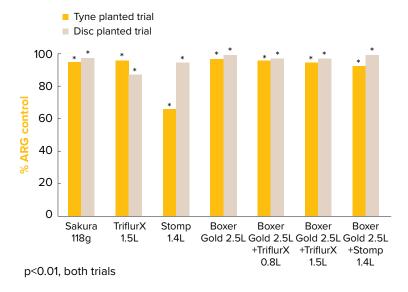




zone immediately around the planting row. In many cases, post sowing pre-emergent application (PSPE) is also being evaluated as it provides more uniform weed efficacy but requires herbicides or rates with improved crop safety together with reduced incorporation characteristics. The main results of the study were that:

SOUTHERN

- The use of a disc planter for IBS of residual herbicides resulted in significantly reduced wheat emergence for all four herbicides evaluated.
- The disc planter set up actually increased the risk of crop damage (Figure 1). 38
- The results reinforce the need to only use narrow-point tynes when using residual herbicides with IBS.



**Figure 1:** Per cent annual ryegrass control based on counts taken on 22 September 2013, 94 days after planting. UTC = untreated control. All treatments applied in 70 L/ha total volume using AIXR110015 nozzles at 300 kPa \* = significant annual ryegrass control compared to untreated within same trial.

Source: GRDC

Note that Boxer Gold® is not registered for triticale, but Sakura® is.

During the trials, the researchers noted variations in efficacy, depending on treatment:

- High levels of annual ryegrass control were achieved by most IBS treatments.
- One of the most consistent products was Sakura®.

The trials highlighted problems with the use of disc planters:

- Crop safety was significantly reduced when a disc planter was used for incorporation.
- The disc set up appeared to have exacerbated crop safety concerns by planting seed in an area of greater herbicide concentration.
- In this scenario, observation suggested that small differences in planting depth may have made a difference to crop safety.

This work reinforces some of the difficulties growers and agronomists face with the use of residual herbicides. Crop safety and efficacy are influenced by a range of factors including planting equipment, planting depth, soil type, stubble load together with rainfall quantity and timing. As an industry we need to have a more thorough



R Daniel, A Mitchell (2014) Pre-emergent herbicides part of the solution but still much to learn. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Pre-emergent-herbicides-part-of-the-solution-but-much-still-to-learn">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Pre-emergent-herbicides-part-of-the-solution-but-much-still-to-learn</a>







understanding of the impacts from these (and perhaps other factors) to ensure we get the best from these important weed management tools.  $^{39}$ 

## 6.7 In-crop herbicides: knockdowns and residuals

Knockdown and residual herbicides control weeds that have emerged after crop or pasture establishment, and can be applied with little damage to the crop or pasture plants.

There are numerous herbicide options for early post-emergent and late post-emergent control of broadleaf weeds; however, there are only early-post emergent control options for grass weeds.  $^{40}$ 

#### The benefits are:

- Post-emergent herbicides give high levels of target weed control, with the additional benefit of improved crop or pasture yield.
- Observations made just before application allow fine-tuning of herbicide selection to match the weeds present.
- The timing of application can be flexible to suit weed size, the stage of crop growth and environmental conditions.
- Some post-emergent herbicides have pre-emergent activity on subsequent weed germinations.

To avoid problems emerging from the use of these herbicides:

- Carefully consider the best post-emergent herbicide to use in any one situation.
- Choose the most suitable formulation of herbicide for each situation.
- Application of post-emergent herbicides to stressed crops and weeds can result in reduced levels of weed control and increased crop damage.
- Crop competition is important for effective weed control when using selective post-emergent herbicides.
- The technique used for application must be suited for the situation in order to optimize control.
- Always use the correct adjuvant to ensure effective weed control.
- Selective post-emergent herbicides applied early and used as a stand-alone tactic have little impact on the weed seedbank.
- The effectiveness of post-emergent herbicides is influenced by a range of plant and environmental factors.  $^{41}$

## **6.7.1** Applying in-crop herbicides

When applying in-crop herbicides:

- Knowledge of a product's translocation and formulation type is important for selecting nozzles and application volumes.
- Evenness of deposit is important for poorly or slowly translocated products.
- Crop growth stage, canopy size and stubble load should influence decisions about nozzle selection, application volume and sprayer operating parameters.
- Correct rates of product application and appropriate water rates are often more
  important for achieving control than the nozzle type, but correct nozzle type can
  widen the spray window, improve deposition and reduce drift risk.
- Travel speed and boom height can affect control and the likelihood of drift.
- Appropriate conditions for spraying are always important. 42

- 41 DAFWA (2016) Herbicides. DAFWA, <a href="https://www.agric.wa.gov.au/herbicides/herbicides?page=0%2C2">https://www.agric.wa.gov.au/herbicides/herbicides?page=0%2C2</a>
- 42 GRDC (2014) In-crop herbicide use Factsheet. GRDC, <a href="https://grdc.com.au/GRDC-FS-InCropHerbicideUse">https://grdc.com.au/GRDC-FS-InCropHerbicideUse</a>



## **MORE INFORMATION**

Weed control in winter crops 2016, <u>Table 12. Herbicides for pre-emergent</u> <u>and post-sowing pre-emergent weed</u> <u>control</u>



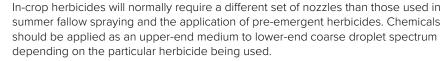
<sup>39</sup> R Daniel, A Mitchell (2014) Pre-emergent herbicides part of the solution but much still to learn. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Pre-emergent-herbicides-part-of-the-solution-but-much-still-to-learn">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Pre-emergent-herbicides-part-of-the-solution-but-much-still-to-learn</a>

Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102">http://www.porkcrc.com.au/1A-102</a> Triticale: Guide Final Fact Sheets.pdf



**TABLE OF CONTENTS** 





SOUTHERN
JANUARY 2018

Remember that this must be combined with the relevant application volume to get enough droplets per square centimetre on the target to achieve good coverage. You must also match the nozzles to your spray rig, pump and controller and desired travel speed.

Operate within the recommended ground speed range and apply the product in a higher application volume. The recommended volume will vary with the product and situation, so read the label and follow the directions.

#### How to get the most out of post-emergent herbicides

Consider the timing of the spray: the younger the weeds, the better. Frequent crop monitoring is critical.

Consider the growth stage of the crop:

- Consider the crop variety being grown and applicable herbicide tolerances.
- Know which species were historically in the paddock and the resistance status of the paddock (and if unsure, send plants away for a <u>Quick-Test</u>).
- Do not spray a crop stressed by waterlogging, frost, high or low temperatures, drought or, for some chemicals, cloudy or sunny days. This is especially pertinent for frosts with grass-weed chemicals.
- Use the correct spray application:
- Consider droplet size with grass-weed herbicides, water volumes with contact chemicals and time of day.
- Observe the plant-back periods and withholding periods.
- Consider compatibility if using a mixing partner.
- Add correct adjuvant. 43

## 6.7.2 Agricultural Chemical Control Areas

Nine Agricultural Chemical Control Areas (ACCA) have been established in Victoria to protect high value herbicide sensitive crops. Within these areas restrictions apply to the types of herbicides, their method of application and the periods in which certain chemicals can be used.

To check if the location you intend to spray is within an ACCA, refer to the map below (Figure 2). Each ACCA is identified in the map by a purple or green shaded area. Click on the shaded area or follow the links for information about each ACCA, including detailed maps, area boundaries and chemical restrictions. Growers need to acquire a permit before using herbicides in these areas: <a href="Application for an Agricultural Chemical Control Area (ACCA)">Application for an Agricultural Chemical Control Area (ACCA)</a> permit



GRDC, In-crop herbicide use

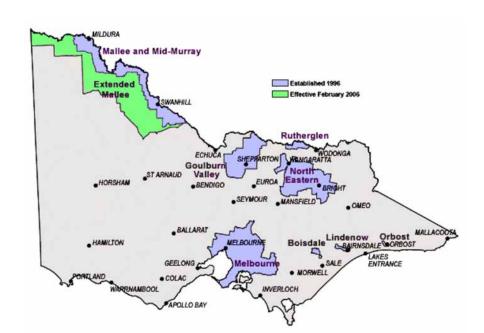
<u>Plant Science Consulting – Quick</u> tests











**SOUTHERN** 

Figure 2: Map showing areas where restrictions apply to herbicides use including; types, method of application and time of year used.

Source: AgVic.

Tables 4, 5 and 6 specify the restrictions placed on herbicide use in the nine ACCA areas of Victoria.

Table 4: Dates ACCA restrictions are operational

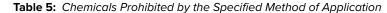
Melbourne Lindenow All year Orbost All year  Boisdale All year  Mallee & Mid Murray 1st August 30th April the following year  Extended Mallee 1st August 30th April the following year  Soulburn Valley 1st September 30th April the following year
Orbost All year  Boisdale All year  Mallee & Mid Murray 1st August 30th April the following year  Extended Mallee 1st August 30th April the following year  Goulburn Valley 1st September 30th April the following
Boisdale All year  Mallee & Mid Murray 1st August 30th April the following year  Extended Mallee 1st August 30th April the following year  Goulburn Valley 1st September 30th April the following
Mallee & Mid Murray  1st August  30th April the following year  Extended Mallee  1st August  30th April the following year  Goulburn Valley  1st September  30th April the following
Extended Mallee 1st August 30th April the following year  Goulburn Valley 1st September 30th April the following
Goulburn Valley 1st September 30th April the following
North Eastern 1st September 30th April the following year
Rutherglen 1st September 30th April the following year



**MORE INFORMATION** 

Customer Service Centre 136 186

Agriculture Chemical Use



ACCA	Chemical	Prohibited method
All ACCAs - except for Extended Mallee	Any formulation of Picloram	Aerial spraying or mister application
	Hexazinone applied as a liquid	
	Products containing Sulfometuron Methyl	
	Ester formulations of Triclopyr	
All ACCAs - except for Extended Mallee	Ester formulations of 2,4-D, 2,4-DB or MCPA	All methods of application
Extended Mallee only	Ester formulations of Triclopyr	Aerial spraying or mister application
Extended Mallee only	Ester formulations of 2,4-D or MCPA	All methods of application

SOUTHERN

Table 6: Chemicals Prohibited Unless an \*ACCA Permit Has Been Granted

ACCA	Chemical	Prohibited method
All ACCAs - except for Extended Mallee	Any formulation of chlorsulfuron, clopyralid, glyphosate or metsulfuron methyl	Aerial spraying or mister application
	Any amine formulation of MCPA, MCPB, 2,4-D, 2,4-DB, dicamba, mecoprop or triclopyr	

All users of agricultural and veterinary chemicals, including ACUP holders, are required to keep specified records for all chemical products used within 48 hours of using the chemical product, and to keep these records for a period of two years. 44

## 6.8 Conditions for spraying

When applying herbicides, the aim is to maximise the amount of chemical that reaches the target and to minimise the amount reaching off-target areas. This results in:

- improved herbicide effectiveness
- reduced damage and/or contamination of off target crops and areas

In areas where a range of agricultural enterprises coexist, conflicts can arise, particularly over the use of herbicides. All herbicides are capable of drifting. When spraying a herbicide, you have a moral and legal responsibility to prevent it from drifting into and contaminating or damaging neighbours' crops and other sensitive areas.

All grass herbicide labels emphasise the importance of spraying only when the weeds are actively growing and when conditions and mild and favourable (Photo 8).  $^{45}$  Any of the following stress conditions can significantly impair both uptake and translocation of the herbicide within the plant, which is likely to result in an incomplete kill or only suppression of weeds:

Moisture stress and drought.



Agriculture Victoria. (2015). Agricultural Chemical Control Areas. http://agriculture.vic.gov.au/agriculture/farm-management/chemicaluse/agricultural-chemical-use/agricultural-chemical-control-areas

DAFWA (2016) Herbicide application. DAFWA, https://www.agric.wa.gov.au/grains/herbicide-application

TABLE OF CONTENTS



- Waterlogging.
- High temperature, low humidity conditions.
- Extreme cold or frosts.
- Nutrient deficiency, especially of nitrogen.
- Use of pre-emergent herbicides that affect growth and root development; i.e. simazine, Balance®, trifluralin, and Stomp®.

SOUTHERN JANUARY 2018

- Excessively heavy dews resulting in poor spray retention on grass leaves.
- Ensure that grass weeds have fully recovered before applying grass herbicides.



Photo 8: Using a boom spray on the crop when there is a slight amount of wind helps prevent spray drift.

Source: DAFWA

## 6.8.1 Minimising spray drift

Before spraying:

- Always check for susceptible crops in the area, for example broadleaf crops such as grape vines, cotton, vegetables and pulses, if you are using a broadleaf herbicide.
- Check sensitive areas such as houses, schools, waterways and riverbanks.
- Notify neighbours of your spraying intentions.

Under the Records Regulation of the Pesticides Act 1999 growers must record the weather and relevant spray details when spraying.

During spraying:

- Always monitor weather conditions carefully and understand their effect on drift hazard.
- Don't spray if conditions are not suitable, and stop spraying if conditions change and become unsuitable.
- Record weather conditions (especially temperature and relative humidity), wind speed and direction, herbicide and water rates, and operating details for each paddock.



TABLE OF CONTENTS





- Supervise all spraying, even when a contractor is employed. Provide a map marking the areas to be sprayed, buffers to be observed and sensitive crops and areas.
- Spray when temperatures are less than 28°C.
- Maintain a downwind buffer. This may be in the crop, e.g. keeping a boom's width from the downwind edge of the paddock.
- Minimise spray release height.
- Use the largest droplets that will give adequate spray coverage.
- Always use the least-volatile formulation of herbicide available.
- If there are sensitive crops in the area, use the herbicide that is the least damaging.

## 6.8.2 Types of drift

Sprayed herbicides can drift as droplets, as vapours or as particles (Photo 9).

Droplet drift is the easiest to control because, under good spraying conditions, droplets are carried down by air turbulence and gravity, to collect on plant or soil surfaces. Droplet drift is the most common cause of off-target damage caused by herbicide application. For example, spraying fallows with glyphosate under the wrong conditions often leads to severe damage to establishing crops.

Particle drift occurs when water and other carriers of herbicides evaporate quickly from the droplet, leaving tiny particles of concentrated herbicide. This can occur with herbicide formulations other than esters. Instances of this form of drift have damaged susceptible crops up to 30 km from the source.

Vapour drift is confined to volatile herbicides such as 2,4-D ester. Vapours may arise directly from the spray or as a result of the herbicide evaporating from sprayed surfaces. Use of 2,4-D ester in summer can lead to vapour-drift damage of highly susceptible crops such as tomatoes, cotton, sunflowers, soybeans and grapes. This may occur hours after the herbicide has been applied.



**Photo 9:** Triticale plants showing spotting on leaves – a sign of spray-drift damage. Source: DelVal Crop Science

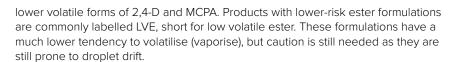
In 2006, the federal regulator of pesticide use, the APVMA, restricted the use of highly volatile for of 2,4-D ester. The changes are now seen with the substitution of





**TABLE OF CONTENTS** 





SOUTHERN

Vapours and minute particles float in the airstream and are poorly collected on catching surfaces. They may be carried for many kilometres in thermal updraughts before being deposited.

Sensitive crops may be up to 10,000 times more sensitive than the crop being sprayed. Even small quantities of drifting herbicide can cause severe damage to highly sensitive plants. 46

## 6.8.3 Factors in the risk of spray drift

Any herbicide can drift. The drift hazard, or off-target potential, of a herbicide in a particular situation depends on the following factors.

- Volatility of the formulation applied—volatility refers to the likelihood that the herbicide will evaporate and become a gas. Esters volatilise whereas amines do not.
- Proximity of crops susceptible to the particular herbicide being applied, and their growth stage. For example, cotton is most sensitive to Group I herbicides in the seedling stage.
- Method of application and equipment used. Aerial application releases spray 3 m above the target and uses relatively low application volumes, while ground rigs have lower release heights and generally higher application volumes, and a range of nozzle types. Misters produce large numbers of very fine droplets that use wind to carry them to their target.
- Size of the area treated—the greater the area treated the longer it takes to apply the herbicide. If local meteorological conditions change, particularly in the case of 2,4-D ester, then more herbicide is able to volatilise.
- Amount of active ingredient (herbicide) applied—the more herbicide applied per hectare the greater the amount available to drift or volatilise.
- Efficiency of droplet capture—bare soil does not have anything to catch drifting droplets, unlike crops, erect pasture species and standing stubbles.
- Weather conditions during and shortly after application.

Changing weather conditions can increase the risk of spray drift.

#### Volatility

Many ester formulations are highly volatile when compared with the non-volatile amine, sodium salt and acid formulations. Table 7  $^{\rm 47}$  is a guide to the more common herbicide active ingredients that are marketed with more than one formulation.



A Storrie, T Cook (2015) Reducing herbicide spray drift. Revised. NSW DPI, http://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/ herbicides/spray-drift

A Storrie, T Cook (2015) Reducing herbicide spray drift. Revised. NSW DPI, http://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/ herbicides/spray-drift



Table 7: Relative herbicide volatility.

Form of active	Full name	Product example
Non-volatile		
Amine salts		
MCPA dma	dimethyl amine salt	MCPA 500
2,4-D dma	dimethyl amine salt	2,4-D Amine 500
2,4-D dea	diethanolamine salt	2,4-D Amine 500 Low Odour®
2,4-D ipa	isopropylamine salt	Surpass® 300
2,4-D tipa	triisopropanolamine	Tordon® 75-D
2,4-DB dma	dimethyl amine salt	Buttress®
dicamba dma	dimethyl amine salt	Banvel® 200
triclopyr tea	triethylamine salt	Tordon® Timber Control
picloram tipa	triisopropanolamine	Tordon® 75-D
clopyralid dma	dimethylamine	Lontrel® Advanced
clopyralid tipa	triisopropanolamine	Archer®
aminopyralid K salt	potassium salt	Stinger®
aminopyralid tipa	triisopropanolamine	Hotshot®
Other salts		
MCPA Na salt	sodium salt	MCPA 250
MCPA Na/K salt	sodium & potassium salt	MCPA 250
2,4-DB Na/K salt	sodium & potassium salt	Buticide®
dicamba Na salt	sodium salt	Cadence®
SOME VOLATILITY		
Esters		
MCPA ehe	ethylhexyl ester	LVE MCPA
MCPA ioe	isooctyl ester	LVE MCPA
triclopyr butoxyl	butoxyethyl ester	Garlon® 600
picloram ioe	isooctyl ester	Access®
2,4-D ehe	ethylhexyl ester	2,4-D LVE 680
fluroxypyr M ester	meptyl ester	Starane® Advanced
Source: NSW DPI		

Source. 1454V Di 1

## 6.8.4 Minimising drift

A significant part of minimising spray drift is the selection of equipment to reduce the number of small droplets produced. However, this in turn may affect coverage of the target, and therefore the possible effectiveness of the pesticide application.

As the number of smaller droplets decreases, so does the coverage of the spray. A good example of this is the use of air-induction nozzles that produce large droplets that splatter. These nozzles produce a droplet pattern and number that are unsuitable for targets such as seedling grasses, which present a small vertical target.

In 2010, the APVMA announced new measures to ensure the number of spray-drift incidents are minimised (Table 8). <sup>48</sup> The changes are restrictions on the droplet size spectrum an applicator can use, the wind speed suitable for spraying, and the downwind buffer zone between spraying and a sensitive target. These changes



<sup>48</sup> A Storrie, T Cook (2015) Reducing herbicide spray drift. Revised. NSW DPI, http://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift









WATCH: IWM: Spray application of herbicides—travel speed



WATCH: IWM: Spray application of herbicides—spray deposition



should be evident on current herbicide labels. Hand-held spraying application is exempt from these regulations.

SOUTHERN

JANUARY 2018

**Table 8:** Nozzle selection guide for ground application.

Distance downwind to susceptible crop	<1 km	1–30 km and more
Risk	High	Medium
Preferred droplet size (to minimise risk)	coarse to very coarse	medium to coarse
Volume median diameter (microns)	310	210
Pressure (bars)	2.5	2.5
Flat fan nozzle size #	11008	11004
Recommended nozzles (examples only)	Raindrop: Whirljet® Air induction: Yamaho Turbodrop® Hardi Injet® Al Teejet® LurmarkDrift-beta®	Drift reduction: DG TeeJet® Turbo TeeJet® Hardi® ISO LD 110 Lurmark® Lo-Drift
Caution	Can lead to poor coverage and control of grass weeds Requires higher spray volumes	Suitable for grass control at recommended pressures Some fine droplets

Source: DPI NSW

Volume median diameter: 50% of the droplets are less than the stated size and 50% greater.

# Refer to manufacturer's selection charts, as range of droplet sizes will vary with recommended pressure. Always use the lowest pressure stated to minimise the small droplets.

## 6.8.5 Spray release height

- Operate the boom at the minimum practical height. Drift hazard doubles as nozzle height doubles. If possible, angle nozzles forward 30° to allow lower boom height with double overlap. Lower heights, however, can lead to more striping, as the boom sways and dips below the optimum height.
- 110° nozzles produce a higher percentage of fine droplets than 80° nozzles, but they allow a lower boom height while maintaining the required double overlap.
- Operate within the pressure range recommended by the nozzle manufacturer. The production of fine droplets that drift increases as the operating pressure is increased

#### 6.8.6 Size of area treated

When large areas are treated relatively large amounts of active herbicide are applied and the risk of off-target effects increases due to the length of time taken to apply the herbicide. Conditions such as temperature, humidity and wind direction may change during spraying. Applying volatile formulations to large areas increases the chances of vapour drift damage to susceptible crops and pastures.

#### 6.8.7 Capture surface

Targets vary in their ability to collect or capture spray droplets. The type of catching surface between the sprayed area and susceptible crops should always be considered in conjunction with the characteristics of the target area when assessing drift hazard.











WATCH: <u>IWM: Spray application of herbicides—water volume with</u> contact sprays



WATCH: IWM: Spray application of herbicides—application volume in stubble

#### SPRAY APPLICATION OF HERBICIDES



WATCH: <u>Advances in weed</u> <u>management: Webinar 2–Spray</u> application in summer fallows



Well grown, leafy crops are efficient collectors of droplets. Turbulent airflow normally carries spray droplets down into the crop.

SOUTHERN

Fallow paddocks or seedling crops have poor catching surfaces. Therefore, drift hazard is far greater when applying herbicide in these situations or adjacent to these poor capture surfaces.

#### 6.8.8 Weather conditions to avoid

Avoid using herbicidal sprays in the following conditions.

Midday turbulence

Up-drafts during the heat of the day cause rapidly shifting wind directions, so avoid spraying in the middle of the day.

High temperatures

Avoid spraying when temperatures exceed 28°C.

Humidity

Avoid spraying under low relative humidity, i.e. when the difference between wet and dry bulbs (Delta T,  $\Delta$ T) exceeds 10°C.

High humidity extends droplet life and can greatly increase the drift hazard under inversion conditions. This results from the increased life of droplets smaller than 100 microns.

Inversions

The most hazardous condition for herbicide spray drift is an atmospheric inversion, especially when combined with high humidity.

Wind

Avoid spraying under still conditions.

11-14 km/h (a moderate breeze, when small branches move, dust is raised or loose paper moves) is suitable for spraying only if using low-drift nozzles or higher volume application, say 80-120 L/ha.

Agronomist's tip: There should always be at least a slight wind when spraying. No wind means there will be a high risk of inversion and too much wind means there is a high risk of spray drift.

The ideal wind speed at which to spray is  $3-10\,\mathrm{km/h}$ , a light breeze, when leaves and twigs are in constant motion.

An inversion exists when temperature increases with altitude instead of decreasing. An inversion is like a cold blanket of air above the ground, and is usually less than 50 m thick. Air will not rise above this blanket; and smoke or fine spray droplets and particles of spray deposited within an inversion will float until the inversion breaks down. Inversions usually occur on clear, calm mornings and nights. Windy or turbulent conditions prevent the formation of inversion layers.

Blankets of fog, dust or smoke and the tendency for sounds and smells to carry long distances indicate inversion conditions. Smoke generators or smoky fires can be used to detect inversion conditions. Smoke will not continue to rise but will drift along at a constant height under the inversion blanket. 49



<sup>49</sup> A Storrie, T Cook (2015) Reducing herbicide spray drift. Revised. NSW DPI, <a href="http://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift">http://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift</a>









In most cases, the herbicides and pesticides that work on wheat and rye will work on triticale. However, some studies indicate that triticale may be less tolerant to some herbicide cocktails than wheat. Newer herbicides as well as pesticides are now being released with recommendations for use on triticale in many parts of the world. 50

SOUTHERN

NVT herbicide-tolerance trails undertaken in NSW from 1996 to 2015 give an indication of triticale's response to a range of herbicides.

In 2004 and 2005, trials in the US tested the tolerance of three triticale varieties (AC Alta, AC Ultima, and Pronghorn) with four herbicides registered for wheat: florasulam + MCPA ester, clodinafop-propargyl, thifensulfuron-methyl/tribenuron-methyl, and sulfosulfuron-methyl + 2,4-D ester. Herbicides were applied at the label rate for wheat and at twice that rate. Crop injury, plant height, biomass, and seed yields were quantified. Neither florasulam + MCPA ester, clodinafop-propargyl, nor thifensulfuronmethyl/tribenuron-methyl used at the standard or double rates significantly injured triticale. Sulfosulfuron-methyl + 2,4-D ester reduced triticale height at the both rates, as well as reduced biomass and yield at the double rate.

The researchers concluded that florasulam + MCPA ester, clodinafop-propargyl, and thifensulfuron-methyl/tribenuron-methyl do not cause significant crop injury, and can be used for weed control in spring triticale, but sulfosulfuron-methyl + 2,4-D ester is not recommended for use in triticale. 51

Cultivars of many broadacre crop species have been found to vary in sensitivity to commonly used herbicides and tank mixes. Using the wrong mixture for a cultivar may result in a loss of grain yield and in reduced farm profit. So the industry can fine-tune understanding of what chemicals can work in a complementary way with different cultivars, GRDC and state government agencies across Australia fund a series of cultivar × herbicide tolerance trials are conducted annually.

The trials aim to provide grain growers and advisers with information on cultivar sensitivity to commonly used in-crop herbicides and tank mixes for a range of crop species including wheat, barley, triticale, oats, lupins, field peas, lentils, chickpeas and faba beans. The intention is to provide data from at least two years of testing at the time of wide-scale commercial propagation of a new cultivar.

To provide growers with clear information about the herbicide interactions of a variety for their region, four regionally based projects were established. They have now been combined under a GRDC national herbicide tolerance program.

The good news is that over 70% of all crop varieties tolerate most herbicides. The remaining varieties may show yield losses of 10-30%, and in some cases a 50% vield loss has been recorded. These results have occurred with the use of registered herbicides applied at label rates under good spraying conditions at the appropriate crop growth stage. 52

Excessive herbicide treatments may limit germination in triticale. The successive effect of five herbicide variants (isoxaben, chlorsulfuron, isoproturon, chlortoluron and control) on the germination and plant growth of triticale cultivars has been explored. Germinative energy and germinating power of winter triticale seeds, obtained from plants treated with herbicide, were generally lower, in particular for the isoproturon



and chlorsulfuron variants. 53



L Raatz, M Hills, R McKenzie, RC Yang, K Topinka, L Hall (2011) Tolerance of spring triticale (x Triticosecale Wittmack) to four wheat herbicides. Weed Technology, 25 (1), 84–89.



Weed kill without crop damage



E Leonard (2012) Weed kill without crop damage. Ground Cover Issue 101 – National Variety Trials Supplement. <a href="https://grdc.co">https://grdc.co</a> <a href="https://grdc.co">Media-Centre/Ground-Cover-Supplements/GCS101Weed-kill-without-crop-damage">https://grdc.co</a>

S Sławomir, M Robert (1996) Successive effect of herbicides on triticale seed germination and plant growth. In Triticale: Today and Tomorrow. Springer Netherlands, pp. 743–747.









## 6.10.1 Avoiding crop damage from residual herbicides

When researching the residual activity and cropping restrictions following herbicide application, the herbicide label is the primary source of information and it should be read thoroughly and followed precisely to minimise the development of resistance, and to maximise paddock health and crop yield.

#### What are the issues?

Some herbicides can remain active in the soil for weeks, months or even years. This can be an advantage, as it ensures good long-term weed control. However, if the herbicide stays in the soil longer than intended it may damage sensitive crop or pasture species sown in subsequent years.

For example, chlorsulfuron (e.g. Glean®) is used in wheat and barley, but it can remain active in the soil for several years and damage legumes and oilseeds. A real difficulty for growers lies in identifying herbicide residues before they cause a problem.

Currently, growers rely on information provided on the labels about soil type and climate. Herbicide residues are often too small to be detected by chemical analysis, or if testing is possible it is too expensive to be part of routine farming practice. Once the crop has emerged, diagnosis is difficult because the symptoms of residual herbicide damage can be confused with, and/or make the crop vulnerable to, other stresses, such as nutrient deficiency or disease. 54

An option for assessing the potential risk of herbicide residues is to conduct a bioassay involving hand planting small test areas of crop into the field in question.

#### Which herbicides are residual?

The herbicides listed in Table 9 all have some residual activity or planting restrictions. Glean® is registered for use in triticale, cereal rye, wheat, and oats. Activity occurs through root and foliar uptake. There are no plant-back recommendations on alkaline soils for triticale and wheat. Ally® is registered for use in triticale, wheat, barley and cereal rye. Activity is by foliar translocation but also root absorption after rain. 55

Product labels DO NOT use consistent terminology or put warnings in the same place so you need to read the entire label carefully.



<sup>54</sup> Agriculture Victoria (2013) Avoiding crop damage from residual herbicides, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/ avoiding-crop-damage-from-residual-herbicides

 $L. Lenaghan. Residual \ herbicides: Group \ B \ and \ C. \ carry-over. \ \underline{http://www.croppro.com.au/resources/BCGGroupBResidual\_herbicides(2)}$ 







**Table 9:** A representative range of active constituents by herbicide group.

,	• • •
Herbicide group	Active constituent
Group B: Sulfonylureas	azimsulfuron, bensulfuron, chlorsulfuron, halosulfuron, iodosulfuron, mesosulfuron, metsulfuron, sulfosulfuron, triasulfuron, tribenuron
Group B: Imidazolinones	imazamox, imazapic, imazapyr, imazethapyr
Group B: Triazolopyrimidines (sulfonamides)	flumetsulam, florasulam, metosulam, pyroxsulam
Group C: Triazines	atrazine, simazine
Group C: Triazinones	metribuzin
Group C: Ureas	diuron
Group D: Dinitroanilines	pendimethalin, trifluralin
Group H: Pyrazoles	pyrasulfotole
Group H: Isoxazoles	isoxaflutole
Group I: Phenoxycarboxylic acids	2,4-D
Group I: Benzoic acids	dicamba
Group I: Pyridine carboxylic acids	aminopyralid, clopyralid
Group K: Chloroacetamides	dimethenamid, metolachlor
Group K: Isoxazoline	pyroxasulfone

Source: AgVic.

#### How can I avoid damage from residual herbicides?

Select a herbicide appropriate for the weed population you have. Make sure you consider what the re-cropping limitations may apply to future rotation options.

Users of chemicals are required by law to keep good records, including weather conditions, but particularly spray dates, rates, batch numbers, rainfall, soil type and pH (including different soil types in the paddock) (Photo 10).  $^{56}$  In the case of unexpected damage, good records can be invaluable.



D Lush (2014) Water solubility key to effective pre-emergents. Ground Cover. No. 110. GRDC,  $\underline{\text{https://grdc.com.au/Media-Centre/Ground-Cover/GC110/Water-solubility-key-to-effective-pre-emergents}$ 



TABLE OF CONTENTS





SOUTHERN

JANUARY 2018

Photo 10: This trial plot is showing crop damage from pre-emergent herbicides due to poor separation of herbicide and crop seed.

Photo: C Preston

If residues could be present, choose the least susceptible crops (refer to product labels). Optimise growing conditions to reduce the risk of compounding the problem with other stresses such as herbicide spray damage, disease and nutrient deficiency. These stresses make a crop more susceptible to herbicide residues. 57

#### 6.10.2 Plant-back intervals

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of a subsequent crop.

Some herbicides have a long residual period. This is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods (e.g. sulfonylureas such as chlorsulfuron) (see Tables 10  $^{58}$  and 11  $^{59}$ ). Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of the active ingredient, such as with the sulfonylureas. On product labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under a heading such as 'Protection of crops' in the general instructions section.

Part of the management of herbicide resistance includes rotation of herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonyl urea, triazines) may be a problem in some paddocks. Remember that plant-back periods begin after rain. 60





Agriculture Victoria (2013) Avoiding crop damage from residual herbicides, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/

B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW DPI, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> pdf\_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

 $W. Hawthorne (2007) Residual herbicides and weed control. Southern Pulse Bulletin. Pulse Australia, \\ \underline{http://www.pulsestorage/app/media/crops/2007\_SPB-Pulses-residual-herbicides-weed-control.pdf}$ 

B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW DPI, http://www.dpi.nsw.gov.au, pdf\_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf









WATCH: <u>Strategic narrow windrow</u> burning.



WATCH: The art of narrow windrow burning



WATCH: Chaff funnelling onto tramlines



WATCH: Capture weed seeds at harvest: Bale Direct System



**Table 10:** Known residual persistence of common pre-emergent herbicides.

SOUTHERN

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high pH soils. Weed control commonly drops off within 6 weeks.
Glean® (chlorsulfuron)	28–42	High. Persists longer in high pH soils. Weed control longer than Logran®.
Diuron	90 (range 1 month to 1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Has had observed long-lasting activity on grass weeds such as black/stink grass ( <i>Eragrostis</i> spp.) and to a lesser extent broadleaf weeds such as fleabane.
Atrazine	60–100, up to 1 year if dry	High. Has had observed long-lasting (>3 months) activity on broadleaf weeds such as fleabane.
Simazine	60 (range 28–149)	Medium—high, with 1 year residual in high pH soils. Has had observed long-lasting (>3 months) activity on broadleaf weeds such as fleabane.
Terbyne® (terbulthylazine)	6.5–139	High. Has had observed long-lasting (>6 months) activity on broadleaf weeds such as fleabane and sow thistle.
Triflur® X (trifluralin)	57–126	High. 6–8 months residual. Higher rates longer. Has had observed longlasting activity on grass weeds such as black grass and stink grass ( <i>Eragrostis</i> spp.).
Stomp® (pendimethalin)	40	Medium. 3–4 months residual.
Avadex® Xtra (triallate)	56–77	Medium. 3–4 months residual.
Balance® (isoxaflutole)	1.3 (metabolite 11.5)	High. Reactivates after each rainfall event. Has had observed long-lasting (> 6 months) activity on broadleaf weeds such as fleabane and sow thistle.
Boxer Gold® (prosulfocarb)	12–49	Medium. Typically quicker to break down than trifluralin, but tends to reactivate after each rainfall.
Sakura® (pyroxasulfone)	10–35	High. Typically quicker breakdown than trifluralin and Boxer Gold, however, weed control persists longer than Boxer Gold®.

Note residual persistence in broadacre trials and paddock experiences. Source: NSW DPI











WATCH: IWM: Weed seed destruction—beer can height



WATCH: Crop rotation with Colin **McAlpine** 



WATCH: Test for resistance to establish a clear picture of paddockby-paddock farm status



WATCH: IWM: Resistance testing— Quick Test sample collection



**Table 11:** Minimum re-cropping intervals and guidelines.

Group and type	Product	pH (H <sub>2</sub> O) or product rate (mL/ ha) as applicable	Minimum re-cropping interval (months after application), and conditions
B, sulfonyl urea (SU)	Chlorsulfurons e.g. Glean®, Seige®,	<6.5	3 months
	Tackle®	6.6–7.5	3 months, minimum 700 mm
		7.6–8.5	18 months, minimum 700 mm
B, sulfonyl urea (SU)	triasulfuron, e.g. Logran®, Nugrain®	7.6–8.5	12 months, >250 mm for grain, 300 mm for hay
		>8.6	12 months, >250 mm grain, 300 mm hay
B, Sulphonamide	Flumetsulam e.g. Broadstrike®		0 months
B, sulfonyl urea (SU)	metsulfuron e.g. Ally®, Associate®	5.6–8.5	1.5 months
	Associate*	>8.5	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area
B, sulfonyl urea (SU)	Metsulfuron + thifensulfuron,	7.8–8.5 organic matter >1.7%	3 months
	e.g. Harmony® M	>8.6 or organic matter <1.7%	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area
B, sulfonyl urea (SU)	Sulfosulfuron e.g. Monza®	<6.5	0 months
		6.5–8.5	10 months

Note: always read labels to confirm product specifications and use details.

Source: Pulse Australia

Warm, moist soils are required to break down most herbicides through the processes of microbial activity. For the soil microbes to be most active they need good moisture and an optimum soil temperature range of 18–30°C. Temperatures above or below this range can adversely affect soil microbial activity and slow herbicide breakdown. Very dry soil also reduces breakdown. Once the soil profile gets very dry it requires a lot of rain to regain and then maintain sufficient topsoil moisture for the microbes to be active again.

For up-to-date plant-back periods, see <u>Weed control in winter crops</u>.

- Herbicide resistance
- Resistance is the inherited ability of an individual plant to survive and reproduce following a herbicide application that would kill a 'wild' individual of the same species.

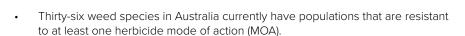


SOUTHERN



**TABLE OF CONTENTS** 





- At June 2014, Australian weed populations have developed resistance to 13 distinct MOAs and at least 39 weed species in Australia have resistance to one or more MOAs
- Herbicide resistant individuals are present at very low frequencies in weed populations before the herbicide is first applied.
- The frequency of naturally resistant individuals within a population will vary greatly within and between weed species.
- A weed population is defined as resistant when a herbicide at a label rate that once controlled the population is no longer effective. (Sometimes an arbitrary figure of 20% survival is used for defining resistance in testing.)
- The proportion of herbicide-resistant individuals will rise (due to selection pressure) in situations where the same herbicide MOA is applied repeatedly and the survivors are not subsequently controlled.
- Herbicide resistance in weed populations is permanent for as long as seed remains viable in the soil. Only weed density can be reduced, not the ratio of resistant-to-susceptible individuals. The exception is when the resistance gene(s) carry a fitness penalty so that resistant plants produce less seed than susceptible ones, but this is rare.

Resistance: remains for many years, until all resistant weed seeds are gone from the soil seedbank. Resistance evolves more rapidly in paddocks with frequent use of the same herbicide group, especially if no other control options are used.

#### Action points:

- Assess your level of risk with the online glyphosate resistance toolkit.
- Aim for maximum effectiveness in control tactics, because resistance is unlikely to develop in paddocks with low weed numbers.
- Do not rely on the same mode of action group.
- Monitor your weed control regularly.
- Stop the seedset of survivors. 61

Herbicide resistance has become far more widespread, reducing the effectiveness of a wide range of herbicide MOAs (Photo 11) 62. Rapid expansion of herbicide resistance and the lack of new modes of action (MOA), require that non-herbicide tactics must be a significant component of any farming system and weed management strategy. Inclusion of non-herbicide tactics is critical to prolong the effective life of remaining herbicides, as well as for new products and modes of action that have not yet been released or indeed invented. Effective herbicides are key components of profitable cropping systems. Protecting their efficacy directly contributes to the future sustainability and profitability of cropping systems.



DAF QId (2015) Stopping herbicide resistance in Queensland. DAF QId, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/ broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance

GRDC (n.d.) Section 1. Herbicide resistance. In Integrated Weed Management Hub. GRDC, https://grdc.com.au/Resources/IWMhub/ Section-1-Herbicide-resistance



**TABLE OF CONTENTS** 





SOUTHERN

Photo 11: 2 4-D-resistant radish, Wongan Hills.

Photo: A Storrie, Source: GRDC.

#### How does resistance start?

Resistance starts in a paddock in several ways. Some rare mutations can occur naturally in weeds already in the paddock, with the likelihood varying from 1 plant in 10,000 to 1 in a billion, depending on the weed and the herbicide used against it. A grower may also import weed seed with the herbicide-resistant gene in contaminated feed, seed or machinery. Resistance may also be introduced by natural seed spread by wind and water or by pollen, which may blow in from a contaminated paddock.

# 6.10.3 General principles to avoid resistance

Herbicides have a limited life before resistance develops, and that usable life is even shorter if they are used repeatedly and as the sole means of weed control, particularly in zero- and minimum-till systems. Resistance can develop within four to eight years for Group A and B herbicides, and after 15 years for Group L and M herbicides (see Table 12 and Figure 3). This can be avoided by:

- keeping weed numbers low
- changing herbicide groups
- · using tillage
- rotating crops and agronomic practices <sup>63</sup>

The industry has gained further insight into the impact and efficacy of integrated weed management strategy components through a computer-simulated model. <sup>64</sup>



GRDC IWM Hub, <u>Herbicide resistance</u>



<sup>63</sup> DAF QId (2015) Stopping herbicide resistance in Queensland. DAF QId, <a href="https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance">https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance</a>

<sup>64</sup> DAF QId (2015) Effectiveness of herbicide resistance management strategies. DAF QId, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance/effectiveness-of-resistance-management-strategies</a>





Table 12: Rules of thumb for the number of years of herbicide application before resistance evolves

Herbicide group	Years to resistance
А	6–8
В	4–6
С	10–15
D	10–15
L	15+
М	15+

Source: DAF Qld

Year 1 Before spraying	Year 1 After spraying	3 years later  - before spraying	After spraying
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Figure 3: How a weed population becomes resistant to herbicides.

Source: GRDC

Strategies to prevent or minimise the risk of resistance developing are based on IWM principles as outlined below.

- Ensure survivors do not set seed and replenish the soil seedbank.
- Keep accurate paddock records of herbicide application and levels of control. Monitor weeds closely for low levels of resistance, especially in paddocks with a history of repeated use of the same herbicide group.
- Rotate between the different herbicide groups, and/or tank mix with an effective herbicide from another MOA group. It is important to use effective stand-alone rates for both herbicides in the mix.
- Aim for maximum effectiveness to keep weed numbers low. The primary aim of weed control is to minimise their impact on productivity, and resistance is much less likely to develop in paddocks with few weeds than in heavily infested paddocks.
- Use a wide range of cultural weed control tools in your weed management plan. Sowing different crops and cultivars provides opportunities to use different weed management options on key weeds. Tillage is useful when it targets a major weed flush and minimises soil inversion, as buried weed seed generally persists longer than on the soil surface. Competitive crops will reduce seed production on weed survivors.









 Avoid introduction or spread of weeds by contaminated seed, grain, hay or machinery. Also, manage weeds in surrounding non-crop areas to minimise risk of seed and pollen moving into adjacent paddocks.

SOUTHERN

JANUARY 2018

Specific guidelines for reducing the risk of glyphosate resistance are outlined in Table 13. Aim to include as many as possible of the risk-decreasing factors in your crop and weed management plans.

**Table 13:** Balancing the risk of weeds developing glyphosate resistance, devised by the national Glyphosate Sustainability Working Group.

Risk increasing	Risk decreasing
Continuous reliance on glyphosate preseeding	Double-knock technique with different MOA
Lack of tillage	Strategic use of alternative knockdown groups
Lack of effective in-crop weed control	Full-disturbance cultivation at sowing
Inter-row glyphosate use (unregistered)	Effective in-crop weed control
Frequent glyphosate-based chemical fallow	Use alternative herbicide groups or tillage for inter-row and fallow weed control
High weed numbers	Non-herbicide practices for weed-seed kill
Pre-harvest desiccation with glyphosate	Farm hygiene to prevent resistance movement

Source: DAF Qld

#### Glyphosate-resistant weeds in Australia

Glyphosate resistance was first documented for annual ryegrass in 1996 in Victoria. Since then, glyphosate resistance has been confirmed in 11 other weed species. Resistance is known in eight grass species and four broadleaf species. Four of these are winter-growing species and eight summer-growing species. The latter have been selected mainly in chemical fallows and on roadsides (Photo 12). 65



**Photo 12:** Winter fallow showing an early glyphosate-resistant sow thistle outbreak.

Photo: A Storrie



<sup>65</sup> Australian Glyphosate Sustainability Working Group (n.d.) Glyphosate-resistant weeds in Australia. Australian Glyphosate Sustainability Working Group , <a href="http://glyphosateresistance.org.au/register\_summary.html">http://glyphosateresistance.org.au/register\_summary.html</a>









# **MORE INFORMATION**

<u>Australian glyphosate resistance</u> <u>register</u>

Strategic risk management

Farm business management: making effective business decisions

RIM



WATCH: <u>Act now: Plan your weed</u> management program

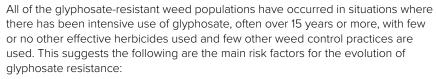


WATCH: Chaff carts 101.



WATCH: <u>Capture weed seeds at harvest: Harrington seed destructor.</u>





SOUTHERN

- Intensive use of glyphosate over 15 years or more.
- Heavy reliance on glyphosate for weed control.
- No other weed controls targeted to stop seed set.

Chemical fallows are heavily dependent on glyphosate for weed control. Therefore, it is highly likely that unconfirmed populations of glyphosate-resistant summer and winter weeds are present in this system. Grape growers are also heavily dependent on glyphosate for weed control. Therefore, it is highly likely that unconfirmed populations of glyphosate resistant annual ryegrass are present in this system. These populations are not recorded on the register of glyphosate resistant populations in Australia. <sup>66</sup>

The <u>online glyphosate-resistance toolkit</u> enables growers and advisers to assess their level of risk for developing glyphosate-resistant weeds on their farm.

# 6.10.4 Ten-point plan to weed out herbicide resistance

WeedSmart has developed a 10-point plan that farmers can use to protect the longevity of chemicals and slow down the development of resistance.  $^{67}$ 

#### 1. Act now to stop weed seedset

Creating a plan of action is an important first step in integrated weed management. A little bit of planning goes a long way.

- Destroy or capture weed seeds.
- Understand the biology of the weeds present.
- Remember that every successful weed-smart practice can reduce the weed seedbank over time.
- Be strategic and committed: herbicide resistance management is not a oneyear decision.
- Research and plan your weed-smart strategy.
- You may have to sacrifice yield in the short term to manage resistance: be proactive.

#### 2. Capture weed seeds at harvest

Destroying or capturing weed seeds at harvest is the number one strategy for combating herbicide resistance and driving down the weed seedbank. There are several ways to do this:

- Tow a chaff cart behind the header.
- Use a Harrington Seed Destructor (Photo 13). 68
- Create and burn narrow windrows.
- Produce hay where suitable.
- Funnel seed onto tramlines in controlled-traffic farming (CTF) systems.
- Use a green or brown manure crop to achieve 100% weed control and build soil nitrogen levels.

Controlling weed seeds at harvest is emerging as the key to managing the increasing levels of herbicide resistance, which is putting Australia's no-till farming system at risk.



 $<sup>{\</sup>tt 66\quad C\ Preston.\ The\ Australian\ Glyphosate\ Sustainability\ Working\ Group.\ \underline{http://www.glyphosateresistance.org.au/}}$ 

<sup>67</sup> WeedSmart. Ten-point plan. WeedSmart, <a href="http://weedsmart.org.au/10-point-plan/">http://weedsmart.org.au/10-point-plan/</a>

<sup>88</sup> A Roginski (2012) Seed destructor shows its national potential. Ground Cover. No. 100. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-issue-100/Seed-destructor-shows-its-national-potential">https://grdc.com.au/Media-Centre/Ground-Cover-issue-100/Seed-destructor-shows-its-national-potential</a>

TABLE OF CONTENTS

**FEEDBACK** 



Photo 13: Harrington weed-seed destructor at work in the paddock.

Source: GRDC

For information on harvest weed-seed control and its application, see <u>Section</u> 12: Harvest.

### 3. Rotate crops and herbicide modes of action

Crop rotation is great for farming systems! Make sure weed management is part of the decision when planning crop rotation. <u>Crop rotation</u> offers many opportunities to use different weed control tactics, both herbicide and non-herbicide, against different weeds at different times. Rotating crops also gives farmers a range of intervention opportunities. For example, we can crop-top lupins and other pulses, swath canola, and delay sowing some crops (e.g. field peas).

Rotations that include both broadleaf crops (e.g. pulses and oilseeds) and cereals allow the use of a wider range of tactics and chemistry.

Growers also have the option of rotating to non-crop options, e.g. pastures and fallows.

Within the rotation it is also important to not repeatedly use herbicides from the same MOA group. Some crops have fewer registered-herbicide options than others, so this needs to be considered too, along with the opportunities to use other tactics, such as the control of harvest weed seed, in place of one or more herbicide applications.

# 4. Test for resistance to establish a clear picture of paddock-bypaddock status

- Before harvest, sample weed seeds and resistance test to determine effective herbicide options.
- Use the 'quick test' option to test emerged ryegrass plants after sowing to determine effective herbicide options before applying in-crop selective herbicides.
- Collaborate with researchers by collecting weeds for surveys during the doubleknock program.
- Visit WeedSmart for more information on herbicide-resistance survey results.

It is clearly too late to prevent the evolution of resistance to many of our common herbicides. However, a resistance test when something new is observed on the farm can be very useful in developing a plan to contain the problem, and in developing new strategies to prevent this resistance evolving further.











WATCH: IWM: Seed test—what's involved



WATCH: Don't cut the rate



WATCH: Don't automatically reach for glyphosate



WATCH: Manage spray drift



Perhaps the best use for herbicide-resistance tests is to use them in a gamechanging situation such as the discovery of a rare resistance gene (e.g. glyphosate resistance) or to determine if a patch of surviving weeds are any worse than what the grower has observed before. This bad patch of weeds gives insight into the future resistance profile of the farm if it is not contained and resistance testing in these situations can be very useful in building preventative strategies.

SOUTHERN

JANUARY 2018

#### 5. Never cut the rate

Australian Herbicide Resistance Initiative (AHRI) researcher Dr Roberto Busi found that ryegrass being sprayed at below the advised rate of Sakura® evolved resistance not only to Sakura® but to Boxer Gold® and Avadex® too. To avoid this problem occurring:

- Use best management practice in spray application: apply according to the directions on the label.
- Consider selective weed sprayers such as WeedSeeker or Weedlt.

## 6. Don't automatically reach for glyphosate

Glyphosate has long been regarded as the world's most important herbicide, so it's natural to reach for it at the first sign of weeds. But what if it didn't work any more? Resistance to this herbicide is increasing rapidly, and in some areas it may fail completely. Why? Too much reliance on one herbicide group gives the weeds opportunities to evolve resistance.

Instead, introduce paraquat products when dealing with smaller weeds, and for a long-term solution farm with a very low seedbank. Also:

- Use a diversified approach to weed management.
- Consider post-emergent herbicides where suitable.
- Consider strategic tillage.

#### 7. Carefully manage spray events

It's important to set up your spray gear to maximise the amount of herbicide that directly hits the target. This makes the spray application more cost-effective by killing the maximum number of weeds possible, and it also protects other crops and pastures from potential damage and/or contamination.

Spray technology has improved enormously in the last 10 years, making it far easier for growers to get herbicides precisely where they need to be. Also, many herbicide labels specify the droplet spectrum to be used when applying the herbicide.

As a general rule, medium to coarse droplet size combined with higher application volumes provides better coverage of the target. Using a pre-orifice nozzle slows droplet speed so that droplets are less prone to bouncing off the target.

Using oil-based adjuvants with air-induction nozzles can reduce herbicide deposition by reducing the amount of air in the droplets. These droplets then fail to shatter when they hit the target, which increases droplet bounce.

- Stop resistant weeds from returning into the farming system.
- Focus on management of survivors in fallows.
- Where herbicide failures occur, do not let the weeds seed. Consider cutting for hay or silage, fallowing or brown manuring the paddock.
- Patch-spray areas of resistant weeds only if appropriate.

#### 8. Plant clean seed into clean paddocks with clean borders

With herbicide resistance on the rise, planting clean seed into clean paddocks with clean borders has become a top priority. Controlling weeds is easiest before the crop is planted, so once that is done plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant ones.

Introducing systems that increase farm hygiene will also prevent new weed species and resistant weeds. These systems could include crop rotations, reducing weed











WATCH: Plant clean seed into clean paddocks with clean borders



WATCH: Best results with double knock tactic



WATCH: Double knock application: a grower's experience



WATCH: Spray application of herbicides: double knock



burdens in paddocks or a harvest weed-seed control such as the Harrington Seed Destructor or windrow burning.

SOUTHERN JANUARY 2018

Lastly, roadsides and fence lines are often a source of weed infestations. Weeds here set enormous amounts of seed because they have little competition, so it's important to control these initial populations by keeping clean borders.

- It is easier to control weeds before the crop is planted.
- Plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant weeds.
- A recent AHRI survey showed that 73% of grower-saved crop seed was contaminated with weed seed.
- The density, diversity and fecundity of weeds are generally greatest along paddock borders and areas such as roadsides, channel banks and fence lines.

### 9. Use the double-knock technique

The beauty of the double-knock technique is in combining two weed-control tactics with different modes of action, on a single flush of weeds. These two 'knocks' happen sequentially, with the second application being designed to control any survivors from the first.

One such strategy is the glyphosate-paraquat double-knock. These two herbicides use different MOAs to eliminate weeds and so make an effective team when paired. When using this combination ensure the paraquat rate is high. The best time to initiate this double-knock is after rainfall. New weeds will quickly begin to germinate and should be tackled at this small stage.

### 10. Employ crop competitiveness to combat weeds

Help your crops win the war against weeds by increasing their competitiveness against weeds. There are numerous options to do this:

- Consider narrow row spacing and increasing seeding rates.
- Consider twin-row seeding points.
- Consider east-west crop orientation.
- Use varieties that tiller well.
- Use high-density pastures as a rotation option.
- Consider brown-manure crops.
- Rethink bare fallows.

# 6.10.5 If you think you have resistant weeds

As soon as resistance is suspected, growers should contact their local agronomist. The following steps are then recommended.

First, consider the possibility of other common causes of herbicide failure by asking:

- Was the herbicide applied in conditions and at a rate that should kill the target weed?
- Did the suspect plants miss herbicide contact or emerge after the herbicide was applied?
- Does the pattern of surviving plants suggest a spray miss or other application problem?
- Has the same herbicide or herbicides with the same MOA been used in the same field or in the general area for several years?
- Has the uncontrolled species been successfully controlled in the past by the herbicide in question or by the current treatment?
- Has a decline in the control been noticed in recent years?
- Is the level of weed control generally good on the other susceptible species?

If resistance is still suspected:





**TABLE OF CONTENTS** 

**FEEDBACK** 



WATCH: <u>Double knock applications:</u> target weed species and application strategy



WATCH: Learn to think outside the drum



WATCH: Crop competition: increasing wheat seeding rate



WATCH: Crop competition: row spacing



Contact crop and food-science researchers in your state agricultural department for advice on sampling suspect plants for testing of resistance status.

SOUTHERN

- Ensure all suspect plants do not set seed.
- If resistance is confirmed, develop a management plan for future years to reduce the impact of resistance and likelihood of further spread. 69

### **Testing services**

For testing of suspected resistant samples, contact:

Plant Science Consulting 22 Linley Avenue, Prospect SA 5082

email: info@plantscienceconsulting.com.au

Phone: 0400 664 460

Charles Sturt University Herbicide Resistance Testing School of Agricultural and Wine Sciences Charles Sturt University Locked Bag 588 Wagga Wagga, NSW 2678 Phone (02) 6933 4001

Charles Sturt University's Graham Centre weed research group

# 6.10.6 Monitoring weeds

Monitoring weed populations before and after any spraying is an important part of management. It encompasses:

- Keeping accurate records.
- Monitoring weed populations and recording results of the herbicide used.
- If herbicide resistance is suspected, preventing weed seedset.
- If a herbicide does not work, finding out why.
- Checking that weed survival is not due to spraying error.
- Conducting your own paddock tests to confirm herbicide failure and determine which herbicides remain effective.
- Obtaining a herbicide-resistance test on seed from suspected plants, testing for resistance to other herbicide MOA groups.
- Working hygienically so as not to introduce or spread resistant weeds in contaminated grain or hay.

Regular monitoring is required to assess the effectiveness of weed management and the expected situation following weed removal or suppression. Without monitoring, it is impossible to accurately assess the effectiveness of a management program or determine how it might be modified for better results. Effective weed management begins with monitoring weeds to assess current or potential threats to crop production, and to determine best methods and timing for control measures.

Regular monitoring and recording details of each paddock allows the grower to:

- spot critical stages of crop and weed development for timely cultivation or other intervention;
- identify the weed flora (species composition), which helps to determine best short- and long-term management strategies; and
- detect new invasive or aggressive weed species while the infestation is still localized and able to be eradicated.

Watch for critical aspects of the weed-crop interaction, such as:

- Weed-seed germination and seedling emergence.
- Weed growth sufficient to affect crops if left unchecked.



 $<sup>{\</sup>sf DAF~Qld~(2015)~Stopping~herbicide~resistance~in~Queensland.~DAF~Qld,} \\ \underline{{\sf https://www.daf.qld.gov.au/plants/field-crops-and-pastures/field$ broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance



**TABLE OF CONTENTS** 





# **MORE INFORMATION**

CropLife Australia

<u>Australian Glyphosate Sustainability</u> Working Group

<u>Australian Herbicide Resistance</u> Initiative

Cotton Info, Weed pack



 The impact of the weed on crops, including harbouring pests, pathogens, or beneficial organisms; or modifying microclimate, air circulation, or soil conditions; as well as direct competition for light, nutrients, and moisture.

SOUTHERN

JANUARY 2018

- · Flowering, seedset, or vegetative reproduction in weeds.
- Efficacy of cultivation and other weed-management practices.

Information gathered through regular and timely field monitoring helps growers to select the best tools and timing for weed-control tactics. Missing vital cues in weed and crop development can lead to costly efforts to rescue a crop, efforts that may not be fully effective. Good paddock scouting can help the grower to obtain the most effective weed control for the least fuel use, labour cost, chemical application, crop damage and soil disturbance.

#### Tips for monitoring

To scout for weeds, walk slowly through the paddock, examining any vegetation that you have not planted. In larger paddocks, walk back and forth in a zigzag pattern to view all parts of the paddock, noting areas of particularly high or low weed infestation. Identify weeds with the help of a good weed guide or identification key for your region, and note the weed species that are most prominent or abundant. Observe how each major weed is distributed through the paddock, noting whether they are randomly scattered, clumped or concentrated in one part of the paddock.

Keep records in a field notebook. Prepare a page for each paddock or crop sown, and take simple notes of weed observations each time the paddock is monitored. Over time, your notes become a timeline of changes in the weed flora over the seasons and in response to crop rotations, cover crops, cultivations and other weed control practices. Many growers already maintain separate records for each paddock. Weed observations (species, numbers, distribution, size) can be included with these.





**TABLE OF CONTENTS** 



# **Insect control**

## Key messages

- To date, triticale varieties are affected by only a few insect pests.
- Triticale has the same insect predators during growth as other cereals, but in general fewer insect control measures are required, with the exception of grainstorage insects.

SOUTHERN

- Triticale is vulnerable to grasshoppers, aphids, armyworms and cutworms.
- Insects are not usually a major problem in cereals, but sometimes they build up to an extent that control is warranted.
- Integrated pest management (IPM) encompasses chemical, cultural and biological control mechanisms to help improve pest control and limit damage to the environment.
- For current chemical control options refer to <u>Pest Genie</u> or the Australian Pesticides and Veterinary Medical Authority (<u>APVMA</u>).

The risks from insect damage in triticale are similar to those for wheat. Triticale is affected by only a few insect pests ¹: it is vulnerable to grasshoppers, aphids, armyworms and cutworms. Management practices for these insects are the same as for other cereals: they should be applied only when continual scouting indicates that the problem has reached an economic threshold for control. ²

Earth mites (redlegged and blue oat mites) can be a problem in early growth, and chemical control may be necessary depending on insect numbers and damage. Aphids may occur in late winter and spring and while usually not a cause of major damage themselves they do transmit Barley yellow dwarf virus (BYDV) and this may warrant control in severe infestations. Monitor seedling crops for lucerne flea, redlegged earth mite and blue oat mite. Seek local advice to determine if the application of insecticide is warranted and ensure grazing withholding periods are met. Aphids can infest early-sown crops and attack the crop again in spring. Early in the season they can spread viral disease while in spring they can cause yield damage. Seek local advice on thresholds and management options. <sup>3</sup>

In the US, it has been recommended to replace early-sown wheat with triticale because of its greater resistance to insect pests. <sup>4</sup> Research in Europe suggests that later sowing may help to limit insect damage to triticale <sup>5</sup>; however, the efficacy of this practice would need to be tested in Australian cropping systems.



M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

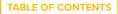
<sup>2</sup> Alberta Agriculture and Forestry (2016) Triticale crop protection. Alberta Agriculture and Forestry, <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10572">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10572</a>

<sup>3</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102">http://www.porkcrc.com.au/1A-102</a> Triticale Guide Final\_Fact\_Sheets.pdf

<sup>4</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>5</sup> H Krusteva, O Karadjova (2011) Impacts of triticale crop sowing date on the insect pest species composition and damage caused. Bulgarian Journal of Agricultural Science, 17 (4), 411–416.









Agronomist's view

SOUTHERN

# 7.1 Potential insect pests

Stay informed about invertebrate pest threats throughout the winter growing season by subscribing to SARDI's <u>PestFacts South Australia</u> and <u>cesar's PestFacts south-eastern.</u>

Subscribers to cesar's PestFacts also benefit from special access to cesar's extensive insect gallery, which can be used to improve skills in identifying pest and beneficial insects. Information from these sources can be combined with information about pest risk on the Queensland Government and GRDC's website of integrated pest management guidelines (Table 1). <sup>6</sup> Table 2 gives a graphic representation of the degree of damage to expect at different cropping stages.

Table 1: Insect pest risk for winter cereals.

High risk	Moderate risk	Low risk	
Soil insects, slugs and snails			
Some crop rotations increase the likelihood of soil insects:	Information on pest numbers prior to sowing	Slugs are rare on sandy soils.	
<ul><li>cereal sown into a long term pasture phase;</li></ul>	from soil sampling, trapping and/or baiting will inform management		
– high stubble loads;	Implementation		
– above average rainfall over summer-autumn.	of integrated slug management strategy		
History of soil insects, slugs and snails	(burning stubble, cultivation, baiting) where history of slugs		
Summer volunteers and brassica weeds will increase slug and snail numbers	Increased sowing rate to compensate for seedling loss caused by establishment pests		
Cold, wet establishment conditions expose crops to slugs and snails	·		
or, posse or ope to orage and or and	Snails are common on sandy soils in SA and western Vic		
Earth mites			
Cereals adjacent to long-term pastures may get mite movement into crop edges	Leaf-curl mite populations (they transmit Wheat streak mosaic virus) can	Seed dressings provide some protection,	
Dry or cool, wet conditions that slows crop growth increases crop susceptibility to damage	be increased by grazing and mild wet summers	except under extreme pest pressure	
History of high mite pressure			



<sup>6</sup> Queensland Government, GRDC (2016) Winter cereals: inset pest risk. In IPM Guidelines, <a href="http://ipmquidelinesforgrains.com.au/crops/winter-cereals/">http://ipmquidelinesforgrains.com.au/crops/winter-cereals/</a>

TABLE OF CONTENTS



Higher risk of Barley yellow dwarf virus (BYDV) disease transmission by aphids in higher rainfall areas where grass weeds are present prior to sowing  Wet summer and autumn promotes survival of aphids on weed and volunteer hosts  Planting into standing stubble can deter aphids landing  Use of seed dressings can reduce levels of virus transmission and delay aphid colonisation  Use of SPS and OPs to control establishment pests can kill beneficial insects and increase the likelihood of aphid survival  Armyworm  Large larvae present when the crop is at late ripening stage  Het autumn and spring promotes the growth of weed hosts (aphids move into crops as weed hosts dry off)  Planting into standing stubble can deter aphids landing  Use of seed dressings can reduce levels of virus transmission and delay aphid colonisation  Use of SPs and OPs to control establishment pests can kill beneficial insects and increase the likelihood of aphid survival  Armyworm  Large larvae present when the crop is at late ripening stage  Rapid crop dry down	High risk	Moderate risk	Low risk
virus (BYDV) disease transmission by aphids in higher rainfall areas where grass weeds are present prior to sowing  Wet summer and autumn promotes survival of aphids on weed and volunteer hosts  Web of seed dressings can reduce levels of virus transmission and delay aphid colonisation  Use of SPs and OPs to control establishment pests can kill beneficial insects and increase the likelihood of aphid survival  Armyworm  Large larvae present when the crop is at late ripening stage  Virus (BYDV) disease transmission weed hosts weed hosts (aphids move into crops as weed hosts (aphids move into crops as weed hosts dry off)  Planting into standing stubble can deter aphids landing  Use of seed dressings can reduce levels of virus transmission)  Use of SPs and OPs to control establishment pests can kill beneficial insects and increase the likelihood of aphid survival  Armyworm  Large larvae present when the crop is at late ripening stage  Papid grop dry down	<u>Aphids</u>		
survival of aphids on weed and volunteer hosts  Stubble can deter aphids landing  Use of seed dressings can reduce levels of virus transmission and delay aphid colonisation  Use of SPs and OPs to control establishment pests can kill beneficial insects and increase the likelihood of aphid survival  Armyworm  Large larvae present when the crop is at late ripening stage  High beneficial insect activity (particularly parasitoids)  Papid crop dry down  Stubble can deter aphids effective for management of virus transmission)  High beneficial insect activity (particularly parasitoids)  Papid crop dry down	virus (BYDV) disease transmission by aphids in higher rainfall areas where grass weeds are present prior to sowing	promotes the growth of weed hosts (aphids move into crops as weed hosts dry off)	areas have a lower risk of BYDV infection High beneficial
Use of seed dressings can reduce levels of virus transmission and delay aphid colonisation  Use of SPs and OPs to control establishment pests can kill beneficial insects and increase the likelihood of aphid survival  Armyworm  Large larvae present when the crop is at late ripening stage  High beneficial insect Activity (particularly parasitoids)  Papid grop dry down	survival of aphids on weed and	stubble can deter aphids	management
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Large larvae present when the crop is at late ripening stage  High beneficial insect No armyworm present at parasitoids)  Papid crop day dawn		control establishment pests can kill beneficial insects and increase the	
crop is at late ripening stage activity (particularly present at parasitoids) vegetative and grain filling	<u>Armyworm</u>		
Stages		activity (particularly parasitoids)	present at vegetative and

SOUTHERN JANUARY 2018

Source: IPM Guidelines

 Table 2: Impact of insect according to crop stage.

Pest	Crop stage			
	Emergence	Vegetative	Flowering	Grainfill
<u>Wireworm</u>	Damaging	Present		
<u>Cutworm</u>	Damaging			
Black headed cockchafer	Damaging	Present		
Earth mites	Damaging	Present		
Slugs, snails*	Damaging			
Brown wheat mite		Damaging		
<u>Aphid</u>	Present	Damaging	Present	Present
<u>Armyworm</u>		Present	Present	Damaging
Helicoverpa armigera				Damaging
Present in crop but ger Crop susceptible to dai * Snails are also a grain cor Source: IPM Guidelines	mage and loss			









Use Table 3  $^{7}$  to assess risk and determine control measures for establishment pests.

SOUTHERN

**Table 3:** Establishment pests affecting cereal crops in the southern cropping region.

	Pre-season	Pre-sowing	Emergence	Crop establishment	
Earth mites	Assess risk	If high risk:	Monitor susceptible crops	As the crop grows,	
and lucerne flea	High risk when:	– use an insecticide seed	through to establishment using direct visual searches.	it becomes less susceptible unless growth is slowed by dry or cool, wet conditions	
	<ul> <li>history of high mite</li> </ul>	dressing on susceptible crops	Be aware of edge effects;		
	pressure	<ul> <li>plan to monitor more frequently until crop</li> </ul>	mites move in from weeds around paddock edges.		
	– pasture rotating into crop	establishment			
	<ul> <li>susceptible crop being planted (e.g. canola, pasture, lucerne)</li> </ul>	<ul> <li>use higher sowing rate to compensate for seedling loss</li> </ul>	If spraying:		
	<ul> <li>seasonal forecast is for dry or cool, wet conditions that</li> </ul>	<ul> <li>consider scheduling a post-emergent insecticide treatment</li> </ul>	<ul> <li>ensure accurate</li> <li>identification of species</li> <li>before deciding on chemical</li> </ul>		
	slow crop growth	If low risk:	– consider border sprays (mites) and 'spot' sprays (lucerne flea)		
	If risk is high:		<ul><li>spray prior to winter egg</li></ul>		
	<ul><li>ensure accurate identification</li></ul>	<ul> <li>avoid insecticide seed dressings (esp. cereal and pulse crops) and</li> </ul>	production to suppress populations and reduce risk		
	<ul> <li>use Timerite® (redlegged earth mites only)</li> </ul>	plan to monitor until crop establishment	in the following season		
	<ul> <li>heavily graze pastures in early-mid spring</li> </ul>				
Slugs	Assess risk	If high risk:	Assess risk	As the crop grows,	
	High risk when:	– burn stubble High risk under cold		it becomes less susceptible unless	
	– high stubble load	<ul> <li>cultivate worst areas</li> </ul>	conditions and slow plant growth	growth is slowed by cool conditions. Re-sowing may be required if	
	– annual average rainfall 450 mm	<ul><li>remove weeds in paddocks/ along fence-lines, at least 8</li></ul>	Use shelter traps or directly search at night when slugs		
	<ul> <li>history of slug infestations</li> </ul>	weeks before sowing	are active to confirm slugs	plant stands are unsatisfactory.	
	– canola being planted	<ul> <li>deploy shelter traps prior to sowing</li> </ul>	as the cause of seedling loss. If slug pressure is high,	unsatisfactory.	
	– summer rainfall	– sow early to get crop	successive baiting may be necessary. Monitoring will		
	– heavy clay soils	established prior to cold conditions	guide bait use.		
		<ul><li>use soil compaction at sowing (e.g. press wheels)</li></ul>			
		<ul> <li>bait at/after sowing prior to emergence</li> </ul>			



<sup>7</sup> Queensland Government, GRDC (2016) Best bet IPM strategy: establishment pests, southern region. On IPM Guidelines, <a href="http://ipmquidelinesforgrains.com.au/wp-content/uploads/BestBet\_EstablishmentSouth2014.pdf">http://ipmquidelinesforgrains.com.au/wp-content/uploads/BestBet\_EstablishmentSouth2014.pdf</a>



TABLE OF CONTENTS





	Pre-season	Pre-sowing	Emergence	Crop establishment
False	Assess risk	Conduct direct visual search	Limited options for control	Damage to
wireworm and true	High risk when:	for adult beetles over summer and autumn. Directly search (in	once crop is sown. Consider re-sowing severely affected	established crops is rare
wireworm	<ul><li>history of wireworm pressure</li></ul>	soil) for beetle larvae 2 weeks prior to sowing.	areas of crop.	
	– soils high in organic matter	If high risk:		
	<ul><li>high stubble and summer/ autumn litter cover</li></ul>	<ul> <li>re-assess crop choice of timing of sowing</li> </ul>		
		<ul> <li>consider an insecticide seed dressing (particularly fipronil) or in-furrow treatment</li> </ul>		
		<ul> <li>use soil compaction at sowing (e.g. press wheels)</li> </ul>		
		<ul> <li>consider higher sowing rate to compensate for seedling loss</li> </ul>		
Scarabs	Assess risk	Dig soil within paddock to	Assess risk	Re-sowing may be an
	High risk when:		High risk when dry conditions	option, but as some species have a 2-year
	– sowing crops into pasture,	If high risk:	slow plant growth	life cycle, larvae can persist through winter
	especially those with a high clover content	– cultivate land	Limited options for control once crop is sown. Larvae of	into spring. ID will
	– previous history of scarab	– avoid sowing grass pastures	most species do not emerge from the soil.	guide this decision.
	damage to crop in that field	<ul> <li>use soil compaction at</li> </ul>	For black-headed pasture	
	<ul> <li>wetter than average seasons</li> </ul>	sowing (e.g. press wheels)	cockchafer, spray around	
	seasons – consider higher s	<ul> <li>consider higher sowing rate to compensate for seedling loss</li> </ul>	heavy dews or light rainfall which will trigger larvae activity	
	Under high pressure:			
	– spray African black beetle adults in spring			
	<ul> <li>void overgrazing pastures</li> </ul>			
Others (e.g.	Assess risk.	If high risk:	Monitor susceptible crops	Damage to
earwigs, slaters,	– high risk when:	<ul><li>burn stubble</li></ul>	through to establishment. Directly search at night to	established crops is rare
millipedes, weevils)	<ul><li>history of high pest pressure</li></ul>	<ul><li>cultivate worst areas</li><li>use cracked wheat baits</li></ul>	confirm pest species as the cause of seedling loss (Note: large numbers of these pests can be found in paddocks without causing crop damage)	
	– minimum/no tillage	<ul> <li>avoid sowing canola</li> </ul>		
	– high stubble load	ŭ		
	– heavier soils		aaage/	
	Monitor in spring using shelter traps, direct searches and/or pitfall traps			

Source: IPM guidelines

# 7.2 Integrated pest management

Pests are best managed by using an integrated pest management (IPM) approach. Careful planning prior to sowing, followed by regular monitoring of crops after sowing, will ensure that potential problems are identified and treated early.

The IPM approach uses a range of management tactics to keep pest numbers below the level where they cause economic damage. It focuses on natural regulation of

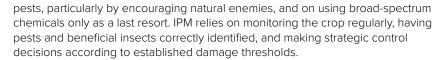


**SOUTHERN** JANUARY 2018



**TABLE OF CONTENTS** 





SOUTHERN
JANUARY 2018

IPM uses a combination of biological, cultural and chemical control methods to reduce insect pest populations. A key aim of IPM is to reduce reliance on insecticides as the sole and primary means of pest control. IPM can improve growers' profitability while reducing environmental damage and limiting the risk of on pesticide exposure on the farm.

# 7.2.1 Key IPM strategies

- Where the risk of establishment pest incidence is low (e.g. earth mites) regular monitoring can be substituted for the prophylactic use of seed dressings.
- Where establishment pests and aphid infestations are clearly a result of invasion from weed hosts around the field edges or neighbouring pasture, a border spray of the affected crop may be sufficient to control the infestation.

### 7.2.2 Insecticide choices

- The redlegged earth mite (RLEM), blue oat mite (BOM), and other mite species can occur in mixed populations. Determine species composition before making decisions as they have different susceptibilities to chemicals.
- Establishment pests have differing susceptibilities to insecticides, synthetic pyrethroids (SPs) and organophosphates (OPs) in particular. Be aware that the use of some pesticides may select for pests that are more tolerant.

### 7.2.3 Insecticide resistance

- RLEM has been found to have high levels of resistance to synthetic pyrethroids such as bifenthrin and alpha-cypermethrin.
- Helicoverpa armigera has historically had high resistance to pyrethroids and the inclusion of biological control agents of IPM are effective where mixed populations of armyworm and *Helicoverpa* spp. occur in maturing winter cereals. <sup>8</sup>

# 7.2.4 Insect sampling methods

Monitoring for insects is an essential part of successful integrated pest management programs. Correct identification of immature and adult stages of both pests and beneficials, and accurate assessment of their presence in the field at various crop stages will ensure appropriate and timely management decisions. Good monitoring procedure involves not just a knowledge of and the ability to identify the insects present, but also good sampling and recording techniques and a healthy dose of common sense.

#### Factors that contribute to quality monitoring

- Knowledge of likely pests and beneficials and their life cycles is essential
  when planning your monitoring program. As well as visual identification, you
  need to know where on the plant to look and what is the best time of day to get
  a representative sample.
- Monitoring frequency and pest focus should be directed at the crop at stages
  when you are likely to incur economic damage. Critical stages may include
  seedling emergence and flowering and grain formation.
- Sampling technique is important to ensure that a representative portion of the crop has been monitored, since pest activity is often patchy. Having defined sampling parameters (e.g. number of samples per paddock and number of leaves per sample) helps sampling consistency. The actual sampling



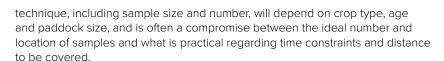


WATCH: <u>Integrated pest management</u>









SOUTHERN

Balancing random sampling with areas of obvious damage is a matter
of common sense. Random sampling aims to give a good overall picture of
what is happening in the paddock, but any obvious hotspots should also be
investigated. The relative proportion of hotspots in a field must be kept in
perspective with less heavily infested areas.

### Keeping good records

Accurately recording the results of sampling is critical for good decision-making and being able to review the success of control measures (Figure 1). <sup>9</sup> Monitoring record sheets should show the following:

- numbers and types of insects found (including details of adults and immature stages)
- size of insects—this is particularly important for larvae
- · date and time
- crop stage and any other relevant information (e.g. row spacing, weather conditions, and general crop observations).

Consider putting the data collected into a visual form that enables you to see trends in pest numbers and plant condition over time. Being able to see whether an insect population is increasing, static or decreasing can be useful in deciding whether an insecticide treatment may be required, and if a treatment has been effective. If you have trouble identifying damage or insects present, keep samples or take photographs for later reference.

Site: Camerons
Date: 15/9/06
Row spacing: 75cm

Sample (1 m row beat)	VS	S	M	L
1	8	5	1	0
2		1	- (	0
3	3	3	0	1
4	3	2	- 1	0
5	2	6	0	0
Average		3.4	0.6	0.2
Adjust for 30% mortality (S*0.7)	(3-420-7)	=2-4		
Mean estimate of larval number (Adjusted S)+M+L	0.6-3.2			

Adjust for row spacing divide by row spacing (m)

3.2

Up- 2 Density Estimate per square metre

**Figure 1:** An example of a field check sheet for chickpeas, showing adjustments for field mortality and row spacings.

Source: DAF Qld

Records of spray operations should include:

- date and time of day
- conditions (wind speed, wind direction, temperature, presence of dew and humidity)
- product(s) used (including any additives)



<sup>9</sup> DAF QId (2012) Insect monitoring techniques for field crops. DAF QId, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/insect-monitoring">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/insect-monitoring</a>

**TABLE OF CONTENTS** 



- amount of product and volume applied per hectare
- method of application including nozzle types and spray pressure
- any other relevant details

# Sampling methods

#### Beat sheet

A beat sheet is the main tool used to sample row crops for pests and beneficial insects (Photo 1). It is particularly effective for sampling caterpillars, bugs, aphids and mites. A standard beat sheet is made from yellow or white tarpaulin material with a heavy dowel on each end. Beat sheets are generally 1.3–1.5 m wide by 1.5–2.0 m deep, with the larger dimensions being preferred for taller crops. The extra width on each side catches insects thrown out sideways when sampling and the sheet's depth allows it to be draped over the adjacent plant row. This prevents insects being flung through or escaping through this row.

SOUTHERN
JANUARY 2018

#### To use the beat sheet:

- Place the sheet with one edge at the base of plants in the row to be sampled.
- Drape the other end over the adjacent row. This may be difficult in crops with wide row spacing (one metre or more) and in this case spread the sheet across the inter-row space and up against the base of the next row.
- Using a one metre stick, shake the plants in the sample row vigorously in the direction of the beat sheet 5–10 times to dislodge insects from the sample row onto the sheet.
- Reducing the number of beat sheet shakes per site greatly reduces sampling precision. The use of smaller beat sheets, such as small fertiliser bags, reduces sampling efficiency by as much as 50%.
- Use datasheets to record type, number and size of insects found on the beat sheet.
- One beat does not equal one sample. The standard sample unit is five non-consecutive one-metre long lengths of row, taken within a 20 m radius; i.e. 5 beats = 1 sample unit. This should be repeated at six locations in the paddock (i.e. 30 beats per paddock).
- The more samples that are taken, the more accurate is the assessment of pest activity, particularly for pests that are patchily distributed such as podsucking bug nymphs.

#### When to use the beat sheet:

- Crops should be checked weekly during the vegetative stage and twice weekly from the start of budding.
- Caterpillar pests are not mobile within the canopy, and checking at any time of the day should result in reporting similar numbers.
- Pod-sucking bugs, particularly green vegetable bugs, often bask on the top of the canopy during the early morning and are more easily seen at this time.
- Some pod-sucking bugs, such as brown bean bugs, are more flighty in the
  middle of the day and therefore more difficult to detect when beat-sheet
  sampling. Other insects (e.g. mirid adults) are flighty no matter what time of day
  they are sampled, so it is important to count them first.
- In very windy weather, bean bugs, mirids and other small insects are likely to be blown off the beat sheet.
- Using the beat sheet to determine insect numbers is difficult when the field and plants are wet.

While the recommended method for sampling most insects is the beat sheet, visual checking in buds and terminal structures may also be needed to supplement beat sheet counts of larvae and other more minor pests. Visual sampling will also assist in finding eggs of pests and beneficial insects.





**TABLE OF CONTENTS** 



Most thresholds are expressed as pests per square metre (pests/m²). Hence, insect counts in crops with row spacing less than one metre must be converted to pests/m². To do this, divide the average insect count per row metre across all sites by the row spacing in metres. For example, in a crop with 0.75 m row spacing, divide the average pest counts by 0.75.

SOUTHERN

JANUARY 2018

#### Other sampling methods

- Visual checking is not recommended as the sole form of insect checking, although it has an important support role. Leaflets or flowers should be separated when looking for eggs or small larvae, and leaves checked for the presence of aphids and silverleaf whitefly. If required, dig below the soil surface to assess soil-insect activity. Visual checking is also important for estimating how the crop is going in terms of average growth stage, pod retention and other agronomic factors.
- Sweep-net sampling is less efficient than beat-sheet sampling and can underestimate the abundance of pest insects in the crop. Sweep netting can be used for flighty insects and is the easiest method for sampling mirids in broadacre crops or crops with narrow row spacing (Photo 1). It is also useful if the field is wet. Sweep netting works best for smaller pests found in the tops of smaller crops (e.g. mirids in mungbeans), is less efficient against larger pests such as pod-sucking bugs, and it is not at all useful in tall crops with a dense canopy such as coastal or irrigated soybeans. At least 20 sweeps must be taken along a single 20 m row.
- Suction sampling is a quick and relatively easy way to sample for mirids. Its
  main drawbacks are unacceptably low sampling efficiency, a propensity to
  suck up flowers and bees, noisy operation, and the high purchase cost of the
  suction machine.
- Monitoring with traps (pheromone, volatile, and light traps) can provide general evidence of pest activity and the timing of peak egg laying for some species. However, it is no substitute for in-field monitoring of actual numbers of pests and beneficials. <sup>10</sup>



**Photo 1:** Using a beat sheet (left) and a sweep net (right) to search for insects.

Sources: The Beatsheet and DAFWA



WATCH: <u>GCTV16</u>: <u>Extension files—IPM</u> <u>beatsheet demo</u>



WATCH: <u>How to use a sweep net to</u> sample for insect pests





<sup>10</sup> DAF QId (2012) Insect monitoring techniques for field crops. DAF QId, <a href="https://www.daf.qld.qov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/insect-monitoring">https://www.daf.qld.qov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/insect-monitoring</a>



TABLE OF CONTENTS

FEEDBACK



WATCH: GCTV11: GRDC's Insect ID app



WATCH: <u>Biopesticides emerge as an alternative cropping tool</u>



# i more information

Insect ID: The Ute Guide is available for <u>Android</u> devices and the <u>iPhone</u>.

IPM Guidelines website

IPM Guidelines, <u>Monitoring tools and techniques</u>

# **Identifying insects**



GRDC's insect ID ute guide is a comprehensive reference for insect pests that commonly affect broadacre crops across Australia, and includes the beneficial insects that may help to control them. Photos have been provided for multiple life-cycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored, and other pests that they may be confused with. Use of this app should result in better management of pests, increased farm profitability and improved chemical usage. <sup>11</sup>

The app features:

- · Region selection.
- Predictive search by common and scientific names.
- Ability to compare photos of insects side by side with insects in the app.
- Identification of beneficial predators and parasites of insect pests
- An option to download content updates inside the app to ensure you're aware of the latest pests affecting crops for each region.
- Ensure awareness of international biosecurity pests.

For pest identification consult the GRDC's Crop insects: Ute Guide Online

# 7.3 Russian wheat aphid

Key points:

- Triticale and rye are thought to be moderately resistant to resistant to Russian wheat aphid.
- Russian wheat aphid is a major pest of cereal crops, found in all major cereal production regions around the world, but not in Australia before 2016.
- During feeding, it injects toxins into the plant that retard growth; heavy infestations will kill the plant.
- Affected plants show whitish, yellow and pink-purple leaf stripes/markings and rolling leaves.
- Russian wheat aphid is approximately 2 mm long, pale yellowish green, with a fine waxy coating. The body is elongated compared with other cereal aphid species (Photo 2).



SOUTHERN

JANUARY 2018

**TABLE OF CONTENTS** 

FEEDBACK



SOUTHERN

Photo 2: The Russian wheat aphid (Diuraphis noxia).

Photo: Michael Nash

The Russian wheat aphid (*Diuraphis noxia*) is a major pest of cereal crops, found in all major cereal production regions around the world. It has only recently been found in Australia. Based on overseas data, RWA tends to favour as hosts, in descending order: barley, durum wheat, bread wheat, triticale, cereal rye, and oats. <sup>12</sup>

Early research on triticale, rye and wheat resistance to RWA suggests that triticale and rye are moderately resistant–resistant to RWA. In this study the highest level of resistance was found in three triticale cultivars that originated, like the RWA, in Russia. <sup>13</sup>

Grain growers and advisers across the southern region are urged to monitor cereal paddocks closely for signs of damage caused by this aphid. If needed, growers should implement a considered management strategy to control the pest.

RWA was recently declared not technically feasible to eradicate from south-east Australia by the National Management Group (NMG) after it was first identified in a wheat crop at Tarlee in South Australia's mid north on 13 May 2016. <sup>14</sup> Since then, the aphid has been identified in cropping regions across South Australia <sup>15</sup> and in the Wimmera and Mallee regions of Victoria. In Victoria, 48 crop samples have been confirmed to have RWA infestations:

- 44 confirmed samples in an area bounded by Edenhope, Stawell, Bendigo, Echuca, Swan Hill, Manangatang, Patchewollock and the South Australian border;
- One sample each at properties to the west of Ararat, to the west of Daylesford, to the west of Werribee, and to the south of Inverleigh (west of Geelong).

Following this declaration, experts are calling on growers and advisers to find, identify, consider aphid numbers and economic thresholds and enact a management strategy (FITE) if needed.

RWA is a major pest of cereal crops worldwide. It is easily spread by the wind and on live plant material. It reproduces asexually, meaning it does not need males and



<sup>12</sup> Farming Ahead (2016) Monitor RWA numbers closely over winter. Kondinin Group, <a href="http://www.farmingahead.com.au/articles/l/12169/2016-06-29/cropping/monitor-rwa-numbers-closely-over-winter">http://www.farmingahead.com.au/articles/l/12169/2016-06-29/cropping/monitor-rwa-numbers-closely-over-winter</a>

<sup>13</sup> KK Nkongolo, JS Quick, WL Meyer, FB Peairs (1989) Russian wheat aphid resistance of wheat, rye, and triticale in greenhouse tests. Cereal Research Communications. 227–232.

<sup>14</sup> A Lawson (2016) Paddock practices southern, June 2016: Monitor RWA numbers closely over winter. GRDC, <a href="https://grdc.com.au/Media-Centre/GRDC-E-Newsletters/Paddock-Practices/Monitor-RWA-numbers-closely-over-winter">https://grdc.com.au/Media-Centre/GRDC-E-Newsletters/Paddock-Practices/Monitor-RWA-numbers-closely-over-winter</a>

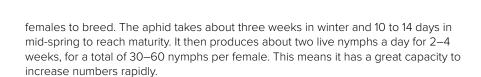
<sup>15</sup> PIRSA (2016) Russian wheat aphid: area affected within South Australia. PIRSA, <a href="http://www.pir.sa.gov.au/">http://www.pir.sa.gov.au/</a> data/assets/pdf file/0006/276432/Russian\_wheat\_aphid\_area\_affected\_20160811.pdf

<sup>16</sup> Agriculture Victoria (2016) Russian wheat aphid. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/russian-wheat-aphid">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/russian-wheat-aphid</a>



**TABLE OF CONTENTS** 





SOUTHERN

Further research is required to determine the impact of local environment factors on RWA population dynamics. <sup>17</sup>

# 7.3.1 Damage caused by RWA

RWA differs from other common cereal aphid species by injecting salivary toxins into the leaf of the host plant during feeding. The toxins kill the photosynthetic chloroplasts, and cause chlorosis and necrosis of the infested leaves. This retards growth and, in cases of heavy infestation, kills the plant. The effect of these toxins is localised and hence only infested leaves will show symptoms. Once the RWA infestation is controlled the new leaf growth is unaffected. <sup>18</sup>

Yield losses are proportionate to RWA abundance, measured as either percentage of plants infested or aphid numbers per shoot. According to overseas data, losses of one tonne per hectare occurred in plants 95% infested with RWA at growth stage (GS) 59. In another overseas study, losses increased from 18% with 15–20 aphids per shoot to 79% with 185–205 aphids per shoot. <sup>19</sup>

#### 7.3.2 Where to look and what to look for

According to South Australian Research and Development Institute (SARDI) entomologists, RWA is being found regularly in early-sown crops and those sown into paddocks containing volunteer cereals. There are also a number of grass-weed and pasture hosts of RWA, including barley grass, brome grass, fescue, ryegrass, wild oats, phalaris and couch grass. RWA particularly favours brome grass, according to overseas information.

Symptoms of RWA damage include longitudinal rolling of leaves where the aphids shelter, and whitish, yellowish to pink-purple chlorotic streaks along the length of the leaves. These symptoms can often be confused with nutrient deficiency or herbicide damage from bleaching herbicides such as diflufenican.

RWA is approximately 2 mm long and a pale yellowish-green colour with a fine, waxy coating. The lack of visible cornicles and elongated body distinguishes RWA from common cereal aphid species.

RWA can be confused with the rose grain aphid; however, it differs due to its dark or black eyes, double short 'tails' (caudal processes), short antennae and apparent lack of cornicles (Figure 2).  $^{20}$ 



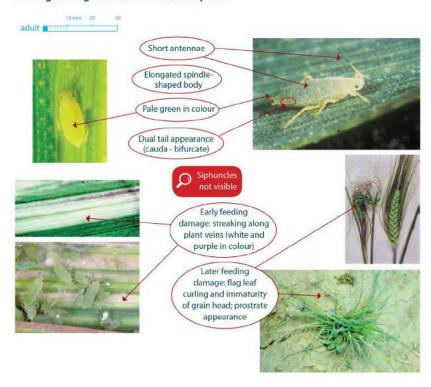
<sup>17</sup> Farming Ahead (2016) Monitor RWA numbers closely over winter. 29 June 2016. Kondinin Group, <a href="http://www.farmingahead.com.au/articles/l/12169/2016-06-29/cropping/monitor-rwa-numbers-closely-over-winter">http://www.farmingahead.com.au/articles/l/12169/2016-06-29/cropping/monitor-rwa-numbers-closely-over-winter</a>

<sup>18</sup> Farming Ahead (2016) Monitor RWA numbers closely over winter. 29 June 2016. Kondinin Group, <a href="http://www.farmingahead.com.au/articles/1/12169/2016-06-29/cropping/monitor-nwa-numbers-closely-over-winter">http://www.farmingahead.com.au/articles/1/12169/2016-06-29/cropping/monitor-nwa-numbers-closely-over-winter</a>

<sup>19</sup> A Lawson (2016) Paddock practices southern, June 2016: Monitor RWA numbers closely over winter. GRDC, <a href="https://grdc.com.au/Media-Centre/GRDC-E-Newsletters/Paddock-Practices/Monitor-RWA-numbers-closely-over-winter">https://grdc.com.au/Media-Centre/GRDC-E-Newsletters/Paddock-Practices/Monitor-RWA-numbers-closely-over-winter</a>

<sup>20</sup> A Lawson (2016) Paddock practices southern, June 2016: Monitor RWA numbers closely over winter. GRDC, <a href="https://qrdc.com.au/Media-centre/GRDC-E-Newsletters/Paddock-Practices/Monitor-RWA-numbers-closely-over-winter">https://qrdc.com.au/Media-centre/GRDC-E-Newsletters/Paddock-Practices/Monitor-RWA-numbers-closely-over-winter</a>

# Distinguishing characteristics/description



SOUTHERN

Figure 2: Distinguishing characteristics of Russian wheat aphid.

Photo: Frank Peairs

Growers are encouraged to work with their agronomist or seek expert advice from an entomologist to help positively identify RWA.

State agriculture departments are keen to take samples of RWA in order to build up scientific information about the pest and sample different populations.

# Measures to increase the likelihood of detecting RWA

The measures that will increase the likelihood of detecting RWA are:

- Target early-sown cereal crops and volunteer cereals (and brome grass, if present), particularly along crop edges.
- Follow a repeatable sampling pattern that targets early-sown and volunteer plants. A perimeter search and a W-shaped search pattern through each paddock will give a consistent sampling effort.
- Look for RWA symptomatic plants:
- Rolling of terminal and sub-terminal leaves (growth stage 20 and above)
- Longitudinal whitish to pink-purplish streaking of leaves (GS20 and above) (Photo 3)  $^{\rm 21}$
- Deformed 'goose-neck' or 'fish-hook' head as result of awn trapped by unrolled flag leaves (GS50 and above) (Photo 4).



<sup>21</sup> Agriculture and Consumer Protection (n.d.) Plate 61. FAO Corporate Document Repository. FAO, <a href="http://www.fao.org/docrep/006/y4011e/y4011e0x.htm">http://www.fao.org/docrep/006/y4011e/y4011e0x.htm</a>

<sup>22</sup> Agriculture and Consumer Protection (n.d.) Plate 62. FAO Corporate Document Repository. FAO, <a href="http://www.fao.org/docrep/006/y4011e/y4011e0x.htm">http://www.fao.org/docrep/006/y4011e/y4011e0x.htm</a>









**Photo 3:** Plants damaged by toxins from feeding RWA, showing stunting and longitudinal striping on tightly rolled leaves.

Source: EA



**Photo 4:** 'Fish hook' deformation of a cereal head (right), caused by feeding RWA, compared to a normal cereal head (left).

Source: FAO

To find the RWA, search within:

- Rolled leaves, particularly in the leaf base (Photo 5).
- Leaf sheaths.
- In high numbers, RWA are being found active on exposed parts at base of plants.
- At low densities plant beating has proven successful for detection. <sup>23</sup>



**SOUTHERN** 

<sup>23</sup> PIRSA (2016) Russian wheat aphid. PIRSA, <a href="http://www.pir.sa.gov.au/biosecurity/plant\_health/exotic\_plant\_pest\_emergency\_response/russian\_wheat\_aphid">http://www.pir.sa.gov.au/biosecurity/plant\_health/exotic\_plant\_pest\_emergency\_response/russian\_wheat\_aphid</a>



# **MORE INFORMATION**

<u>Russian wheat aphid: Taking and</u> submitting samples for identification



### **VIDEOS**

WATCH: GCTV20: Russian wheat aphid—recommendations for ongoing treatment



WATCH: <u>Integrated pest management</u> to combat the Russian wheat aphid





SOUTHERN

JANUARY 2018

Photo 5: Colony of Russian wheat aphids.

Photo: Frank Peairs

### 7.3.3 Thresholds for control

While registered chemical control tactics will be important in managing infestations of RWA, growers are encouraged to consider international economic thresholds (see below) as a guide for when to spray for the pest.

While the economic thresholds for control still need to be determined for Australian conditions, aphid numbers should be a key consideration before making the decision to spray. The key message is not to implement prophylactic insecticide applications, and to reconsider the need to spray where RWA is present in very low numbers.

Current international advice suggests an economic threshold of 20% of plants infested up to the start of tillering and 10% of plants infested thereafter. These thresholds serve as a guide and need to be considered according to the individual situation. The decision to spray should be based on a number of factors including:

- Aphid numbers.
- Crop growth stage and time of season.
- · Crop yield potential.
- The cost of the control option to be employed.
- The presence of Beneficial insect populations.
- Yield loss under Australian conditions.
- Forecast weather conditions.
- · Other insect pests present.

In most of the cases identified in SA and Victoria to date, RWA has been present in very low numbers and infestations have been well below international economic thresholds. Regular monitoring of aphid numbers through winter and spring will be required to ensure appropriate control measures can be implemented as required. Overseas data indicate that RWA is susceptible to heavy winter rainfall, and the combination of cold, wet weather will help check its build up during mid-winter.

To ensure protection of the major yield-contributing leaves it is most important to control RWA below threshold levels from the start of stem elongation, through flagleaf development and ear emergence (GS30–60). Vigilant monitoring for RWA is











# **MORE INFORMATION**

Russian wheat aphid: a new pest for Australian cereal crops

Ramp up monitoring for Russian wheat aphid

Paddock practices, southern, June 2016: Monitor RWA numbers closely over winter

Plant Health Australia, <u>Russian wheat</u> aphid

Russian wheat aphid surveillance reporting sheet (PDF, 279.7 KB)

NSW DPI, <u>Exotic pest alert:</u>
<u>Identification of Russian wheat aphid</u>
and associated damage

PIRSA, <u>Russian wheat aphid: Paddock decontamination protocol</u> (DOC, 197 KB)

Biosecurity Portal, <u>RWA distribution</u> map

encouraged during these crop stages, and should continue through flowering to dough development.  $^{\rm 24}$ 

SOUTHERN
JANUARY 2018

# 7.3.4 Management of RWA

### Control options

An emergency Australian Pesticides and Veterinary Medicines Authority (APVMA) permit, PER82792, has been issued for the use of products containing 500 g/L chlorpyrifos (rate: 1.2 L/ha), with a LI700 surfactant (rate: 240 mL/ha), and products containing 500 g/kg pirimicarb (rate: 200–250 g/ha) to control RWA in winter cereals.

The authority has also issued permit PER82304 for the use of products containing 600 g/L IMIDACLOPRID as their only active constituent. Application rate is 120 mL product per 100 kg seed. This is for seed treatment only, and only for the control of Russian wheat aphid in winter cereals.

Note that these chemical control strategies are likely to change as new data allows for new permits and labels to be produced.

The permits must be read and understood by all persons, and operated on in accordance with the rules:

- Permit 82792 [PDF file, 33.3 KB]
- Permit 82792 [MS Word document, 46.8 KB]
- Permit 82304 [PDF file, 48.2 KB]
- Permit 82304 [MS Word document, 48.0 KB]

Chemical users must read and understand all sections of chemical labels and permits prior to use. There are numerous prohibitory statements on the product labels that it is critical to heed so as to correctly manage the risks associated with the use of the chemicals. Examples of such statements include:

- Do not spray any plants in flower while bees are foraging.
- Do not re-apply to the same crop within seven days (unless specifically recommended in the directions for use).
- Do not apply if heavy rains or storms that are likely to cause surface runoff are forecast in the immediate area within two days of application.
- Do not allow animals or poultry access to treated area within three days of application.

Other instructions that apply are:

- As well as following all prohibitory statements, observe all relevant withholding periods, export slaughter intervals (ESIs) and export grazing intervals (EGIs).
- Adopt best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent properties.
- Keep traffic out of affected areas and minimise movement in adjacent areas. <sup>25</sup>
- As for all field chemical use, it is recommended that users consider the risks
  of chemical use to bees that may be present in the local area. Chemical users
  are encouraged to contact hive owners as soon as possible so they can take
  appropriate steps to minimise the risks to their hives. Contact details can
  generally be found on the hives, or you can contact the owner of the land where
  the hives are located.



<sup>24</sup> A Lawson (2016) Monitor RWA numbers closely over winter. GRDC, <a href="https://grdc.com.au/Media-Centre/GRDC-E-Newsletters/Paddock-Practices/Monitor-RWA-numbers-closely-over-winter">https://grdc.com.au/Media-Centre/GRDC-E-Newsletters/Paddock-Practices/Monitor-RWA-numbers-closely-over-winter</a>

<sup>25</sup> Agriculture Victoria (2016) Russian wheat aphid: Treatment Advice 23/06/2016. Factsheet. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/\_data/assets/word\_doc/0017/321164/Final-RWA-Treatment-Factsheet.docx-docx">http://agriculture.vic.gov.au/\_data/assets/word\_doc/0017/321164/Final-RWA-Treatment-Factsheet.docx-docx</a>



# 7.4 Aphids

Aphids are usually regarded as a minor pest of winter cereals, but in some seasons they can build up to very high densities. Aphids are most prevalent on cereals in late winter and early spring. High numbers often occur in years when there is an early break in the season, and mild weather in autumn and early winter provide favourable conditions for colonisation and multiplication.

SOUTHERN

JANUARY 2018

The major species of aphids that can infest winter cereals are:

- Oat or wheat aphid
- Corn aphid
- · Rose-grain aphid

Aphids are a group of soft-bodied bugs commonly found in a wide range of crops and pastures. Identification of crop aphids is very important when making control decisions. Distinguishing between aphids can be easy in the non-winged form but challenging with winged aphids. See a <u>pictorial guide to distinguishing</u> winged aphids.

# 7.4.1 Oat or wheat aphid

The oat aphid (*Rhopalosiphum padi*) is a relatively common aphid that is most prevalent in wheat and oats. It has an olive-green body with a characteristic rust-red patch on the end of the abdomen. Oat aphids are an important vector of Barley yellow dwarf virus (BYDV). They can affect cereals by spreading BYDV as well as by causing direct-feeding damage to plants when in sufficient numbers. When populations exceed thresholds, the use of targeted spraying with selective insecticides is recommended.

The oat aphid is an introduced species that is a common pest of cereals and pasture grasses. It is widespread, being found in all states of Australia. It typically colonises the lower portion of plants, with infestations extending from around the plant's base, up on to the leaves and stems.

Oat aphids vary in colour from olive-green to greenish-black and are usually identifiable by a dark rust-red patch on the tip of the abdomen, although under some conditions this is not apparent. Adults are approximately 2 mm long, pear-shaped, and have antennae that extend half the body length (Figure 3). Adults may be winged or wingless; they tend to develop wings when plants become overcrowded or unsuitable. <sup>26</sup>

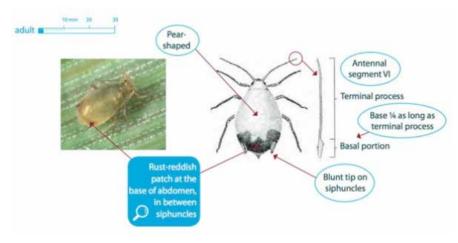


Figure 3: Distinguishing characteristics of oat or wheat aphids.

Source: cesar





# 7.4.2 Corn aphid

The corn aphid (*Rhopalosiphum maidis*) is introduced, and a relatively minor pest of cereal crops. It attacks crops at all stages, but most damage occurs when high populations infest cereal heads. The corn aphid is most prevalent in years when there is an early break to the season, followed by mild weather in autumn. This aphid transmits a number of plant viruses, which can cause significant yield losses.

SOUTHERN

JANUARY 2018

Corn aphids are light green to dark green, with two darker patches at the base of each cornicle (siphuncle). Adults grow up to 2 mm long, have an oblong-shaped body, and antennae that extend to about a third of the body length (Figure 4). The legs and antennae are typically darker in colour.

Nymphs are similar to adults but smaller in size and always wingless, whereas adults may be winged or wingless.  $^{\rm 27}$ 

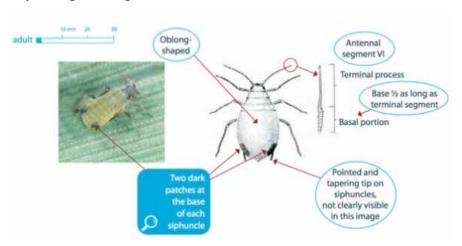


Figure 4: Distinguishing characteristics of corn aphids.

Source: cesar

# 7.4.3 Rose-grain aphid

The rose-grain aphid (*Metopolophium dirhodum*) is an introduced species that has been recorded in South Australia, Victoria, Tasmania, New South Wales and Queensland.

Adults and nymphs are sap-suckers. Under heavy infestations, plants may turn yellow and appear not to be thriving. They can spread Barley yellow dwarf virus in wheat and barley.

Adults are 3 mm long, green to yellow-green, with long and pale siphunculi (tube-like projections on either side at the rear of the body) and may have wings (Photo 6). <sup>28</sup> There is a dark green stripe down the middle of the back. Antennae reach beyond the base of the siphunculi. Nymphs are similar, but smaller in size. Because of its distinctive colour, it is unlikely to be confused with other aphids.



<sup>27</sup> P Umina, S Hangartner (2015) Corn aphid. cesar, <a href="http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Corn-aphid">http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Corn-aphid</a>

<sup>28</sup> DAF QId (2011) Rose-grain aphid. DAP QId, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/rose-grain-aphid">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/rose-grain-aphid</a>



**TABLE OF CONTENTS** 





SOUTHERN
JANUARY 2018

Photo 6: Adult rose-grain aphid with nymphs.

Source: DAF Qld

# 7.4.4 Conditions favouring aphid development

Aphids are most prevalent on cereals in late winter and early spring. High numbers often occur in years when there is an early break in the season, and mild weather in autumn and early winter provide favourable conditions for colonisation and multiplication.

However, they can be found all year round, often persisting on volunteer grasses and self-sown cereals during summer and early autumn. Winged aphids fly into crops from grass weeds, pasture grasses or other cereal crops, and colonies of aphids start to build up within the crop.

The aphids favour different environments:

- Oat aphid—basal leaves, stems and back of ears of wheat, barley and oats.
- Corn aphid—inside the leaf whorl of the plant, where cast skins indicate their presence; it is seldom on wheat or oats.
- Grain aphid—colonises the younger leaves and ears of wheat, oats and barley. <sup>29</sup>

Aphids can reproduce both asexually and sexually, although in Australia the sexual phase is often lost. Aphids reproduce asexually whereby females give birth to live young.

Temperatures during autumn and spring are optimal for aphid survival and reproduction. During these times, the aphid populations may breed several generations. Populations peak in late winter and early spring; development rates are particularly favoured when daily maximum temperatures reach 20–25°C. Young, wingless aphid nymphs develop through several growth stages, moulting at each stage into a larger individual.

Plants can become sticky with the honeydew excreted by aphids. When plants become unsuitable or overcrowding occurs, the population produces winged aphids (alates), which migrate to other plants or crops.



<sup>29</sup> IPM Guidelines (2016) Aphids in winter cereals. IPM Guidelines, <a href="http://ipmquidelinesforgrains.com.au/pests/aphids/aphids-in-winter-cereals/">http://ipmquidelinesforgrains.com.au/pests/aphids/aphids-in-winter-cereals/</a>





# 7.4.5 Thresholds for control

When determining economic thresholds for aphids, it is critical to consider several other factors before making a decision. Most importantly, the current growing conditions and moisture availability should be assessed. Crops that are not moisture stressed have a greater ability to compensate for aphid damage and will generally be able to tolerate far higher infestations than moisture-stressed plants before a yield loss occurs.

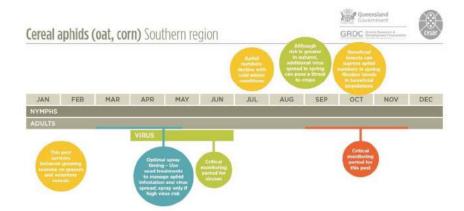
The recommended control rate is more than 15 aphids per tiller on 50% of tillers if the expected yield will exceed 3 t/ha.

Thresholds for managing aphids to prevent the incursion of aphid-vectored virus have not been established and will be much lower than any threshold to prevent yield loss via direct feeding.  $^{30}$ 

Aphid populations can decline rapidly, which may make control unnecessary. In many years aphid populations will not reach threshold levels.

# 7.4.6 Managing aphids

Though aphid numbers are rarely high enough to warrant control, it is important to know the critical periods for aphid management (Figure 5).  $^{31}$ 



**Figure 5:** Lifecycles, critical monitoring and management periods for cereal aphids in the southern region of Australia.

Source: cesar and DAF Qld

#### **Biological control**

There are many effective natural enemies of aphids. Hoverfly larvae, lacewings, ladybird beetles and damsel bugs are known predators that can suppress populations. Aphid parasitic wasps lay eggs inside bodies of aphids and evidence of parasitism is seen as bronze-coloured enlarged aphid 'mummies'. As mummies develop at the latter stages of wasp development inside the aphid host, it is likely that many more aphids have been parasitised than indicated by the proportion of mummies. The naturally occurring aphid fungal diseases *Pandora neoaphidis* and *Conidiobolyus obscurus* can also suppress aphid populations.

#### **Cultural control**

Sowing resistant cereal varieties is the most effective method of reducing losses. See crop variety guides for susceptibility ratings.



P Umina, S Hangartner (2015) Oat aphid. cesar, <a href="http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Oat-aphid">http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Oat-aphid</a>

<sup>81</sup> PIRSA (2015) Pest notes, southern: corn aphid. Fact sheet. PIRSA, SARDI, and cesar, <a href="http://www.pir.sa.gov.au/">http://www.pir.sa.gov.au/</a> data/assets/pdf file/0006/275496/Corn\_Aphid.pdf



**TABLE OF CONTENTS** 





Where feasible, sow into standing stubble and use a high sowing rate to achieve a dense crop canopy, to assist in deterring aphid landings.

**OUTHERN** 

Delayed sowing avoids the autumn peak of cereal aphid activity and reduces the incidence of BYDV. However, delaying sowing generally reduces yields, and this loss must be balanced against the benefit of lower virus incidences.

#### Chemical control

The use of insecticide seed treatments can delay aphid colonisation and reduce early infestation, aphid feeding and the spread of cereal viruses.

There are several insecticides registered against corn aphids in various crops including cereals. A border spray in autumn or early winter, when aphids begin to move into crops, may provide sufficient control without the need to spray the entire paddock.

Avoid the use of broad-spectrum sprays as 'insurance', and apply insecticides only after monitoring and distinguishing between aphid species. Consider the populations of beneficial insects before making a decision to spray, particularly in spring when, if left untouched, these natural enemies can play an important role in suppressing aphid populations. <sup>32</sup>

### Monitoring

Monitor all crop stages from seedling stage onwards. Look on leaf sheaths, stems, within whorls and heads, and record the number of large and small aphids (adults and juveniles), beneficials (including parasitised mummies), and the impact of the infestation on the crop.

Stem elongation to late flowering is the most vulnerable stage. Frequent monitoring is required to detect rapid increases of aphid populations.

Check regularly at at least 5 points in the paddock, and sample 20 plants at each point. Populations may be patchy: densities at crop edges may not be representative of the whole paddock.

The average number of aphids found on samples of stems or tillers gives a useful measurement of their density. Repeated sampling will provide information on whether the population is increasing (lots of juveniles relative to adults), stable, or declining (lots of adults and winged adults). <sup>33</sup>

# 7.5 Cutworm

Cutworms (*Agrotis* spp.) are caterpillars of several species of night-flying moths, one of which is the well-known bogong moth. The mature grubs are plump, smooth caterpillars (Photo 7). <sup>34</sup> The caterpillars are called cutworms because they cut down young plants as they feed on stems at or below the soil surface. They are most damaging when caterpillars transfer from summer and autumn weeds onto newly emerged seedlings. Natural predators and early control of summer and autumn weeds will help reduce larval survival prior to crop emergence. If required, cutworms can be controlled with insecticides; spot spraying may provide adequate control.



IPM Guidelines, <u>Monitoring for insect</u> pests and beneficials

IPM Guidelines, Keeping records



 $<sup>32 \</sup>quad \text{P Umina, S Hangartner (2015) Oat aphid. cesar, } \underline{\text{http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Oat-aphid.}}$ 

<sup>33</sup> IPM Guidelines (2016). Aphids in winter cereals. Queensland Government and GRDC, <a href="http://ipmquidelinesforgrains.com.au/pests/aphids/aphids-in-winter-cereals/">http://ipmquidelinesforgrains.com.au/pests/aphids/aphids-in-winter-cereals/</a>

P Umina, S Hangartner 2015) Cutworm. cesar, <a href="http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Cutworm">http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Cutworm</a>



TABLE OF CONTENTS

**FEEDBACK** 



SOUTHERN

Photo 7: Cutworm larva in typical curled position that it adopts when disturbed.

Source: cesar

There has been a mixed response to cutworm damage in triticale in Australia. In trials in WA, it was found that after being attacked by cutworm four weeks after sowing, triticale could regenerate quickly. 35 In the south-west slopes of New South Wales, near Tarcutta, cutworms were reported to have caused severe damage to a several germinating triticale crops. The damage observed was patchy, although in some areas 100% of the plants died. Most problems were observed in paddocks that had contained weeds and stubble over summer, while clean paddocks that had been cropped in previous years typically had few problems. Prolonged autumn green feed is likely to have allowed caterpillars to develop to a large size by the time crops started to emerge. Chemical control was required in the worst-affected paddocks, and re-sown crops appeared to be emerging well. (The report was published before the crop matured, so the outcome was not recorded.) 36

Cutworms are sporadic pests that are widely distributed in South Australia, Tasmania, Victoria, Western Australia, New South Wales and Queensland, Winter-generation moths emerge in late spring and summer. Eggs are laid onto summer and autumn weeds, where larvae can then emerge onto newly sown crops.

There are several species of pest cutworms, and they are similar in appearance. Generally, the larvae of all species grow to about 40-50 mm long and are relatively hairless, with a distinctly plump, greasy appearance and dark head (Figure 6). 37



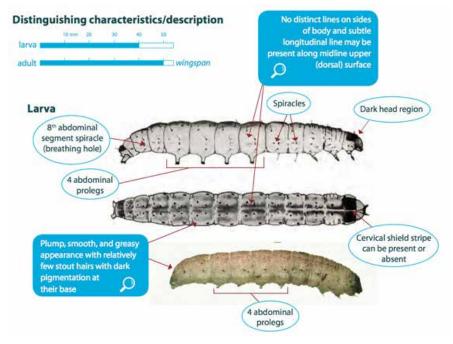
<sup>35</sup> C Johnstone (2011) Triticale variety demonstration 2011. Online Farm Trials, http://www.farmtrials.com.au/trial/10587

McDonald G, Govender A & Umina P. PestFacts south-eastern Issue No. 3 – 21st May 2010. Cutworms. cesar pty ltd. http://www. cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2010/pestfacts-issue-no-3-21st

P Umina, S Hangartner 2015) Cutworm. cesar, <a href="http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Cutworm">http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Cutworm</a>

**TABLE OF CONTENTS** 

FEEDBACK

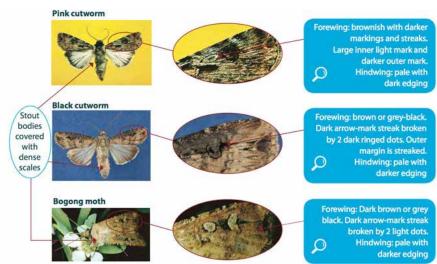


**SOUTHERN** 

Figure 6: Distinguishing characteristics of the cutworm.

Source: cesar

Moths of the common cutworm (sometimes referred to as bogong moths) have dark brown or grey-black forewings with dark arrow markings on each wing, above a dark streak broken by two lighter coloured dots (Figure 7). Moths of the pink cutworm have grey-brown forewings with darker markings and streaks, and a large inner light mark and darker outer mark. Moths of the black cutworm have brown or grey-black forewings with a dark arrow mark broken by two dark rings.



**Figure 7:** Distinguishing characteristics of the adult forms of the pink, black and common cutworm.

Source: cesar

# 7.5.1 Damage caused by cutworms

Larvae feed at ground level, chewing through leaves and stems. Stems are often cut off at the base. Winter crops are most susceptible in autumn and winter, although damage can occur throughout the year, especially in irrigated crops. Damage mostly occurs at night when larvae are active. When numbers of larvae are high, crops can







be severely thinned (Photo 8). Smaller larvae can cause similar damage to lucerne fleas when they feed on the surface tissue of leaves. Young plants are favoured and are more adversely affected than older plants.

SOUTHERN

JANUARY 2018

Occasionally another, undescribed genus of caterpillars, which are marked by a herringbone pattern on the abdomen, inflict cutworm-like damage on emerging crops.



Photo 8: Pink cutworm damage to the plant (left) and paddock (right).

Source: cesar

# 7.5.2 Thresholds for control

Treatment of cereals and canola is warranted if there are two or more larvae per 0.5 m of row.

### 7.5.3 Managing cutworm

The critical periods for controlling cutworm are illustrated in Figure 8.

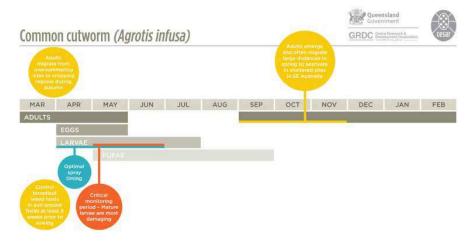


Figure 8: Critical periods for controlling cutworms.

Source: cesar

### **Biological control**

Naturally occurring insect fungal diseases that affect cutworms can reduce populations. Wasp and fly parasitoids, including the orange caterpillar parasite (Netelia producta), the two-toned caterpillar parasite (Heteropelma scaposum) and





**TABLE OF CONTENTS** 





SOUTHERN

the orchid dupe (Lissopimpla excelsa) can suppress cutworm populations. Spiders are generalist predators that will also prey upon cutworms.

#### Cultural control

As autumn cutworm populations may be initiated from populations harboured by crop weeds or volunteers in and around the crop, removal of this green bridge 3-4 weeks before crop emergence will remove food for the young cutworms.

If required, cutworms can be easily controlled with insecticides, and spot spraying may provide adequate control. Spraying in the evening is likely to be most effective.

#### Chemical control

If required, cutworms can be easily controlled with insecticides. Several chemicals are registered for controlling them, the choice depending on the state and crop of registration. Spot spraying often provides adequate control in situations where cutworms are confined to specific regions within paddocks. Spraying in the evening is likely to be more effective as larvae are emerging to feed and insecticide degradation is minimised. 38

#### 7.6 Mites

#### 7.6.1 Redlegged earth mite

The redlegged earth mite (Halotydeus destructor) (RLEM) is a major pest of pastures, crops and vegetables in regions of Australia with cool wet winters and hot, dry summers. This pest costs the Australian grains industry approximately \$44.7 million per year. <sup>39</sup> The RLEM, was accidentally introduced into Australia from the Cape region of South Africa in the early 1900s. The mite is commonly controlled using pesticides, although non-chemical options are becoming increasingly important due to evidence of resistance and concern about the long-term sustainability of pesticide use.

The RLEM is widespread throughout most agricultural regions of southern Australia. It is found in southern NSW, on the east coast of Tasmania, the south-east of SA, the south-west of WA and throughout Victoria (Figure 9). 40 Genetic studies have found high levels of gene flow and migration within Australia. Although individual adults only move short distances between plants in winter, recent surveys have shown an expansion of the range of the mite in Australia over the last 30 years. Long-range dispersal is thought to occur via the movement of eggs in soil that adheres to livestock and farm machinery, or through the transportation of plant material. Movement also occurs during summer when over-summering eggs are transported by wind.



<sup>38</sup> P Umina, S Hangartner (2015) Cutworm. cesar, http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Cutworm

GRDC (2013) Ground cover supplement: emerging issues with diseases, weeds and pests. GRDC, https://grdc.com.au/Media-Centre/ Ground-Cover-Supplements/GCS102

 $P. Umina, S. Hangartner (2015). Red legged earth mite. cesar, \\ \underline{http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/}$ Redlegged-earth-mite



TABLE OF CONTENTS

**FEEDBACK** 



Figure 9: The known distribution of redlegged earth mites in Australia.

Source: cesar

Adult RLEM are 1 mm in length and 0.6 mm wide (i.e. about the size of a pin head) with eight red-orange legs and a completely black velvety body (Figure 10). Newly hatched mites are 0.2 mm long, are pinkish-orange and have six legs. They are not generally visible to the untrained eye. The larval stage is followed by three nymphal stages in which the mites have eight legs and resemble the adult, but are smaller and sexually undeveloped.

Other mite pests, in particular blue oat mites and the Balaustium mite, are sometimes confused with RLEM in the field. Blue oat mites can be distinguished from RLEM by an oval orange-reddish mark on their back, while the Balaustium mite has short hairs covering its body and can grow to twice the adult size of RLEM. Unlike other species that tend to feed singularly, RLEM generally feed in groups of up to 30 individuals.



**SOUTHERN** 

TABLE OF CONTENTS

FEEDBACK

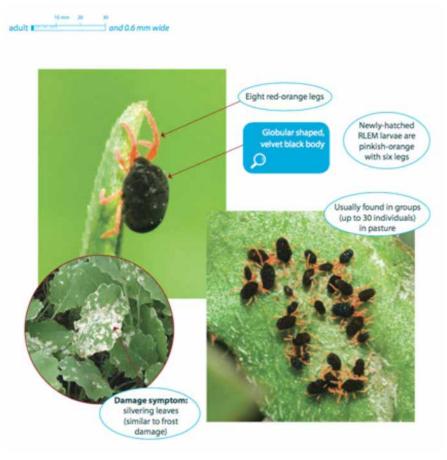


Figure 10: Distinguishing characteristics of RLEM.

Source: cesar

#### Damage caused by RLEM

RLEM hosts include pasture legumes, subterranean and other clovers, medics and lucerne. The mites is particularly damaging to seedlings of all legumes, oilseeds and lupins when it occurs in high numbers. It feeds on ryegrass and young cereal crops, especially oats. It also feeds on several weed species, including Paterson's curse, skeleton weed, variegated thistle, ox-tongue, smooth cats' ear and capeweed.

Typical mite damage appears as silvering or whitening of attacked foliage. Mites use their mouthparts to lacerate the leaf tissue and suck up the sap that is discharged. The resulting cell and cuticle damage promotes desiccation, retards photosynthesis and produces the characteristic silvering that is often mistaken as frost damage. RLEM are most damaging to newly establishing pastures and emerging crops, greatly reducing seedling survival and development. In severe cases, entire crops may need re-sowing following an RLEM attack.

RLEM feeding reduces the productivity of established plants and has been found to be directly responsible for reduction in the palatability of pasture to livestock.

#### Managing RLEM

Carefully inspect susceptible pastures and crops from autumn to spring for the presence of mites and evidence of damage. It is especially important to inspect crops regularly in the first three to five weeks after sowing. Mites are best detected feeding on the leaves in the morning or on overcast days. In the warmer part of the day RLEM tend to gather at the base of plants, sheltering in leaf sheaths and under debris. They will crawl into cracks in the ground to avoid heat and cold. When disturbed during feeding they will drop to the ground and seek shelter.



SOUTHERN

JANUARY 2018

**TABLE OF CONTENTS** 



RLEM compete with other pasture pests, such as blue oat mites, for food and resources. Competition within and between mite species has been demonstrated in pastures and on a variety of crop types. This means control strategies that only target RLEM may not entirely remove pest pressure, because other pests can fill the gap. This can be particularly evident after chemical applications, which are generally more effective against RLEM than other mite pests.

SOUTHERN

JANUARY 2018

It is important to understand the critical phases of the mite's life cycle so as to implement effective control (Figure 11).

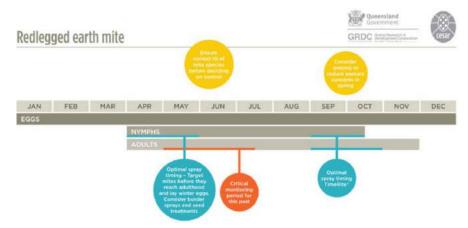


Figure 11: Critical periods for managing RLEM.

Source: cesar

#### Biological control

There is evidence of natural RLEM populations showing resistance to some chemicals, therefore, alternative management strategies are needed to complement current control methods

At least 19 predators and one pathogen are known to attack earth mites in eastern Australia. The most important predators of RLEM appear to be other mites, although small beetles, spiders and ants also play a role in reducing populations. A predatory mite (*Anystis wallacei*) has been introduced as a means of biological control. However, although locally successful, it disperses and establishes only slowly, so the benefits of utilising this mite have yet to be demonstrated.

Preserving natural enemies may prevent RLEM population explosions in established pastures, but this is often difficult to achieve. This is mainly because the pesticides generally used to control RLEM are broad-spectrum and kill beneficial species as well as the pests. The chemical impact on predator species can be minimised by choosing a spray that has least impact and by reducing the number of chemical applications. Although there are few registered alternatives for RLEM, there are groups that have low-moderate impacts on many natural enemies such as cyclodienes.

Natural enemies that inhabit windbreaks and roadside vegetation have been demonstrated to suppress RLEM in adjacent pasture paddocks. However, the application of border sprays to prevent mites moving into a crop or pasture also kills beneficial insects, thereby inadvertently protecting RLEM populations.

#### Cultural control

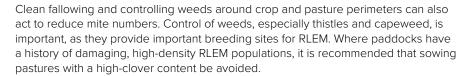
Using cultural control methods can decrease the need for chemical control. Rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival. For example, prior to planting a susceptible crop such as canola, a paddock may be sown to cereals or lentils to help reduce the risk of RLEM population build up. Cultivation can also help reduce RLEM populations by significantly decreasing the number of over-summering eggs. Hot stubble burns can provide a similar effect.





**TABLE OF CONTENTS** 





SOUTHERN

Appropriate grazing management can reduce RLEM populations to below damaging thresholds, possibly because shorter pasture results in lower relative humidity, which increases mite mortality and limits food resources.

Other cultural techniques including modification of tillage practices, trap or border crops, and mixed cropping can reduce overall infestation levels to below the economic control threshold, particularly when employed in conjunction with other measures. 41

#### Chemical control

Chemicals are the most commonly used control against earth mites. While a number of chemicals are registered for control of active RLEM in pastures and crops, there are no currently registered pesticides that are effective against RLEM eggs.

#### Autumn sprays

Controlling first generation mites before they have a chance to lay eggs is the only effective way to avoid the need for a second spray. Hence, pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, before adults begin to lay eggs. The timing of chemical application is critical.

Pesticides with persistent residual activity can be used as bare-earth treatments, either before sowing or at sowing to kill emerging mites. This will protect seedlings which are most vulnerable to damage.

Foliage sprays are applied once the crop has emerged, and are generally effective.

Systemic pesticides are often applied as seed dressings. Seed dressings act by maintaining the pesticide at toxic levels within the growing plant, and affect the mites as they feed. This strategy aims to minimise damage to plants during the sensitive establishment phase. However, if mite numbers are high, plants may be badly damaged before the pesticide has much effect.

#### Spring sprays

Research has shown that one accurately timed spring spray of an appropriate chemical can significantly reduce populations of RLEM the following autumn. This approach works by killing mites before they start producing diapause eggs in mid—late spring. The optimum date can be predicted using climatic variables, and tools such as Timerite® can help farmers identify the optimum date for spraying. Spring RLEM sprays will generally not be effective against other pest mites.

Repeated successive use of the spring spraying technique is not recommended as it could lead to populations evolving resistance to the pesticide. To prevent the development of resistance, the selective rotation of products with different modes of action is advised.



WATCH: <u>Green peach aphid and</u> <u>redlegged earth mite resistance in</u> Australia's southern cropping region

Entomologist Dr Paul
Umina, was a green pear aphids and
redlegged earth mites
in the southern region



**TABLE OF CONTENTS** 



#### 7.6.2 Balaustium mite

The Balaustium mite (*Balaustium medicagoense*), has recently been identified in the Australian grains industry as an emerging pest of winter crops and pasture. This mite is the only species of the genus *Balaustium* recorded in Australia and was probably introduced from South Africa, along with the redlegged earth mite (Halotydeus destructor), in the early 1900s. *It* attacks a variety of agriculturally important plants.

The mite is found sporadically in areas with a Mediterranean climate in Victoria, New South Wales, South Australia and Western Australia (Figure 12). <sup>42</sup> It has also been found in Tasmania, although its exact distribution is unclear. *Balaustium* mites are typically active from March to November, although they can persist on green feed during summer if it is available.

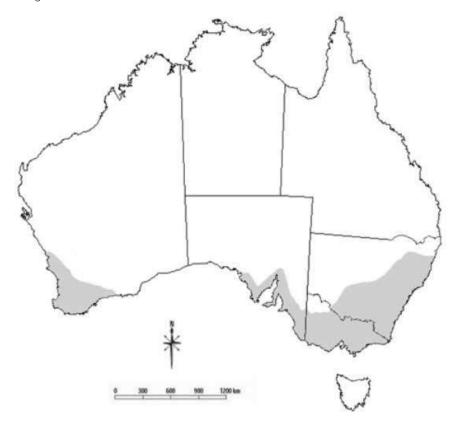


Figure 12: The known distribution of Balaustium mites in Australia.

Source: cesar

Balaustium mites are quite often confused with other pest mites, such as the redlegged earth mite, and the blue oat mite (*Penthaleus* spp.). They have a rounded dark red-brown body and red legs similar to other pest mites, and the distinctly short, stout hairs covering their entire body give them a velvety appearance (Figure 13). Adults reach about 2 mm in size, which is twice the size of other earth mite species. Balaustium mites also have distinct pad-like structures on their front legs, and move slower than redlegged earth mites and blue oat mites.



<sup>42</sup> P Umina, S Hangartner (2015) Balaustium mite. cesar, <a href="http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Balaustium-mite">http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Balaustium-mite</a>



**TABLE OF CONTENTS** 

FEEDBACK

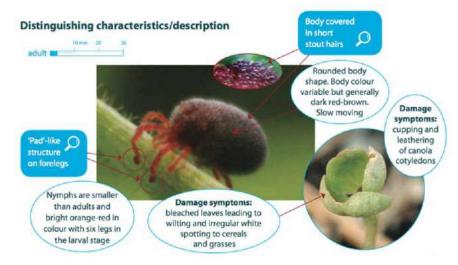


Figure 13: Characteristics of adult Balaustium mite.

Source: cesar

Newly laid eggs of Balaustium mites are light maroon in colour, becoming darker prior to the egg hatching. The bright orange larvae have six legs. The larval stage is followed by a number of nymphal stages in which mites have eight legs and resemble adults, but are much smaller.  $^{43}$ 

#### Damage caused by Balaustium mite

Balaustium mites feed on plants using their adapted mouthparts to probe the leaf tissue of plants and suck up sap. In most situations, they cause little damage, however when numbers are high and plants are already stressed due to other environmental conditions, significant damage to crops can occur. Under high infestations, seedlings or plants can wilt and die. Balaustium mites typically attack leaf edges and leaf tips.

There are no economic thresholds for this pest.

#### Management

It is important to understand the critical phases of the mite's life cycle so as to implement the most effective control (Figure 14).



Figure 14: Critical periods for Balaustium mite management.

Source: cesar



<sup>43</sup> D Grey (2010) Balaustium mite. Note AG1413. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/</a> pest-insects-and-mites/balaustium-mite



**TABLE OF CONTENTS** 





APVMA



The impact of mite damage is increased when plants are under stress from adverse conditions such as prolonged dry weather or waterlogged soils. Ideal conditions for seedling growth enable plants to tolerate higher numbers of Balaustium mites. Carefully inspect susceptible pastures and crops from autumn to spring for the presence of mites and evidence of damage. It is especially important to inspect crops regularly in the first three to five weeks after sowing.

SOUTHERN

Crops sown into paddocks that grew pasture the previous year should be regularly inspected for Balaustium mites. Weeds present in paddocks prior to cropping should also be checked for the presence and abundance of Balaustium mites. Mites are best detected when feeding on the leaves, especially on or near the tips, during the warmest part of the day. They are difficult to find when conditions are cold and/or wet.

One of the most effective methods to sample mites is using a D-vac. Typically, a standard petrol-powered garden blower-vacuum machine, e.g. those manufactured by Stihl or Ryobi, is used. A sieve is placed over the end of the suction pipe to trap mites vacuumed from plants and the soil surface.

#### Biological control

There have been no biological control agents (predators or parasites) identified in Australia that are effective in controlling Balaustium mites. Alternative methods such as cultural control can prove to be effective at controlling this mite. Early control of summer weeds, within and around paddocks, especially capeweed and grasses can help prevent mite outbreaks. Rotating crops or pastures with non-host crops can also reduce pest colonisation, reproduction and survival. For example, prior to planting a susceptible crop like cereals or canola, a paddock could be sown to a broadleaf plant that Balaustium mites have not been reported to attack, such as vetch. 44

#### Chemical control

Currently no chemical has been registered to control Balaustium mite in any state or territory of Australia. The APVMA maintains a database of all chemicals registered for the control of agricultural pests in Australia. When a chemical is approved, it will appear on the database, so check the website for changes, or consult chemical resellers or a local chemical standards officer.

#### 7.6.3 Blue oat mite

Blue oat mites (Penthaleus spp.) are species of earth mites that are major agricultural pests in southern Australia and other parts of the world, attacking various pasture, vegetable and crop plants. Blue earth mites (BOM) were introduced from Europe, and were first recorded in New South Wales in 1921. Management of these mites in Australia has been complicated by the recent discovery of three distinct species of BOM, which had previously been believed to be a single species.

The three species are Penthaleus major, P. falcatus and P. tectus. Although they are commonly found in Mediterranean climates in Victoria, New South Wales, South Australia, Western Australia and eastern Tasmania (Figure 15) 45, the distribution of each species differs.



 $D \ Grey \ (2010) \ Balaustium \ mite. \ Note \ AG1413. \ Agriculture \ Victoria, \\ \underline{http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/diseases-$ 

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TABLE OF CONTENTS





SOUTHERN

Figure 15: The known distribution of blue oat mites in Australia.

Source: cesar

Adult BOM are 1 mm in length and approximately 0.7–0.8 mm wide, with 8 redorange legs. They have a blue-black coloured body with a characteristic red mark on their back (Figure 16). Larvae are approximately 0.3 mm long, are oval in shape, and have three pairs of legs. On hatching, BOM are pink-orange in colour, soon becoming brownish and then green.





TABLE OF CONTENTS





Figure 16: Distinguishing characteristics of blue oat mite.

Source: cesar

BOM are often misidentified as redlegged earth mites in the field, which has meant that the damage caused by BOM has been under-represented. Despite having a similar appearance, RLEM and BOM can be readily distinguished from each other: RLEM have a completely black body and tend to feed in larger groups of up to 30 individuals, whereas BOM have the red mark on their back and are usually found singularly or in very small groups.

#### Damage caused by BOM

Feeding causes silvering or white discoloration of leaves and distortion, or shrivelling in severe infestations. When there are large mite populations, Affected seedlings can die at emergence. Unlike redlegged earth mites, blue oat mites typically feed singularly or in very small groups.

Mites use adapted mouthparts to lacerate the leaf tissue of plants and suck up the sap discharged. Resulting cell and cuticle destruction promotes desiccation, retards photosynthesis and produces the characteristic silvering that is often mistaken as frost damage (Photo 9). 46 BOM are most damaging to newly establishing pastures and emerging crops, greatly reducing seedling survival and retarding development.



SOUTHERN

JANUARY 2018

 $Agriculture\ Victoria\ (2007)\ Blue\ oat\ mite.\ Note\ AG\ 1300.\ Agriculture\ Victoria\ , \\ \underline{http://agriculture.vic.gov.au/agriculture/pests-diseases-and-pests-d$ weeds/pest-insects-and-mites/blue-oat-mite

TABLE OF CONTENTS





Photo 9: Typical blue oat mite damage to leaf.

Source: Agriculture Victoria

Young mites prefer to feed on the sheath leaves or tender shoots near the soil surface, while adults feed on more mature plant tissues. Feeding reduces the productivity of established plants and is directly responsible for reductions in pasture palatability to livestock. Even in established pastures, damage from large infestations may significantly affect productivity.

The impact of mite damage is increased when plants are under stress from adverse conditions such as prolonged dry weather or waterlogged soils. Ideal growing conditions for seedlings enable plants to tolerate higher numbers of mites.

#### **Managing BOM**

It is important to understand the critical phases of the mite's life cycle so as to implement the most effective control (Figure 17).

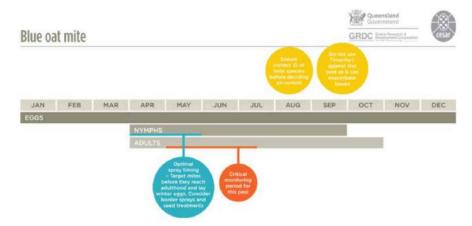


Figure 17: Critical time periods for managing BOM.

Source: cesar

#### Biological control

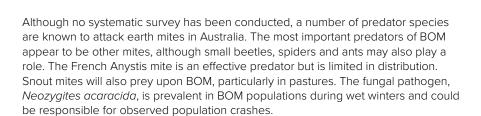
Integrated pest management programs can complement current chemical control methods by introducing non-chemical options, such as cultural and biological control.





**TABLE OF CONTENTS** 





OUTHERN

Preserving natural enemies when using chemicals is often difficult because the pesticides generally used are broad-spectrum and kill the beneficial species as well as the pests. Impact on natural enemies can be reduced by using a pesticide that has the least impact and by minimising the number of applications. Although there are few registered alternatives for BOM control, there are groups such as the chloronicotinyls, which are used in some seed treatments, that have low-moderate impacts on many natural enemies.

#### Cultural control

Cultural controls such as rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival, decreasing the need for chemical control. When P. major is the predominant species, canola and lentils are potentially useful rotation crops, while pastures containing predominantly thick-bladed grasses should be carefully monitored and rotated with other crops. In situations where P. falcatus is the most abundant mite species, farmers can consider rotating crops with lentils, while rotations that involve canola may be the most effective means of reducing the impact of P. tectus.

Many cultural control methods for BOM can also suppress other mite pests, such as RLEM. Cultivation will significantly decrease the number of over-summering eggs, while hot stubble burns can provide a similar effect. Many broad-leaved weeds provide an alternative food source, particularly for juvenile stages. As such, clean fallowing and the control of weeds within crops and around pasture perimeters, especially bristly ox-tongue and cats ear, can help reduce BOM numbers.

Appropriate grazing can also reduce mite populations to below damaging thresholds. This may be because shorter pasture results in lower relative humidity, which increases mite mortality and limits food resources. Grazing pastures in spring to less than 2 t/ha feed on offer (dry weight), can reduce mite numbers to low levels and provide some level of control the following year. 47

#### Chemical control

Chemicals are the most common method of control against earth mites. Unfortunately, all currently registered pesticides are only effective against the active stages of mites: they do not kill eggs.

While a number of chemicals are registered in pastures and crops, differences in tolerance levels between species complicates management of BOM. P. falcatus has a high natural tolerance to a range of pesticides registered against earth mites in Australia, and is responsible for many control failures involving earth mites. The other BOM species have a lower level of tolerance to pesticides and are generally easier to control with chemicals in the field.

Chemical sprays are commonly applied at the time of infestation, when mites are at high levels and crops already show signs of damage. Control of first-generation mites before they can lay eggs is an effective way to avoid having to spray a second time. Pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, as adults will then begin laying eggs. While spraying pesticides in spring can greatly reduce the size of RLEM populations the following autumn, this strategy will generally not be as effective for the control of BOM.

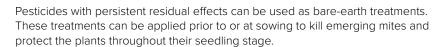


Agriculture Victoria (2007). Blue oat mite. http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/ blue-oat-mite



TABLE OF CONTENTS





SOUTHERN

Systemic pesticides are often applied as seed dressings to maintain the pesticide at toxic levels within the plants as they grow. This can help minimise damage to plants during the sensitive establishment phase; however, if mite numbers are high, significant damage may still occur before the pesticide has much effect.

To prevent the build-up of resistant populations, spray pesticides only when necessary and rotate pesticides from chemical classes with different modes of action. To avoid developing multiple pesticide resistance, rotate chemical classes across generations rather than within a generation.

Information on the registration status, rates of application, and warnings related to withholding periods, occupational health and safety (OH&S), residues and off-target effects should be obtained before making decisions on which pesticide to use. This information is available from the chemical standards branch of your state agriculture department, chemical resellers, APVMA and the pesticide manufacturer. Always consult the label and material safety data sheet (MSDS) before using any pesticide.

#### 7.6.4 Bryobia mite

There are over 100 species of Bryobia mite worldwide, with at least seven found in Australian cropping environments. Unlike other broadacre mite species, which are typically active from autumn to spring, Bryobia mites prefer the warmer months of the year. Bryobia mites are smaller than other commonly occurring pest mites. They attack pastures and numerous winter crops earlier in the season.

Bryobia mites (sometimes referred to as clover mites) are sporadic pests. They are unlikely to be a problem over winter, although they can persist throughout all months of the year. They are broadly distributed throughout most agricultural regions in southern Australia with a Mediterranean-type climate, including Victoria, South Australia, New South Wales and Western Australia (Figure 18). 48 They have also been recorded in Tasmania and Queensland.



P. Umina, S. Hangartner, G. McDonald (2015) Bryobia mite. cesar, <a href="http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/">http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/</a>.Bryobia-mite

**TABLE OF CONTENTS** 

**FEEDBACK** 



Figure 18: Known distribution of Bryobia mites in Australia.

Bryobia mites reach no more than about 0.75 mm in length as adults. They have an oval shaped, dorsally flattened body that is dark grey, pale orange or olive in colour, and eight pale red-orange legs. The front pair of legs is much larger than the others, and approximately 1.5 times their body length. If seen under a microscope, they have a sparsely distributed set of broad, spade-like hairs, that appear like white flecks (Figure 19).

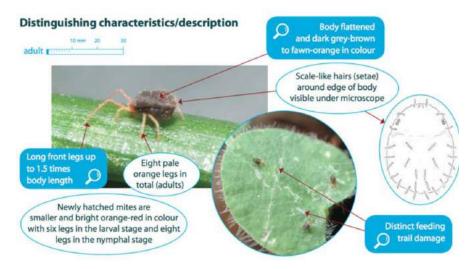


Figure 19: Distinguishing characteristics of Bryobia mites.

Source: cesar







#### Damage cause by Bryobia mites

Bryobia mites tend to cause the most damage in autumn where they attack establishing pastures and emerging crops, greatly reducing seedling survival and retarding development. They feed on the upper surfaces of leaves and cotyledons by piercing and sucking up leaf material. This feeding causes distinctive trails of whitishgrey spots on leaves. Extensive feeding damage can lead to cotyledons shrivelling. On grasses, Bryobia mite feeding can resemble that of redlegged earth mites.

SOUTHERN

There are no economic thresholds for control.

#### Managing Bryobia mites

To know the best times and methods for controlling Bryobia mites, it is important to understand their life cycle (Figure 20).  $^{49}$ 

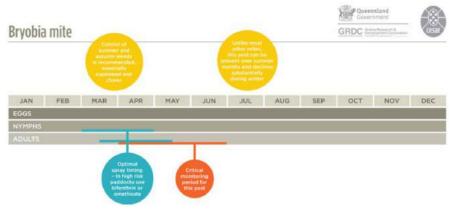


Figure 20: Critical control periods for the Bryobia mite.

Source: cesar

#### Biological control

There are currently no known biological control agents for Bryobia mites in Australia.

#### Cultural control

Crops that follow pastures with a high clover content are most at risk. Avoid planting susceptible crops such as canola, lupins, vetch and lucerne into these paddocks. Early control of summer and autumn weeds within and around paddocks, especially broadleaf weeds such as capeweed and clovers, can help prevent mite outbreaks.

#### Chemical control

Some insecticides are registered for use against Bryobia mites; however, be aware that recommended rates used against other mites might be ineffective against *Bryobia* spp., which have a natural tolerance to several chemicals. Insecticides do not kill mite eggs. Generally organophosphate insecticides provide better control against Bryobia mites than synthetic pyrethroids. <sup>50</sup>

#### 7.7 Lucerne flea

The lucerne flea (*Sminthurus viridis*) is a springtail that is found in both the northern and southern hemispheres but is restricted to areas that have a Mediterranean climate. It is thought to have been introduced to Australia from Europe and has since become a significant agricultural pest of crops and pastures across the southern states. It is not related to the fleas which attack animals and humans.



<sup>49</sup> P Umina, S Hangartner, G McDonald (2015) Bryobia mite. cesar, <a href="http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Bryobia-mite">http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Bryobia-mite</a>

<sup>50</sup> P Umina, S Hangartner, G McDonald (2015) Bryobia mite. cesar, <a href="http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Bryobia-mite">http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Bryobia-mite</a>







Lucerne fleas are common pests found in Victoria, Tasmania, South Australia, New South Wales and Western Australia (Figure 21). Higher numbers are often found in the winter rainfall areas of southern Australia, including Tasmania, or in irrigation areas where moisture is plentiful. They are generally more problematic on loam/clay soils. Lucerne fleas are often patchily distributed within paddocks and across a region.

SOUTHERN



Figure 21: The known distribution of the Lucerne flea in Australia.

The lucerne flea (Sminthurus viridis) is a springtail; this is a group of arthropods that have six or fewer abdominal segments and a forked tubular appendage or furcula under the abdomen. It is not related to the true fleas. Springtails are one of the most abundant of all macroscopic insects and are frequently found in leaf litter and other decaying material, where they are primarily detritivores. Very few species, among them the lucerne flea, are regarded as crop pests around the world.

The adult lucerne flea is approximately 3 mm long, light green—yellow in colour and often with mottled darker patches over the body. It is wingless and has an enlarged, globular abdomen (Figure 22). 51 Newly hatched nymphs are pale yellow and 0.5–0.75 mm long, and as they grow they resemble adults, but are smaller.



 $P. Umina, S. Hangartner, G. McDonald (2015) \\ Lucerne flea. cesar, \\ \underline{http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/}$ Lucerne-flea

**TABLE OF CONTENTS** 

FEEDBACK

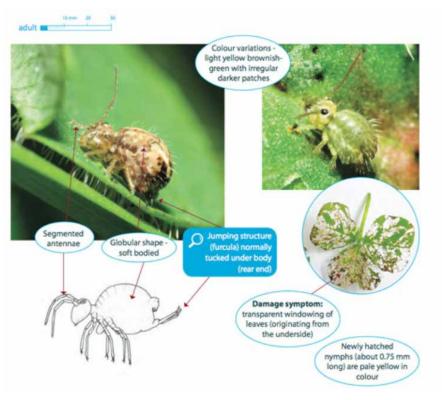


Figure 22: Distinguishing characteristics of the lucerne flea.

Source: cesar

## 7.7.1 Damage caused by the lucerne flea

Although grasses and cereals are not preferred hosts, lucerne fleas can cause damage to ryegrass, wheat and barley crops. In pastures, lucerne fleas have a preference for subterranean clover and lucerne.

Lucerne fleas move up plants from ground level, eating tissue from the underside of foliage. They use a rasping process to consume the succulent green cells of leaves, avoiding the more fibrous veins and leaving behind a layer of leaf membrane. This makes the characteristic small, clean holes in leaves which can appear as numerous tiny 'windows'. In severe infestations this damage can stunt or kill plant seedlings.

#### 7.7.2 Managing the lucerne flea

Monitoring is the key to reducing the impact of the lucerne flea. Crops and pastures grown in areas where the lucerne flea has previously been a problem should be monitored fortnightly for damage from autumn through to spring. Weekly monitoring is better where there have been problems in previous years. Susceptible crops and pastures should also be carefully inspected for the presence of the flea and evidence of the damage it causes.

It is important to frequently inspect winter crops, particularly canola and pulses, in the first three to five weeks after sowing, as crops are most susceptible to damage immediately following the emergence of seedlings.

Lucerne fleas are often concentrated in localised patches or hot spots, so it is important to have a good spread of monitoring sites in each paddock. Examine foliage for characteristic lucerne flea damage and check the soil surface where insects may be sheltering.

Some sprays must be applied at a particular growth stage, so it is also important to note the growth stage of the population. Spraying immature lucerne fleas before





TABLE OF CONTENTS



they have a chance to reproduce can effectively reduce the size of subsequent generations.

Lucerne fleas compete for food and resources with other agricultural pests, such as redlegged earth mites and blue oat mites. This means control strategies that only target one species may not reduce the overall pest pressure because other pests can fill the gap. It is therefore important to assess the complex of pests before deciding on the most appropriate control strategy.

SOUTHERN

JANUARY 2018

#### Biological control

Several predatory mites, various ground beetles, and spiders prey on lucerne fleas. Snout mites (which have orange bodies and legs) are particularly effective predators of this pest (Photo 10). The pasture snout mite (Bdellodes lapidaria) and the spiny snout mite (Neomulgus capillatus), have been the focus of biological control efforts against lucerne fleas.

The pasture snout mite was originally found in Western Australia but has since been distributed to eastern Australia, where there are some examples of this mite successfully reducing lucerne flea numbers. Although rarer, the spiny snout mite can also drastically reduce lucerne flea populations, particularly in autumn.



Photo 10: Predatory adult snout mite.

Photo: A. Weeks

#### Cultural control

Appropriate grazing management can reduce lucerne flea populations to below damaging thresholds. This may be because shorter pasture limits food resources and lowers the relative humidity, which increase insect mortality.

Broad-leaved weeds can provide alternative food sources, particularly for juvenile stages. Clean fallowing and the control of weeds, especially capeweed, within crops and around pasture perimeters, can therefore help reduce lucerne flea numbers.

Other cultural techniques such as cultivation, trap crops and border crops, and mixed cropping can help reduce overall infestation levels to below economically damaging levels, particularly when employed in conjunction with other measures. Grasses are less favourable to the lucerne flea and as such can be useful for crop borders and pastures.





**TABLE OF CONTENTS** 



In pastures, avoid clover varieties that are more susceptible to lucerne flea damage, and avoid planting susceptible crops such as canola and lucerne into paddocks with a history of lucerne flea damage. 52

#### Chemical control

Lucerne fleas are commonly controlled post-emergence, usually after damage is first detected. Control is generally achieved with an organophosphate insecticide (e.g. omethoate). In areas where damage is likely, a border spray may be sufficient to stop invasion from neighbouring pastures or crops. In many cases, spot spraying, rather than blanket spraying, may be all that is required.

If the damage warrants control, treat the infested area with a registered chemical approximately three weeks after lucerne fleas have been observed on a newly emerged crop. This will allow for the further hatch of over-summering eggs but will occur before the lucerne fleas reach maturity and begin to lay winter eggs.

In pastures, a follow-up spray may be needed roughly four weeks after the first spray to control subsequent hatchings, and to kill new insects before they lay more eggs. Grazing the pasture before spraying will help open up the canopy to ensure adequate spray coverage. The second spray is unlikely to be needed if few lucerne fleas are observed at that time.

Crops are most likely to be damaged where they follow a weedy crop or a pasture in which lucerne fleas have not been controlled. Therefore, controlling the fleas in the season prior to the sowing of susceptible crops is recommended.

Caution is advised when selecting an insecticide. Several chemicals registered for redlegged earth mites (i.e. synthetic pyrethroids such as cypermethrin) are known to be ineffective against lucerne fleas. When both lucerne fleas and redlegged earth mites are present, it is recommended that control strategies account for both pests: use a product registered for both, at the higher rate of the two, to ensure effective control.

Information on the registration status, rates of application and warnings related to withholding periods, OH&S, residues and off-target effects should be obtained before making decisions on which insecticide to use. This information is available from the chemical standards branch of your state agriculture department, chemical resellers, APVMA and the pesticide manufacturer. Always consult the label and MSDS before using any insecticide.

#### 7.8 **Armyworm**

Armyworms are caterpillar pests of grass pastures and cereal crops. They are the only caterpillars that growers are likely to encounter in cereal crops, although occasionally native budworms will also attack grain when underlying weed hosts dry out. Armyworms mostly feed on leaves, but under certain circumstances will feed on the seed stem, resulting in head loss. The change in feeding habit is caused by depletion of green leaf material or crowding. In the unusual event of extreme food depletion and crowding, armyworms will 'march' out of crops and pastures in search of food, hence their common name.

Barley, oats and rice are most susceptible to economic damage, but armyworms are also commonly found in wheat, triticale and grass pastures where extreme defoliation or head loss occasionally occurs.

There are three common species of armyworm found in southern Australia:

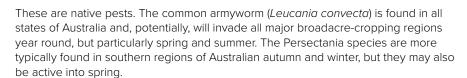
- common armyworm (Leucania convecta)
- southern armyworm (Persectania ewingii)
- inland armyworm (Persectania dyscrita)



 $G\ McDonald\ (2008)\ Lucerne\ flea.\ Note\ AG0415.\ Updated.\ Agriculture\ Victoria,\ \underline{http://agriculture.vic.gov.au/agriculture/pests-diseases-to$ and-weeds/pest-insects-and-mites/lucerne-flea

**TABLE OF CONTENTS** 





SOUTHERN

JANUARY 2018

Caterpillars of the three species are similar in appearance. They grow from about 2 mm to 40 mm in length. They have three prominent white or cream stripes running down the back and sides of their bodies. They are most obvious where they start on the thoracic segment ('collar') immediately behind the head, and become apparent in larvae that are >10 mm. They have no obvious hairs, are smooth to touch and curl up when disturbed. Armyworms have four abdominal prolegs (Figure 23). 53

Mature caterpillars are 30–40 mm long. For accurate identification, they must be reared through to the adult (moth) stage.

Armyworms can be distinguished from other caterpillar pests that may be found in the same place by their stripes, which stay constant no matter what variation there is in the colour of the body. Other species of caterpillar which may be confused with armyworms include:

loopers (tobacco looper or brown pasture looper) which walk with a distinct looping action and have one or two pairs of abdominal prolegs—whereas armyworms have four pairs, and do not walk with a looping action once they are >10 mm.

budworm larvae, which have prominent but sparse hairs and bumps on their skin, or anthelid larvae which are covered in hairs—whereas armyworms are smooth-bodied with no obvious hairs.

cabbage moth larvae, which wriggle vigorously when disturbed—whereas armyworms curl up into a tight C.

 cutworm (brown or common cutworm) larvae, which have no obvious stripes or markings and are uniformly brown, pink or black.

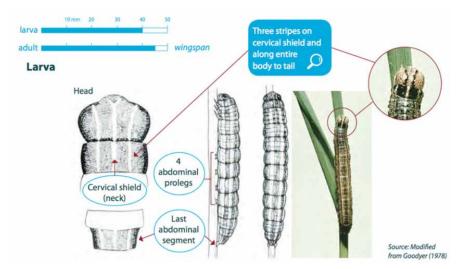


Figure 23: Distinguishing characteristics of armyworm larvae.

Source: cesar

The moths are often seen flying on warm, humid nights. They are medium-sized, with a wingspan of 30–40 mm. Each species has a characteristic colour and wing markings (Figure 24):

Southern armyworm—grey-brown to red-brown forewings with white zigzag markings on the outer tips and a pointed white 'dagger' in the middle of the forewing, and dark grey hind wings.





**TABLE OF CONTENTS** 



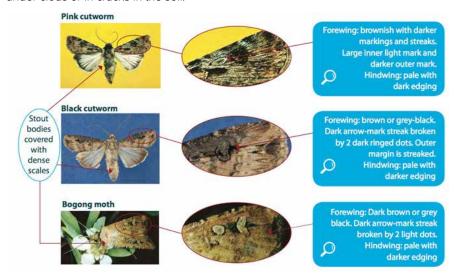
 Inland armyworm—similar to the southern armyworm except the white 'dagger' is divided into two discrete light ellipses which almost touch, and pale grey hind wings.

SOUTHERN

JANUARY 2018

• Common armyworm—the forewings are dull yellow to reddish-brown, speckled with tiny black dots, and a small white dot near the centre.

Pupae of all three species are about 20 mm long and shiny brown. They are found under clods or in cracks in the soil.  $^{54}$ 



**Figure 24:** Distinguishing characteristics of the moths of the three armyworm species.

Source: cesar

#### 7.8.1 Damage caused by armyworms

Armyworms prefer lush growth that provides good cover and protection. Bare patches adjacent to barley fields or damage to weeds may indicate armyworm presence before it is evident in crops. <sup>55</sup> The crops affected include all Gramineae crops: cereals, grassy pastures, and maize.

The caterpillars produce green—straw-coloured droppings the size of a match head. These are visible between the rows.

The young larvae feed initially on the leaf surface of pasture grasses and cereals. As the winter and spring progress and the larvae grow, they chew scallop marks from the leaf edges, leaving leaf margins that look tattered, chewed or scalloped. This becomes increasingly evident by mid to late winter. In extreme cases whole leaves may be severed at the stem. By the end of winter or early spring, the larvae are reaching full size and maximum food consumption. It is this stage that farmers most frequently notice them, as complete leaves and tillers may be consumed or severed from the plant.

The most damage, however, is caused in ripening crops when the foliage dries off. The armyworms then begin to eat any green areas remaining. In cereals, the last section of the stem to dry out is usually just below the seed head. Armyworms, particularly the older ones, that chew at this vulnerable spot cause lopping of the heads and can devastate a crop nearing maturity in one or two nights. Generally, the larger the armyworm, the greater the damage. In wheat and barley whole heads are severed, while in oats individual grains are bitten off below the glumes.

Damaging infestations or outbreaks occur in three situations:



<sup>54</sup> G McDonald (1995) Armyworms. Note AG0412. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/armyworms">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/armyworms</a>

IPM Guidelines (2016) Armyworm. Queensland Government and GRDC, http://ipmguidelinesforgrains.com.au/pests/armyworm/



**TABLE OF CONTENTS** 





Agriculture Victoria, Armyworms

 In winter when young tillering cereals are attacked and can be completely defoliated. The caterpillars may come from:

SOUTHERN
JANUARY 2018

- the standing stubble from the previous year's cereal crop, in which the eggs are laid;
- neighbouring pastures which dry out, forcing the resident armyworms to march into the crop.
- In spring and early summer when crops commence ripening and seed heads may be lopped.
- In early summer when grass pastures are cut for hay, particularly in Gippsland.

#### 7.8.2 Thresholds for control

Economic threshold estimated at 10 grubs/ $m^2$ . (The threshold for triticale is higher than barley because heads are rarely lopped.)  $^{56}$ 

For winter outbreaks (during tillering), economic thresholds of 8 to 10 larvae per  $m^2$  provide a guide for spray decisions. For spring outbreaks (during crop ripening) spraying is recommended when the density of larvae exceeds 1 to 3 larvae per  $m^2$  although this figure must be interpreted in the light of:

- · timing of harvest;
- green matter available in the crop;
- · expected return on the crop; and
- larval development stage (if most are greater than 35–40 mm or pupating, it may not be worth spraying).

#### 7.8.3 Managing armyworms

#### Sampling and detection

Signs of the presence of armyworms include:

- Chewing or leaf scalloping along the leaf margins.
- Caterpillar excreta (frass) which collects on leaves or at the base of the plant.
- Cereal heads or oat grains on the ground. Oat grains may be attached to a small
  piece of stalk (1–2 mm), whereas wind-removed grains are not. Barley heads may
  be severed completely, or hang from the plant by a small piece of stalk.

Early detection is essential, particularly when cereals and pasture seed or hay crops are at the late ripening stage. Although accurate estimates of caterpillar densities require considerable effort, the cost saving is worthwhile.

Sampling can be achieved by using a sweep-net or bucket, or visually searching the ground or crop for caterpillars or signs of damage.

The sweep-net or bucket method provides a rapid and approximate estimate of infestation size. The utensil should be swept across the crop in 1800 arcs numerous times, preferably 100 times, at different sites in the crop, to give an indication of density and spread. Armyworms are most active at night, so sweeping will be most effective at dusk. Average catches of more than 5–10 per 100 sweeps suggest that further searches on the ground are warranted to determine approximate densities.

When ground sampling, it is necessary to do at least ten spot checks in the crop, at each site counting the number of caterpillars within a square metre.

Most farmers fail to detect armyworms until the larvae are almost fully grown, by which stage 10–20% of the crop may be damaged. The earlier the detection, the less the damage. The young larvae (up to 8 mm) cause very little damage, and are more difficult to find. The critical time to look for armyworms is the last three to four weeks



IPM Guidelines (2016) Armyworm. Queensland Government and GRDC, <a href="http://ipmquidelinesforgrains.com.au/pests/armyworm/">http://ipmquidelinesforgrains.com.au/pests/armyworm/</a>

<sup>57</sup> G McDonald (1995) Armyworms. Note AG0412. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/armyworms">http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/armyworms</a>

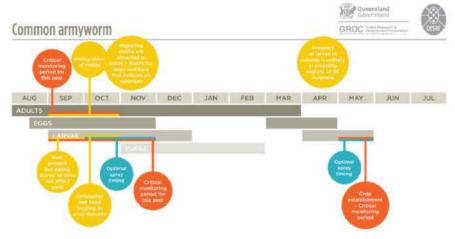






before harvest.  $^{58}$  In order to control them, it is important to understand their life cycle and know when to monitor for them (Figure 25).  $^{59}$ 

SOUTHERN



**Figure 25:** Critical monitoring and management stages in the armyworm life cycle.

Source: cesar

#### **Biological control**

Around 20 species of predators and parasitoids have been recorded attacking armyworms. The most frequently observed predators are predatory shield bugs, ladybeetles, carabid beetles, lacewings and common brown earwigs. Parasitoids include tachnid flies and a number of wasp species (e.g. *Netelia*, *Lissopimpla* and *Campoletis spp.*). Viral and fungal diseases are recorded as killing armyworms. Predator outbreaks are more common when there are high densities of armyworms.

#### Cultural control

Control weeds to remove alternative hosts, and keep an eye on other crops, too: armyworms often feed on ryegrass before moving into cereal crops. Standing stubble from previous crops, dead leaves on crops, and grassy weeds are suitable sites for female armyworm to lay eggs.

Larvae may move into cereals if adjacent pastures are chemically fallowed, spray topped or cultivated in spring. Monitor for at least a week after doing any of these things. Damage is generally confined to crop margins.

#### Chemical control

There are several insecticides registered against armyworms in broadacre crops. See the <u>APVMA</u> website for current chemical options. The biological insecticide *Bacillus thuringiensis* (Bt) is effective on armyworms and is also 'soft' on natural enemies. Spray *Bt* late in the day/evening to minimise UV breakdown of the product, and ensure the insecticide is sprayed out within 2 hours of mixing. Make sure the appropriate strain is used for the target pest, add a wetting agent and use high water volumes to ensure good coverage on leaf surfaces. When insecticides are required, it is recommended that applications be carried out in the late afternoon or early evening. <sup>60</sup>

To be effective, chemical control requires good coverage to ensure contact with the caterpillars. Control is more difficult in high-yielding crops with thick canopies where larvae rest under the leaf litter at the base of plants.



IPM Guidelines, Common predators

IPM Guidelines, Common parasitoids

IPM Guidelines, <u>Viral and fungal</u> diseases of crop pests



IPM Guidelines, Farm hygiene



<sup>58</sup> McDonald G. (1995). Armyworms. <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/armyworms">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/armyworms</a>

 $<sup>59 \</sup>quad \text{G McDonald (2015) Armyworm. cesar, } \underline{\text{http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Armyworm}}$ 

<sup>60</sup> G McDonald. (2016). Armyworm – cesar PestNotes southern. <a href="http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Armyworm">http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Armyworm</a>



TABLE OF CONTENTS



Be aware of withholding periods when chemical control is used close to harvest. 61

#### 7.9 Slugs and snails

Slugs and snails are predominantly pests in the southern and western regions (Table 4).  $^{\rm 62}$ 

Increased slug and snail activity may be due to the increase in zero-till and minimum-till farming and greater stubble retention, because the organic content of paddocks increases under such systems, providing more food, especially to young slugs and snails.

Other risk factors include prolonged wet weather, trash blankets, weedy fallows and a previous history of slugs and snails. Slugs and snails are best controlled before the crop is planted.

**Table 4:** Description of common slugs and snails.

		,	o .	
Species	Distinguishing features	Characteristic damage	Seasonal occurrence	Other characteristics
Slugs				
Grey field or reticulated slug	Light grey to fawn	th dark brown (Complete areas of crop may be missing.)	Autumn to spring when conditions are moist, especially when soil moisture is	Resident pest
Deroceras reticulatum	mottling			Surface active, but seeks moist refuge in soil macropores
	35-50 mm long			
Photo: Michael Nash, SARDI	Produces a white mucus.		greater than 25%	
Black-keeled slug	Black or brown with a	tinuing from (complete areas if conditions all the way of crop may be are moist, but generally later in the season in colder regions		Burrows, so cereal or maize crops fail to emerge
Milax gagates	its saddle all the way		are moist, but	ğ
	down its back to the tip of the tail		in the season in	Prefers sandy soil in high-rainfall areas (>550 mm), and heavier soils in low-rainfall areas (<500
	40-60 mm long			mm)
				Surface active (feeding), but seeks moist refuge in soil macropores



Photo: Michael Nash, SARDI

 $<sup>61 \</sup>hspace{0.5cm} \textbf{IPM Guidelines (2016) Armyworm. Queensland Government and GRDC, } \underline{\textbf{http://ipmquidelinesforgrains.com.au/pests/armyworm/}}$ 

<sup>62</sup> IPM Guidelines (2016) Slugs and snails. Queensland Government and GRDC, <a href="http://ipmguidelinesforgrains.com.au/pests/slugs-and-snails/">http://ipmguidelinesforgrains.com.au/pests/slugs-and-snails/</a>



TABLE OF CONTENTS



Species	Distinguishing features	Characteristic damage	Seasonal occurrence	Other characteristics
Brown field slug  Deroceras invadens or D.  Iaeve  Photo: Michael Nash, SARDI	Usually brown all over with no distinct markings 25–35 mm long Produces a clear mucus	Rasping of leaves Leaves a shredded appearance	All year round if conditions are moist	Prefers warmer conditions and pastures  Less damaging than grey field and black-keeled slugs
Snails  Vineyard or common white snail  Cernuella virgata  Photo: Michael Nash, SARDI	Coiled white shell with or without a brown band around the spiral  Mature shell diameter 12–20 mm  Open, circular umbilicus*  Under magnification regular straight scratches or etchings can be seen across the shell	Shredded leaves where populations are high Found up in the crop prior to harvest	Active after autumn rainfall Breeding occurs once conditions are moist (usually late autumn to spring)	Mainly a contaminant of grain  Congregates on summer weeds and off the ground on stubble
White Italian snail Theba pisana	Mature snails have coiled white shells with broken brown bands running around the spiral  Some individuals lack the banding and are white  Mature shell diameter	Shredded leaves where populations are high. Found up in the crop prior to harvest.	Active after autumn rainfall. Breeding occurs once conditions are moist (usually late autumn to spring).	Mainly a contaminant of grain.  Congregates on summer weeds and up off the ground on stubble.



Photo: Michael Nash, SARDI

12-20 mm

Semi-circular or partly closed umbilicus\*

Under magnification cross hatched scratches can be seen on the shell



SOUTHERN JANUARY 2018



#### **TABLE OF CONTENTS**

Photo: Michael Nash, SARDI



Species	Distinguishing features	Characteristic damage	Seasonal occurrence	Other characteristics
Conical or pointed snail  Cochlicella acuta  Photo: Michael Nash, SARDI	Fawn, grey or brown Mature snails have a shell length of up to 18 mm. The ratio of the shell length to its diameter at the base is always greater than two	Shredded leaves where populations are high Found up in the crop prior to harvest	Active after autumn rainfall Breeding occurs once conditions are moist (usually winter to spring)	Mainly a contaminant of grain  Can be found over summer on and in stubble and at the base of summer weeds
Small pointed snail  Prietocella barbara	Fawn, grey or brown  Mature shell size of 8–10 mm  The ratio of its shell length to its diameter at the base is always two or less	Shredded leaves where populations are high Found up in the crop prior to harvest	Active after autumn rainfall Breeding occurs once conditions are moist (usually winter to spring)	A contaminant of grain, especially hard to screen from canola grain as the same size  Mainly found over summer at the base of summer weeds and stubble  Like slugs, will go into soil macropores  Especially difficult to control with bait at current label rates

<sup>\*</sup> Umbilicus: a depression on the bottom (dorsal) side of the shell, where the whorls have moved apart as the snail has grown. The shape and the diameter of the umbilicus is usually species-specific.

Source: IPM Guidelines

#### 7.9.1 Economic thresholds for control

Thresholds (Table 5) can be unreliable due to the interaction between weather, crop growth and snail activity. For example, high populations in the spring do not always relate to the number of slugs and snails harvested. Their movement into the crop canopy is dictated by weather conditions prior to harvest. 63

**Table 5:** Thresholds for controlling snails and slugs in a paddock. If there are more than the number specified per metre for a given pest then actions for controlled the pest should be taken.

Pest	Number of pest per square metre
Round snails	20
Small pointed snails	40
Grey field slug	5-15
Black-keeled slug	1-2

#### 7.9.2 Managing slugs and snails

#### **Biological control**

Free-living nematodes when carrying bacteria that kill snails and slugs are thought to help reduce populations under certain paddock conditions.



SOUTHERN

 $IPM\ Guidelines\ (2016)\ Slugs\ in\ seedling\ crops.\ Queensland\ Government\ and\ GRDC,\ \underline{http://ipmguidelinesforgrains.com.au/pests/slugs-permanent}$ and-snails/slugs-in-seedling-crops/





Note that baits containing methiocarb are toxic to a number of other invertebrates and beneficials.

**OUTHERN** 

#### Natural enemies of slugs

Some species of carabid beetles can reduce slug populations, but generally not below established economic thresholds. Many other soil fauna, such as are protozoa, may cause high levels of slug egg mortality under moist, warm conditions. Biological controls alone cannot be solely relied on for slug control.

#### **Cultural** control

- Hard grazing of stubbles
- Cabling and/or rolling of stubbles when soil temperature is above 35°C
- Burning if numbers are very high and you can ensure hot, even burns
- Cultivation that leaves a fine, consolidated tilth
- Removal of summer weeds and volunteers

#### Chemical control

#### Snails

Molluscidial baits containing either metaldehyde or chelated iron are IPM compatible. Apply to the bare soil surface when snails are active after autumn rain, as early as March. Aim to control snails pre-season.

Mature snails over 7 mm in length or diameter will feed on bait while bait is less effective on juveniles. Baiting before egg lay is vital. Try to bait when snails are moving from resting sites after summer rains. Stop baiting eight weeks before harvest to avoid bait contamination in grain. Bait rates need to be at the highest label rate to achieve a greater number of bait points. As the actual number is yet to be determined, label rates may be revised ion the future. In cool, moist conditions, snails can move 30 m/week, so treated fields can be re-invaded from fence lines, vegetation and roadsides. Rain at harvest can cause snails to crawl down from crops.

#### Slugs

Baiting is the only chemical option available to manage slugs. Molluscidial baits containing metaldehyde or chelated iron are IPM compatible. Baits containing methiocarb are also toxic to carabid beetles, one of the few predators of slugs. Different responses to bait can be due to species behaviour. The value of applying bait after a significant rainfall event prior to sowing is still to be tested.

For black-keeled slugs, broadcast baits when dry or place with seed at sowing.

For grey field slugs, broadcast baits.

Do not underestimate slug populations: always use rate that gives 25–30 per metre.

Calibrate bait spreaders to ensure width of spread, evenness of distribution and correct rate. Make sure to bait after/at sowing prior to crop emergence when soil is moist (>20% soil moisture). Re-apply baits to problem areas 3–4 weeks after first application if monitoring indicates slugs are still active.

Note that the number of baits/ha is more important than total weight of bait per hectare. The minimum baits needed for effective control is 250,000 bait points per hectare.

#### Monitoring snails

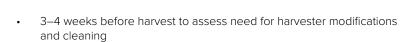
<u>Monitor</u> regularly to establish numbers, types and activity (Table 6), and measure success of controls. Look for snails early morning or in the evening when conditions are cooler and snails are more active.

Key times to monitor:



TABLE OF CONTENTS





SOUTHERN

- after summer rains, check if snails are moving from resting sites
- summer to pre-seeding, check numbers in stubble before and after rolling, slashing or cabling

#### Monitoring technique:

- sample 30 x 30 cm quadrat at 50 locations across the paddock.
- if two groups (round and conical) are present, record the number of each group separately
- to determine the age class of round snails, place into a 7 mm sieve box, shake gently to separate into two sizes >7 mm (adults) and <7 mm (juveniles).
- make sieve boxes from two stackable containers, e.g. sandwich boxes, remove the bottom from one and replace by a punch-hole screen with screen size of 7 mm round or hexagonal
- use 5 sampling transects in each paddock, one each at 90 degrees to each fence line and the fifth running across the centre of the paddock, and take five samples (counts), 10 metres apart along each transect

Record the size and number of the snails in each sample. Average the counts for each transect and multiply this figure by 10 to calculate the number of snails per square metre in that area of the paddock.

Table 6: Monitoring snails at different stages of crop development.

Pre-sowing	Seedling-vegetative stages	Grain fill and podding stage	Harvest
High risk:	Damage:	Can be found	Predominantly a grain
weedy fields	consume cotyledons, which may	up in the crop prior to harvest.	contaminant
alkaline calcareous soils	resemble crop failure	Check for snails	At harvest, snails move up in the crop and may shelter
retained stubble	shredded leaves where populations are high	under weeds or shake mature	between grains or under leaves. They can also be
wet spring, summer, autumn	chewed leaf margins	crops unto tarps.	found in windrows.
history of snails	irregular holes		The small pointed snail is
All species congregate at the base of summer weeds or in topsoil. Pointed snails can also be found at the base	Wide range of sizes indicates snails are breeding in the area. If most snails are the same size, snails		especially hard to screen from canola grain due to similar size. Buyers will reject grain if:
of or up in stubble as well as inside stubble stems.	are moving in from other areas.		more than half a dead or one live snail is found in 0.5 L of
Appear to build up most rapidly in	Round snails favour resting places off the ground on stubble, vegetation and		wheat
canola, field peas and beans, but can feed and multiply in all crops and	fence posts		more than half a dead or one
pastures.	Pointed snails are found on the ground		live snail is found in 200 g pulse sample
Most active after rain and when conditions are cool and moist	in shady places		
Dormant in late spring and summer			

Source IPM Guidelines

#### Monitoring slugs

Monitor with surface refuges to provide an estimate of active density (Table 7). Refuges include:

- terracotta paving tiles
- carpet squares or similar

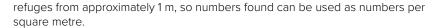
Use a 300 mm by 300 mm refuge when soil moisture is favourable (more than 20%) as slugs require moisture to travel across the soil surface. Slugs are attracted to the











Place refuges in areas of previous damage, after rainfall, on damp soil before sowing. Use 10 refuges per 10 hectares.

Check the refuges early in the morning, as slugs seek shelter in the soil as it gets warmer. Alternatively, put out metaldehyde bait strips and check the following morning for dead slugs. Monitor for plant damage.

Slug populations are not evenly distributed in the paddock and are often clumped. Where crop damage is evident inspect the area at night. 64

**Table 7:** Monitoring slugs at different stages of crop development.

#### **Pre-sowing Germination-vegetative stages** High risk: Damage: · high rainfall areas >450 mm a year · rasping of leaves, above-average spring-autumn · leaves have a shredded appearance rainfall complete areas of crop may be cold, wet establishment conditions missing no-till stubble retained Slugs will eat all plant parts but the summer volunteers

seedling stage is most vulnerable and this is when major economic losses can

SOUTHERN

Grey and brown field slugs are mainly surface-active but the black-keeled slug burrows and can feed directly on germinating seed

**MORE INFORMATION** 

GRDC factsheet, Slug identification and management

Source IPM Guidelines

#### 7.10 Wireworms and false wireworms

previous paddock history of slugs soils high in clay and organic matter

Slugs are nocturnal and shelter during

dry conditions and generally not visible

Wireworms and false wireworms are common, soil-inhabiting pests of newly sown winter and summer crops. Wireworms are the larvae of several species of Australian native beetles which are commonly called click beetles. They are from the family Elateridae. False wireworms are also the larval form of adult beetles, some of which are known as pie-dish beetles. They belong to another family, Tenebrionidae, and have distinctively different forms and behaviour.

Both groups inhabit native grassland and improved pastures where they generally cause little damage. However, cultivation and fallowing decimates their food supply, so any new seedlings that grow may be attacked and sometimes destroyed. They attack the pre-emergent and post-emergent seedlings of all oilseeds, grain legumes and cereals, particularly in light, well-draining soils with a high organic content. Crops with fine seedlings, such as canola and linola, are most susceptible.

The incidence of damage caused by wireworms and false wireworms is increasing with increasing use of minimum tillage and short fallow periods.

#### 7.10.1 False wireworms

False wireworms are the larvae of native beetles which normally live in grasslands or pastures, and cause little or no damage there. In crops, they are mostly found in paddocks with large amounts of stubble or crop litter, and they may affect all winter-sown crops.

There are a large and varied number of species of false wireworms, but all species exhibit some common characteristics. Larvae are cylindrical, hard bodied, fast moving, golden brown to black-brown or grey with pointed, upturned tails or a pair



IPM Guidelines (2016) Slugs in seedling crops. Queensland Government and GRDC, http://ipmquidelinesforgrains.com.au/pests/slugsand-snails/slugs-in-seedling-crops/



TABLE OF CONTENTS



of prominent spines on the last body segment. There are several common groups (genera) of false wireworms found in south-eastern Australia:

SOUTHERN

JANUARY 2018

- the grey or small false wireworm (Isopteron (Cestrinus) punctatissimus)
- the large or eastern false wireworm (Pterohelaeus spp.)
- the southern false wireworm (Gonocephalum spp.)

In the grey or small false wireworm, the larvae grow to about 9 mm in length. They are grey-green, have two distinct protrusions from the last abdominal (tail) segment, and tend to have a glossy or shiny exterior (Figure 26). Hence, they are most easily recognised in the soil on sunny days when their bodies are reflective. The adults are slender, dark brown and grow to about 8 mm in length. The eggs are less than 1 mm in diameter. There are several species of this pest genus, although *I. punctatissimus* appears to be the one most associated with damage (Figure 26). 65

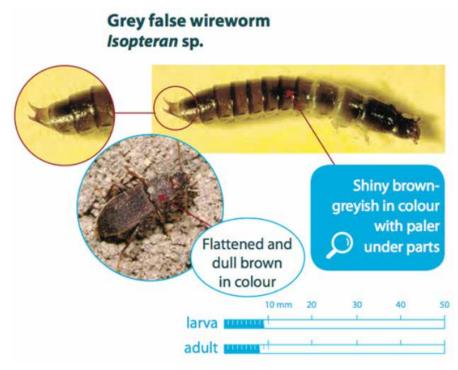


Figure 26: Distinguishing characteristics of the grey false wireworm.

Source: cesar

The large or eastern false wireworms are the largest group of false wireworms. They are the most conspicuous in the soil, and grow up to 50 mm in length. They are light cream to tan in colour, with tan or brown rings around each body segment, giving the appearance of bands. The last abdominal segment has no obvious protrusions, although, under a microscope, a number of distinct hairs can be seen. Adults are large, conspicuous and often almost ovoid beetles with black shiny bodies (Photo 11). 66



 $<sup>\</sup>texttt{G McDonald (2016) Grey false wireworm. Updated. cesar, \underline{http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Grey-to-agriculture/pestno$ 

 $<sup>\</sup>hbox{G McDonald (2016) Eastern false wireworm. Updated. cesar, \underline{\hbox{http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/} } \\$ Eastern-false-wireworm







Photo 11: Eastern false wireworm adult beetle (left) and larva (right).

Source: cesar

Southern false wireworms (Gonocephalum spp.) grow to about 20 mm in length, and have similar body colours and markings to the large false wireworm. Adults are generally dark brown-grey, oval beetles, which sometimes have a coating of soil on the body (Figure 27). <sup>67</sup> The edges of adults' bodies are flanged, hence the common name pie-dish beetle.

# Vegetable beetle Gonocephalum spp.

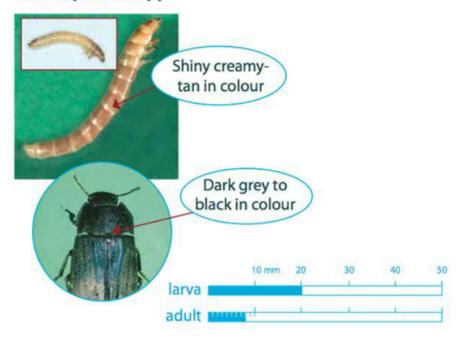


Figure 27: Distinguishing characteristics of the southern false wireworm.

Source: cesar

#### Biology

Usually only one generation occurs each year. However, some species may take up to 10 years to complete the life cycle. Adults emerge from the soil in December and January, and lay eggs in or just below the soil surface, mostly in stubbles and crop litter. Hence, larvae are most commonly found in paddocks where stubble has been retained.



 $P. Umina, G. McDonald (2015). Southern false wireworm. cesar, \\ \underline{http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/lineary/lin$ Southern-False-wireworm



**TABLE OF CONTENTS** 



Larvae of most false wireworm species prefer to feed on decaying stubble and soil organic matter. When the soil is reasonably moist, the larvae are likely to aggregate in the top 10–20 mm where the plant litter is amassed. However, when the soil dries, the larvae move down through the soil profile, remaining in or close to the subsoil moisture, and occasionally venturing back to the soil surface to feed. Feeding is often at night when the soil surface is dampened by dew.

SOUTHERN

JANUARY 2018

Nothing is known about what triggers the false wireworm to change from feeding on organic matter and litter to feeding on plants. However, it is recognised that significant damage of plants is likely to occur when soils remain dry for extensive periods. Larvae are likely to stop feeding on organic matter when it dries out, and when crop plants provide the most accessible source of moisture.

#### Damage caused by false wireworms

Affected crops may develop bare patches, which could be large enough to require re-sowing (Photo 12).  $^{68}$  Damage is usually greatest when crop growth is slow due to cold, wet conditions.



Photo 12: False wireworm damage to pasture.

Source: SARDI

Infestations of the small false wireworm can be as high as hundreds of larvae per square meter, although densities as low as five larger false wireworm larvae per square meter can cause damage under dry conditions.

The larvae of the small false wireworm are mostly found damaging fine seedling crops shortly after germination. They feed on the hypocotyl (seedling stem) at or just below the soil surface. This causes the stem to be ring-barked, and eventually the seedling may be lopped off, or it wilts in warm conditions. Larger seedlings (e.g. those of grain legumes) may also be attacked, but the larvae appear to be too small to cause significant damage.

The larger false wireworms can cause damage to most field crops. The larvae can hollow out germinating seed, sever the underground parts of young plants, or attack the above-surface hypocotyl or cotyledons. In summer, adult beetles may also chew off young sunflower seedlings at ground level. Damage is most severe in crops sown into dry seedbeds and when germination is slowed by continued dry weather.



<sup>68</sup> P Umina, G McDonald (2015) Southern false wireworm. cesar, <a href="http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/">http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/</a> Southern-False-wireworm



#### 7.10.2 True wireworm

The true wireworms are many species in the family Elateridae. The slow-moving larvae in this family tend to be less common in broadacre cropping regions, although they are always present. They are generally associated with wetter soils than the larvae of false wireworms.

Larvae grow to 15–40 mm, are soft-bodied, and flattened, and these characteristics help distinguish them from false wireworms. Their colour ranges from creamy yellow in the most common species to red-brown; their head is dark brown and wedge-shaped. The tail piece is characteristically flattened and has serrated edges. Adults are known as click beetles, due to their habit of springing into the air with a loud click when placed on their backs. The beetles are dark brown, elongated and 9–13 mm long (Figure 28). <sup>69</sup>

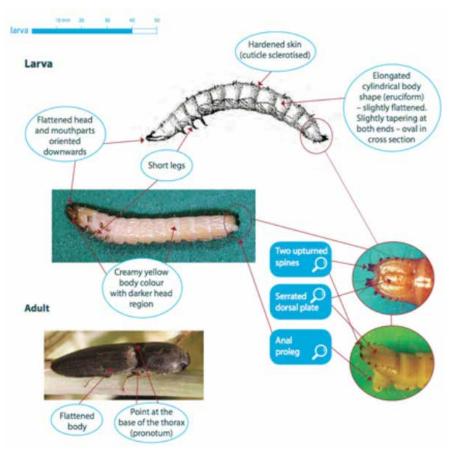


Figure 28: Distinguishing characteristics of true wireworms.

Source: cesar

#### Biology

There may be one or several generations per year, depending on the species. Wireworms prefer low-lying, poorly drained paddocks and are less common in dry soils. Larvae are reasonably mobile through the soil, and will attack successive seedlings as they emerge. Most damage occurs from April to August. Adults emerge in spring, and are typically found in summer and autumn in bark, under wood stacks or flying around lights.

There is little known of the biology of most species, although one species (*Hapatesus hirtus*) is better understood. It is known as the potato wireworm although it is found in many other crops and pastures as well as in potatoes. It is very long-lived and









probably takes five years or more to pass through all the wireworm stages before pupating and finally emerging as an adult beetle.

SOUTHERN

After emerging, adult click beetles mate and lay eggs, and then may spend a winter sheltering under the bark of trees. The connection between trees and adult beetles is probably why damage is often, but not always, most pronounced along tree lines. The wireworms have a long life in the soil and are active all year, even in winter.

#### Damage

The damage caused by wireworms is similar to that of false wireworms, except that most of it is restricted to below the soil surface. Larvae eat the contents of germinating seeds, and the underground stems of establishing plants, causing wilting and death.

#### 7.10.3 Sampling and detection of wireworms

The principles for detection and control of false and true wireworms are generally similar, although different species may respond slightly differently according to soil conditions.

#### Sampling

Paddocks should be sampled immediately before sowing. There are two methods, although neither is 100% reliable. This is because larvae change their behaviour according to soil conditions, particularly soil moisture and temperature. The two methods are:

- Soil sampling—take a minimum of five random samples from the soil. Each sample should consist of the top 20 mm of a 0.50 m x 0.50 m area. Carefully inspect the soil for larvae. Calculate the average density per square metre by multiplying the average number of larvae found in the samples by 4. Control should be considered if the average exceeds 10 small false wireworms, or 10 larger false wireworms.
- Seed baits—these have been used to successfully sample true and false wireworms in Queensland and overseas. In Victoria, they have not been rigorously tested. Preliminary work has shown that they can be used to show the species of larvae present, and to give an approximation of density. Take about 200-300 g of a large seed, such as that of any grain legume, and soak for 24 hours. Select 5–10 sites in the paddock and place a handful of the soaked seed into a shallow hole (50 mm) and cover with about 10 mm of soil. Mark each hole with a stake, and excavate each hole after about seven days. Inspect the seed and surrounding soil for false wireworm larvae. This technique is most likely to be successful when there is some moisture in the top 100 mm of soil.

#### Detection

Larvae of the small false wireworms are relatively difficult, although not impossible, to see in grey and black soils because of their small size and dark colour. However, they can be found in the top 20 mm of dry soil by carefully examining the soil in full sun. Larvae of the other false wireworm species are more prominent because of their relatively pale colour and large size.

#### 7.10.4 Control

Crop residues and weedy summer fallows favour survival of larvae and oversummering beetles. Clean cultivation over summer will starve adults and larvae and expose them to hot, dry conditions, thus preventing population increases. Suitable crop rotations may also limit increases in population numbers.

Seedbeds must be sampled before sowing if control is to be successful. Insecticides may be applied to soil or seed at sowing. Most chemicals registered to control false wireworms are seed treatments, although these may not be consistently reliable. They probably work best when the seedling grows rapidly in relatively moist soils.









Adults may also be controlled with insecticide incorporated into baits. If damage occurs after sowing, no treatment is available, other than re-sowing bare patches with an insecticide treatment.  $^{70}$  The critical periods for control of false wireworm and shown in Figure 29.  $^{71}$ 

SOUTHERN

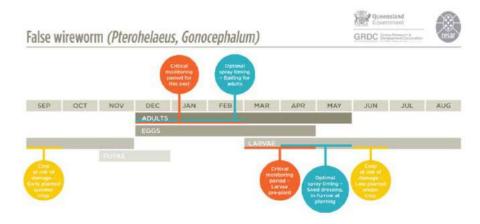


Figure 29: Critical periods for controlling the false wireworm.

Source: cesar

## 7.11 Plague locusts

The Australian plague locust (*Chortoicetes terminifera*) is a native insect (Photo 13).  $^{72}$  It is a pest of pastures, field crops, and vegetables, infrequently in South Australia and Victoria, and more commonly in New South Wales and southern Queensland.  $^{73}$ 

Following the major Australian plague locust outbreak in southern Australia in 2010 and early 2011, locust numbers have returned to near-normal levels in most areas.

Landholders should be aware that locusts can have an impact on Victorian and southern Australian agriculture in any season, but effects are usually on a local scale.



Photo 13: Australian plague locust on grass leaf.

Source: DAFWA

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- 73 Agriculture Victoria. Australia plague locust: Identification and biology. Factsheet. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/plaque-locusts/fact-sheet-identification-and-biology">http://agriculture/pests-diseases-and-weeds/pest-insects-and-mites/plaque-locusts/fact-sheet-identification-and-biology</a>



<u>Australian plague locust: identification</u> <u>and biology</u>

Australian Plague Locust Commission

<u>Australian plague locust response:</u> assessment of effects in Victoria



WATCH: Locust videos











# Nematode management

#### Key messages

The most important root and crown diseases of cereal crops in southern
 Australia are cereal cyst nematode (CCN), take-all, rhizoctonia root rot, crown rot
 and root-lesion nematode (RLN).

SOUTHERN

- Triticale is highly resistant to *Pratylenchus neglectus* <sup>1</sup> and resistant to *Pratylenchus thornei* <sup>2</sup>.
- Triticale is thought to be resistant to cereal cyst nematode (CCN)<sup>3</sup>, due to its cereal rye component<sup>4</sup>.
- At least 20 % of cropping paddocks in south-eastern Australia have populations
  of RLNs high enough to reduce yield 5, with more than 90 percent of paddocks
  in the Wimmera and Mallee regions having RLNs present 6.
- Yield losses can be reduced by rotation with resistant and tolerant crops and varieties, good nutrition and sowing early. Variety choice is critical in managing nematode populations in the soil.
- Triticale can reduce soil nematodes such as *P. neglectus* and *P. thornei* (RLNs) and *Heterodera avenae* (CCN). <sup>7</sup>
- Soil testing is the best way to diagnose nematode infestations in paddocks, and to inform subsequent management decisions.

The most important root and crown diseases of cereal crops in southern Australia are cereal cyst nematode (CCN), take-all, rhizoctonia root rot, crown rot and root-lesion nematode (RLN). These diseases can cause significant yield loss in crops. Fortunately, they can be easily controlled with crop rotation and use of resistant varieties. <sup>8</sup>

Successful management relies on:

- farm hygiene to keep fields free of RLN;
- growing tolerant varieties when RLN are present, to maximise yields; and rotating with resistant crops to keep RLN at low levels.
- Test soil to monitor population changes in rotations and to determine RLN species and population density.
- Avoid consecutive susceptible crops in rotations to limit the build-up of RLN populations.
- Choose rotation crops with high resistance ratings, so that fewer nematodes remain in the soil to infect subsequent crops.

Many growers use triticale as a disease break in their rotations, and value the benefits of triticale for its contribution to soil conservation (Table 1). Triticale assists in maintaining soil health by reducing the presence of nematodes, such as root-lesion nematodes and cereal cyst nematodes. <sup>9</sup>

- 1 M Williams (2013) Root out nematodes and get them tested. Grains and Research Development Corporation, 28/10/2013. <a href="https://grdc.com.au/Media-Centre/Media-News/West/2013/10/Root-out-nematodes-and-get-them-tested">https://grdc.com.au/Media-Centre/Media-News/West/2013/10/Root-out-nematodes-and-get-them-tested</a>
- A Wherrett V Vanstone (2016) Root lesion nematode. Soil Quality. http://soilquality.org.au/factsheets/root-lesion-nematode
- 3 M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="https://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e0/y5f53e00.pdf</a>
- 4 R Asiedu, JM Fisher, CJ Driscoll (1990) Resistance to Heterodera avenue in the rye genome of triticale. Theoretical and applied genetics, 79(3), 331–336.
- 5 G Holloway (2013) Cereal root diseases. Agriculture Victoria. <a href="http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases">http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases</a>
- 6 CropPro (2014) Root lesion nematode (RLN). http://www.croppro.com.au/crop\_disease\_manual/ch03s07.php
- 7 KV Cooper, RS Jessop, NL Darvey 'Triticale in Australia' in M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="http://www.fao.gov/?/avy55340/6553400.ndf">http://www.fao.gov/?/avy55340/6553400.ndf</a>
- 8 G Hollaway (2013) Cereal root diseases. Agriculture Victoria. <a href="http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases">http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases</a>
- 6 KV Cooper, RS. Jessop, NL. Darvey 'Triticale in Australia' in M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="http://www.fao.org/3/a-v5553e/v5553e0.org/">http://www.fao.org/3/a-v5553e/v5553e0.org/</a>





Variety	CCN resistance	Pratylenchus neglectus resistance	Pratylenchus thornei resistance
Astute(b	R	RMR	MS
Berkshire(b	-	MR	MS
Bison(b	R	MR	RMR
Canobolas(1)	-	MR	MSS
Chopper(D	R	MRMS	MSS
Endeavour(1)	-	MR	SVS
Fusion(1)	R	RMR	MS
Goanna	R	MRMS	SVS
KM10	-	MR	MSp
Rufus	R	MSS	MSS
Tahara	R	MR	S
Tobruk(D	-	MR	SVS
Tuckerbox	-	MRMS	S
Yowie	R	MR	MSS

SOUTHERN

Maturity: E = early, M = mid-season, L = late, VL = very late

Height: M = medium, T = tall Colour: W = white, Br = brown Disease resistance order from best to worst: R > RMR > MRMS > MS > MS > S > S > SVS > VS.  $\rho$  = provisional ratings—treat with caution.

R = resistant M = moderately S = susceptible V = very

# Varieties marked may be more susceptible if alternative strains are present.

Source: Agriculture Victoria

# Cereal root disease management in Victoria and southern Australia

Take home messages:

- Minimise losses associated with root diseases by inspection of plant roots in the previous crop or using a PreDicta B soil test prior to sowing to identify at risk paddocks.
- Crown rot will be an important disease during if the season finishes with a dry spring as inoculum levels are high from the previous season. Reduce risk by rotating to non-cereal crops.
- In paddocks with high numbers of root-lesion nematodes, yield losses can be minimised by selecting partially tolerant cultivars and avoiding late sowing. Resistant cultivars can reduce nematode densities and therefore reduce losses in subsequent intolerant crops.
- Cereal cyst nematodes are very damaging if numbers are allowed to increase by growing susceptible cereals.
- Rhizoctonia root rot will likely be a low risk if there is a wet summer with multiple rainfall events, provided summer weeds are controlled.
- Take-all will be a low risk if there is a dry spring, limiting inoculum build up.

Cereal root diseases can have serious impacts on grain yield in the absence of adequate control. The key to preventing root diseases is to identify paddocks at risk by inspecting the roots of previous cereal crops or taking a PreDicta B soil test prior to sowing. Knowledge of the potential root diseases in a paddock then enables the most appropriate control strategies to be implemented prior to and/or at sowing. Management must be implemented prior to sowing as there are no in-crop management options available for the control of root diseases, compared with many foliar diseases. 10



G Hollaway, J Fanning, F Henry, A McKay (2015) GRDC Update Papers: Cereal root disease management in Victoria. Grains Research and Development Corporation, 24/02/2015. <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Cereal-root-disease-management-in-Victoria">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Cereal-root-disease-management-in-Victoria</a>

**TABLE OF CONTENTS** 



# 8.1 Root-lesion nematodes (RLN)

#### Key points

- Root-lesion nematodes, Pratylenchus neglectus and Pratylenchus thornei, are the main root-lesion nematodes causing yield loss in the southern agricultural region of Australia. They often occur together.
- Root-lesion nematodes cost Australian growers in excess of \$250 million/annum.

SOUTHERN

- Root-lesion nematodes reduce development of lateral roots, which decreases the ability of plants to extract water and nutrients.
- Triticale is highly resistant to *P. neglectus*, <sup>11</sup> resistant to *P. thornei* <sup>12</sup>.
- At least 20 % of cropping paddocks in south-eastern Australia have populations of RLNs high enough to reduce yield <sup>13</sup>, with over 90 percent of paddocks in the Wimmera and Mallee regions having RLNs present <sup>14</sup>.
- Wheat is the main host, but varieties vary in resistance and tolerance.
   Traditional break crops can also be hosts; the host range varies for each Pratylenchus species.
- Yield losses can be reduced by rotation with resistant and tolerant crops and varieties, good nutrition and sowing early. Variety choice is critical in managing nematode populations in the soil.
- Soil testing is the best way to diagnose nematodes infestations in paddocks and will subsequently inform management decisions.

Root-lesion nematodes (Pratylenchus spp.) occur throughout the cereal growing regions of South Australia. RLNs are a genus of microscopic plant parasitic nematode that are soil-borne, ~0.5 to 0.75 mm in length, and will feed and reproduce inside roots of susceptible crops or plants. RLNs are migratory root endoparasites that are widely distributed in the cereal-growing regions of Australia, and can reduce grain yield by up to 50% in many current varieties. There are two common species of RLN in the southern region: Pratylenchus thornei (Pt) and Pratylenchus neglectus (Pn). They often occur together.

*P. neglectus* has a wide host range, infecting all cereals as well as crops grown in rotation with cereals (grain legumes, pasture legumes and oilseeds). However, nematode multiplication differs both between and within host species. Damage caused by *P. neglectus* impairs root function, limiting water and nutrient uptake, leading to poor growth and yield decline. In preliminary experiments, a yield loss of 20% has been recorded for an intolerant wheat variety. Trials were conducted at infested sites to determine the ability of cereal species and varieties to multiply the nematode. Further tests were conducted in the glasshouse to compare nematode multiplication on roots of triticale, wheat and rye varieties. Roots of triticale were found to contain fewer nematodes than the other cereals. Triticale is thus a useful rotational crop for areas infested with the root-lesion nematodes. <sup>15</sup>

Triticale is thought to be susceptible to *P. penetrans*; however, this information is based on preliminary trials and from observations of samples submitted to AGWEST Plant laboratories. More research is needed. <sup>16</sup>

At least 20% of cropping paddocks in south eastern Australia have populations of RLNs high enough to reduce yield.  $^{17}$ 

The extent of RLN occurrence across Australia has recently been estimated (Figure 1).



M Williams (2013) Root out nematodes and get them tested. Grains Research and Development Corporation, 28/10/2013. https://grdc.com.au/Media-Centre/Media-News/West/2013/10/Root-out-nematodes-and-get-them-tested

A Wherrett V Vanstone (2016) Root lesion nematode. Soil Quality. http://soilquality.org.au/factsheets/root-lesion-nematode

<sup>13</sup> G Hollaway (2013) Cereal root diseases. Agriculture Victoria. <a href="http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases">http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases</a>

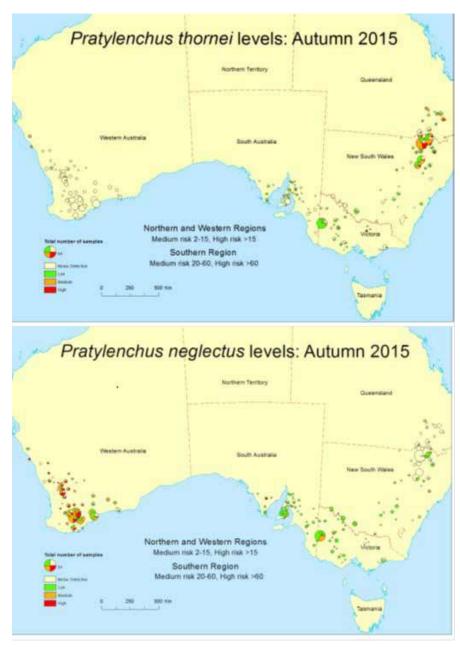
<sup>14</sup> CropPro (2014) Root lesion nematode (RLN). http://www.croppro.com.au/crop\_disease\_manual/ch03s07.php

V Vanstone, M Farsi, T Rathjen, K Cooper (1996) Resistance of triticale to root lesion nematode in South Australia. In Triticale: Today and Tomorrow, 557–560 (H Guedes-Pinto, N Darvey, VP Carnide (ed.s)). Springer Netherlands.

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<sup>17</sup> G Hollaway (2013) Cereal root diseases. Agriculture Victoria. <a href="http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases">http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases</a>

FEEDBACK



**Figure 1:** The distribution of RLNs, based on samples submitted to PreDicta B, SARDI in autumn 2015 for (top) Pratylenchus thornei and (bottom) P. neglectus. These coloured areas may be at a higher risk to RLN infestation. Maps are reproduced with permission from <u>SARDI</u>.

Source: GRDO

Root-lesion nematodes emerged as potential problems in cereals (and other crops) after management strategies were implemented to control cereal cyst nematode and take-all. Yield losses in the southern region are variable and currently under investigation, but present estimates for intolerant varieties indicate a 1% yield loss per 2 nematodes per gram soil. *Pratylenchus thornei* (Photo 1) occurs throughout the root zone and is often more damaging than *P. neglectus*, which tends to be concentrated in the top 15 cm of the soil.

Root-lesion nematodes survive summer as dormant individuals in dry soil and roots, and become active after rain. They can survive several wetting/drying cycles.











WATCH: GCTV6: Root-lesion nematodes



WATCH: <u>Understanding root-lesion</u> <u>nematodes</u>

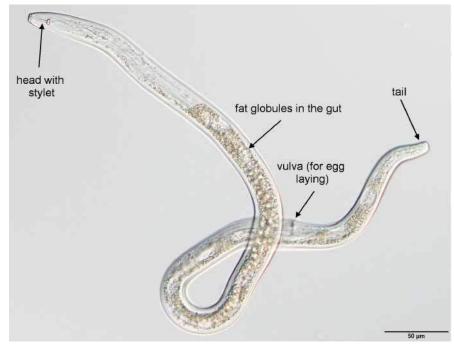




About three generations of nematodes are produced each season, with the highest multiplication in spring.  $^{\rm 18}$ 

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JANUARY 2018



**Photo 1:** A Pratylenchus thornei adult female viewed under the microscope. The nematode is approximately 0.65 mm long.

Source: GRDC

# 8.1.1 Symptoms

## Paddock

- Crops appear patchy with uneven growth, and may appear nutrient deficient (Photo 2).
- Double sown and more fertile areas are often less affected.
- There may be stunted growth and waviness across the paddock.



**Photo 2:** Poor vigour cereal in high RLN plot (left), compared with healthy plot with low RLN (right).

Photo: Grant Hollaway. Source: Soil Quality



<sup>18</sup> A McKay (2016) Root lesion nematode—South Australia. Soil Quality. <a href="http://www.soilquality.org.au/factsheets/root-lesion-nematode-south-australia">http://www.soilquality.org.au/factsheets/root-lesion-nematode-south-australia</a>





#### Plant

- Affected plants are stunted, poorly tillered, and can wilt despite moist soil.
- Roots can have indistinct brown lesions, or (more often) generalised root browning (Photo 3).
- Badly-affected roots are thin and poorly branched, with fewer and shorter laterals.
- Roots may appear withered, with crown roots often less affected than primary roots.
- Roots can assume a 'noodle-like' root-thickening appearance.
- Unlike cereal cyst nematodes, root-lesion nematodes do not cause the roots to swell or knot, and no cysts are produced.  $^{20}$



**Photo 3:** Discolouration and lack of lateral roots on cereals is caused by rootlesion nematodes.

Photo: Frank Henry. Source: Soil Quality



WATCH: <u>How to diagnose root-lesion</u> <u>nematodes</u>.





DAFWA (2016) Diagnosing root lesion nematode in cereals. Department of Agriculture and Food, Western Australia, 06/09/2016 <a href="https://agric.wa.gov.au/n/2166">https://agric.wa.gov.au/n/2166</a>

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**TABLE OF CONTENTS** 





#### PreDicta B

Cereal root diseases cost grain growers in excess of \$200 million a year in lost production. Much of this can be prevented.

SOUTHERN

PreDicta B (B = broadacre) is a DNA-based soil testing service that identifies soil-borne pathogens that pose a significant risk to broadacre crops prior to seeding (Photo 4).

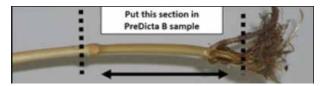


Photo 4: Sampling for PreDicta B

Source: GRDC

PreDicta B includes tests for:

- take-all (Gaeumannomyces graminis var tritici (Ggt) and G. graminis var avenae
- rhizoctonia barepatch (Rhizoctonia solani AG8)
- crown rot (Fusarium pseudograminearum and F. culmorum)
- blackspot of peas (Mycosphaerella pinodes, Phoma medicaginis var pinodella and Phoma koolunga)

# Access PreDicta B testing service

PreDicta B diagnostic testing services may be accessed through a SARDI-accredited agronomist. They will interpret the results, and provide advice on management options to reduce the risk of yield loss.

PreDicta B samples are processed weekly between February to mid-May (prior to crops being sown) every year.

PreDicta B is not intended for in-crop diagnosis. See the crop diagnostic webpage for other services.

## 8.1.2 Varietal resistance or tolerance

Triticale is highly resistant to P. neglectus 21, and resistant to P. thornei 22.

Triticale is thought to be susceptible to *P. penetrans*, but this information is based on preliminary trials and from observations of samples submitted to AGWEST Plant laboratories. More research is needed. 23

# 8.1.3 Damage caused by RLN

RLNs are more likely to be a problem when:

- susceptible varieties are grown sequentially, increasing nematode numbers
- an intolerant crop is sown
- sowing is delayed 24

During recent years, the Department of Economic Development and SARDI have conducted field studies to quantify losses caused by root-lesion nematodes in the Southern cropping region. This work measured grain yield in the presence of



**MORE INFORMATION** 

GRDC Update Paper: Root-lesion

**VIDEOS** 

WATCH: Root-Lesion Nematodes.

surprising impacts on RLN numbers

Resistant cereal varieties have

management

nematodes; importance, impact and

- M Williams (2013) Root out nematodes and get them tested. Grains Research and Development Corporation, 28/10/2013. https://grdc. com.au/Media-Centre/Media-News/West/2013/10/Root-out-nematodes-and-get-them-tested
- A Wherrett V Vanstone (2016) Root lesion nematode. Soil Quality. http://soilquality.org.au/factsheets/root-lesion-nematode
- $A\ Wherrett\ V\ Vanstone\ (2016)\ Root\ lesion\ nematode.\ Soil\ Quality.\ \underline{http://soilquality.org.au/factsheets/root-lesion-nematode}$ 
  - G Hollaway (2013) Cereal root diseases. Agriculture Victoria. http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plantdiseases/grains-pulses-and-cereals/cereal-root-diseases











high and low numbers of the target nematode. Table 2 shows the average yield loss caused by root-lesion nematodes in the five most intolerant cereal cultivars in Victorian field trials. There were large seasonal effects observed. The yield losses caused by *P. neglectus* were less than those caused by *P. thornei*.

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**Table 2:** Average yield loss due to root-lesion nematodes in the five most intolerant cereal cultivars across five growing seasons along with average rainfall.

	P. thornei (Bany	vena)	P. neglectus (Dooen)		
Year	Yield loss (%) Rainfall (mm)		Yield loss (%)	Rainfall (mm)	
2011	12.2	241	2.0	256	
2012	9.9	268	6.7	254	
2013	1.9	353	2.5	326	
2014	4.3	253	6.7	215	

Source: GRDC

# 8.1.4 Conditions favouring development

Nematodes can spread through a district in surface water (such as floodwater), and can be moved from one area to another in soil adhering to vehicles and machinery. They have the ability to quickly build up populations in the roots of susceptible crops and remain in the soil during fallow. As a result, the yield of following crops can be significantly reduced.

# How long does it take to reduce P. thornei in soils?

Key points:

- P. thornei (Pt) populations greater than 40,000 per kg of soil at harvest will
  requires a double break of around 40 months free of a host to reduce the
  population below the accepted threshold of 2000 Pt/kg. P. thornei populations
  greater than 10,000 per kg at harvest will requires a single break of around 30
  months free of a host to reduce the population below the accepted threshold
  of 2000 Pt/kg.
- Weeds can be a host, so fallows must be weed-free and free of volunteers.

Cereal cropping trials in the Northern region have highlighted the importance of the initial population when reducing nematode populations below the damage threshold. Over 30 months, the rate of decline in nematode populations with various starting populations and in a particular cropping sequence were monitored. High population of 80 nematodes/cm³ (~80,000 Pt/kg) took four years to reduce below the threshold of two nematodes per cubic centimetre. This would require two non-host crops such as sorghum and fallows to reduce the population. A moderate initial population of 50 nematodes/cm³ took three and a half years (Figure 2), requiring the equivalent of a single non-host summer crop and fallows. A population of 20 nematodes/cm³ took 24 months.

The long survival mechanisms of root-lesion nematodes highlight the importance of knowing the size of the population at the end of each season. Once a population increases, non-host, resistant crops or fallows are required to reduce the population below the damage threshold. Planting susceptible or tolerant crops within this time period will increase populations to higher levels that will take longer to reduce, thereby limiting cropping options, and potentially reducing the profitability of the overall farming system. As resistant wheat varieties are released they can be used to provide a winter decline option to increase non-host periods within the rotation. <sup>25</sup>



<sup>25</sup> J Which, J Thompson (2016) GRDC Update Paper: How long does it take to reduce Pt populations in the soil? <a href="https://grdc.com.au/">https://grdc.com.au/</a> Research-and-Development/GRDC-Update-Papers/2016/02/how-long-does-it-take-to-reduce-Pratylenchus-thornei-populations-in-the-soil

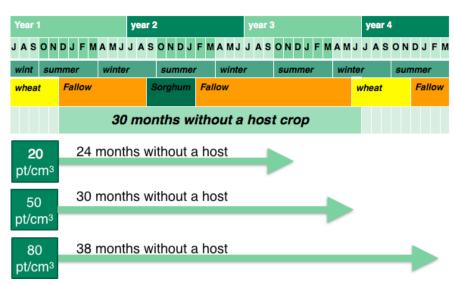








How long does it take to reduce Pratylenchus thornei (Root-lesion nematode) population in the soil?



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**Figure 2:** An example of a non-host fallow showing the time required to reduce different starting populations of root-lesion nematodes.

Source: GRDC

## 8.1.5 Thresholds for control

The damage threshold has been estimated at 2000 nematodes/kg soil (or 2/g soil). Control is warranted for paddocks with populations over this density threshold. <sup>26</sup>

# 8.1.6 Management of RLN

Key points:

- Know your enemy—soil test to determine whether RLN are an issue and which species are present.
- Select wheat varieties with high tolerance ratings to minimise yield losses in RLN infected paddocks.
- To manage RLN populations, it is important to increase the frequency of RLN resistant crops in the rotation
- Multiple resistant crops in a rotation will be necessary for long-term management of RLN populations.
- There are consistent varietal differences in Pt resistance within wheat and chickpea varieties.
- Avoid crops or varieties that allow the build-up of large populations of RLN in infected paddocks.
- Monitor the impact of your rotation.

#### There are four key strategies in reducing the risk of root-lesion nematodes:

- 1. Have soil tested for nematodes in a laboratory.
- 2. Protect paddocks that are free of nematodes by controlling soil and water run-off and cleaning machinery; plant nematode-free paddocks first.
- Choose tolerant wheat varieties to maximise yields (go to <u>nvtonline.com.au</u>).
   Tolerant varieties grow and yield well when RLN are present.
- 4. Rotate with resistant crops to prevent increases in root-lesion nematodes (Figure 3, Table 3). When high populations of RLN are detected, you may need to grow at least two resistant crops consecutively to decrease populations. In addition, ensure that fertiliser is applied at the recommended rate to ensure the yield potential of tolerant varieties is achieved.

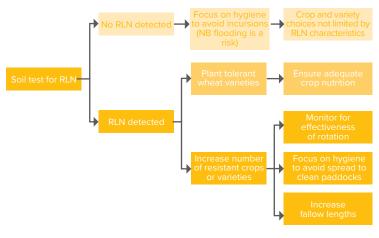


<sup>26</sup> GRDC (2015) Tips and tactics: Root lesion nematodes (Southern Region). Grains Research and Development Corporation, 03/03/2015. www.grdc.com.au/TT-RootLesionNematodes



**TABLE OF CONTENTS** 





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**Figure 3:** RLN management flow chart. It highlights the critical first step in the management of RLN, which is to test the soil and determine whether there is an issue to manage. Where RLN are present, growers should focus on both planting tolerant wheat varieties and increasing the number of resistant crops/varieties in the rotation.

Source: GRDC

**Table 3:** Susceptibility of some non-cereal crop and pasture species to root-lesion nematode infection.

RLN species	Susceptible	Moderately susceptible	Resistant
Pratylenchus neglectus	canola, chickpeas, mustard	common vetch, lentils	field peas, narrow leaf lupins, faba beans, triticale, safflower, cereal rye, medic, clover
Pratylenchus thornei	chickpeas, vetch, faba beans	canola, mustard, field peas*, lentils	field peas*, lupins

<sup>\*</sup>New field pea varieties are more susceptible to P. thornei than older varieties—check classification of specific varieties.

# There are four major control strategies against RLN:

- Nematicides (control in a drum). There are no registered nematicides for RLN in broadacre cropping in Australia. Screening of potential candidates continues to be conducted but RLN are a very difficult target with populations frequently deep in the soil profile.
- Nutrition. Damage from RLN reduces the ability of cereal roots to access nutrients and soil moisture and can induce nutrient deficiencies. Underfertilising is likely to exacerbate RLN yield impacts, but overfertilising is still unlikely to compensate for a poor variety choice.
- 3. **Variety choice and crop rotation.** These are currently our most effective management tools for RLN, with the focus is on two different characteristics: tolerance (ability of the variety to yield under RLN pressure) and resistance (impact of the variety on the build-up of RLN populations). Varieties and crops often have varied tolerance and resistance levels to Pt and Pn.
- 4. Fallow. RLN populations will generally decrease during a 'clean' fallow but the process is slow and expensive in lost 'potential' income. Long fallows may also decrease Mycorrhizal (VAM) levels and create more cropping issues than they solve. <sup>27</sup>

GRDC Tips and tactics: Root-lesion nematodes Southern Region.



<sup>(</sup>i) MORE INFORMATION

B Burton, R Norton, R Daniel (2015) GRDC Update Paper: Root lesion nematode; importance, impact and management. Grains Research and Development Corporation, 03/08/2015. <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management</a>









WATCH: Root-lesion nematodes

– What can I do?



WATCH: <u>Crop variety effect on nematodes</u>



# 8.2 Cereal cyst nematodes

#### Key points:

 Triticale is thought to be resistant to cereal cyst nematode (CCN) <sup>28</sup> likely owing to its parent crop, cereal rye <sup>29</sup>.

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JANUARY 2018

- CCN is a threat to cereals in the Southern and Western growing regions.
- CCN is most damaging in low rainfall districts/seasons, especially with late breaks.
- Rotations—use break crops to minimise carry-over of CCN host species (e.g. canola, lupins, chickpeas) as non-host crops are more effective than resistant cereals in reducing levels of CCN.
- Be aware of and try to minimise consecutive cereal hosts during your rotation.
   CCN levels can become damaging after only one or two seasons of a susceptible crop.
- Grow resistant cereal cultivars to limit levels of CCN in the soil.
- Control volunteer cereal hosts and grass weeds during late summer/early autumn and in break crops.
- Sow early where possible to ensure better root development.
- Maintain optimum soil fertility to 'get-ahead' of CCN infections.

Cereal cyst nematode is a pest of graminaceous crops worldwide. It is a significant problem across eastern Australia, becoming more problematic in areas where intensive cereal cropping occurs. These nematodes will only infect, feed and develop on cereals and other grasses (particularly wild oat); non-cereal crops will not host CCN, so are useful in rotations to limit damage caused to cereals.

Cereal cyst nematodes usually occur early in the season, and can occur on heavy or light soils.

CCN juveniles hatch from eggs contained in the cysts remaining from previous seasons, in response to lower temperatures and autumn rains. Hatching is delayed by late breaks or dry autumns, and this increases the risk of crop damage. Once hatched, the young nematodes seek out the roots of host plants. While male nematodes remain free-living in the soil, females penetrate roots and begin feeding. After mating occurs, the females produce eggs within their body. As the season progresses, the females remain feeding at the same infection site and begin to swell into the characteristic white spheres. This process takes 6–9 weeks, and CCN females remain like this until the host plant begins to senesce. The females die, and their cuticle hardens and turns brown to form a cyst. Cysts are particularly hardy, and remain in the soil over summer until temperatures fall and the autumn rains begin which stimulates hatching of the next generation. Cereal cyst nematodes have only one life cycle per year (Figure 4), but each cyst contains several hundred eggs, so populations can increase rapidly on susceptible cereals. 30

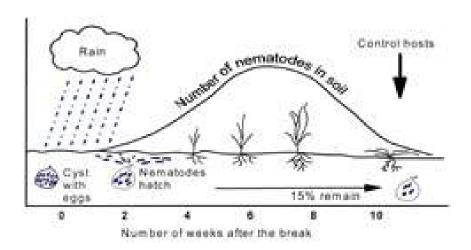


<sup>28</sup> M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. <a href="https://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>9</sup> R Asiedu, JM Fisher, CJ Driscoll (1990) Resistance to Heterodera avenue in the rye genome of triticale. Theoretical and applied genetics 79(3), 331–336.

A Wherrett V Vanstone (2016) Cereal cyst nematode. Soil Quality. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

FEEDBACK



**Figure 4:** Life cycle of the cereal cyst nematode.

Source: AgVic

In the autumn, nematodes hatch in response to moisture and low temperatures ( $<15^{\circ}$ C) over a period of several weeks, with the peak hatch occurring about six weeks after the autumn break. After a further eight weeks, these nematodes will form viable eggs. Therefore, to prevent CCN multiplying, it is necessary to control host plants within 10 weeks of crop germination.

Each year approximately 80 % of nematodes hatch from cysts after the autumn break, while the remaining 20 % stay dormant until the following season. This is why it will take at least two years with 'break' crops to control CCN. Under dry (drought) conditions, however, up to 50 % of nematodes remain dormant, and an extra year of 'break' crop is advisable.  $^{31}$ 

## 8.2.1 Symptoms and detection

The symptoms of CCN infection can be readily recognised. Above ground, patches of unthrifty yellowed and stunted plants can be observed (Photo 5). Planting a susceptible crop in successive years will result in these patches becoming larger with time.

Closer examination of the roots will reveal symptoms that are typical of CCN. Below ground, cereal roots can appear 'knotted' (Photo 6), and 'ropey' or swollen (Photo 7). Development of root systems is retarded and shallow. In spring, characteristic 'white cysts' (about the size of a pin head) can be seen with the naked eye if roots are carefully dug and washed free of soil. These are the swollen bodies of the female CCN, each containing several hundred eggs. <sup>32</sup>



G Hollaway, F Henry (2013) Cereal root diseases. Agriculture Victoria. <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases</a>

<sup>32</sup> A Wherrett, V Vanstone (2016) Cereal cyst nematode. Soil Quality. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode









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**Photo 5:** CCN will cause distinct patches of yellowed and stunted plants. Note the likeness of symptoms to poor nutrition or water stress.

Photo: Vivien Vanstone, DAFWA, Nematology. Source: Soil Quality

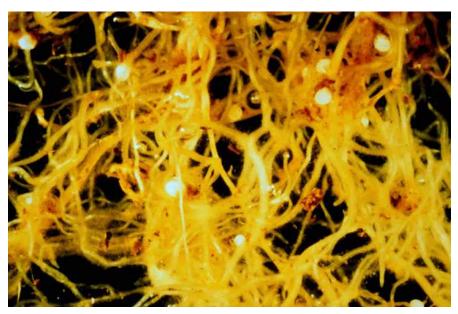


**Photo 6:** CCN produce 'knotting' of cereal roots.

Photo: Vivien Vanstone, DAFWA, Nematology. Source: Soil Quality







**Photo 7:** Cereal roots infected with CCN appear 'ropey' and swollen.

Source: CropPro

# 8.2.2 Varietal resistance or tolerance

Triticale is thought to be resistant to cereal cyst nematodes (CCN)  $^{33}$  due to its cereal rye component  $^{34}$ .

# 8.2.3 Damage caused by CCN

In serious outbreaks of CCN, it may be important to avoid cereals for two years to ensure an adequate reduction in the population. Just two CCN eggs per of gram soil can cause significant economic loss to intolerant cereal crops. Levels of 1–5 eggs per gram of soil can reduce yield of intolerant cultivars by up to 20%. <sup>35</sup>

# 8.2.4 Management

In general, cereal cyst nematodes (CCN) have been well managed in Victoria through the widespread use of resistant cultivars.

It is recommended to plan ahead for a disease break of at least two years following susceptible cereals on paddocks infested with wild oats. Timing of host removal is critical when establishing a disease break. In calculating the critical date to chemical fallow or remove host species from break crops, consideration should be given to the time taken for host plants to die after herbicide application. Nematodes will continue to feed until the plant is dead.

Host plants, particularly wild oats and susceptible self-sown cereals, must be controlled before the nematodes have completed the development of eggs. This is approximately 10 weeks after the autumn break (see Figure 8).

The use of resistant cereals and non-host crops, or fallow in rotations as part of a two-year break is an effective method to control CCN.

In areas prone to CCN, such as the Wimmera and Mallee, it is important to maintain a high proportion of CCN resistant cereals in the rotation.



<sup>33</sup> M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-y5553e/v5553e00.pdf

<sup>34</sup> R Asiedu, JM Fisher, CJ Driscoll (1990) Resistance to Heterodera avenue in the rye genome of triticale. Theoretical and applied genetics 79(3), 331–336.

A Wherrett, V Vanstone (2016) Cereal Cyst Nematode. Soil Quality. <a href="http://www.soilquality.org.au/factsheets/cereal-cyst-nematode">http://www.soilquality.org.au/factsheets/cereal-cyst-nematode</a>



**TABLE OF CONTENTS** 





#### Disease breaks for CCN

- grass-free pulse and oilseed crops or legume pasture
- resistant cereals (See the relevant local <u>Cereal Diseases Guide</u> for a list of CCN resistant cereal varieties.)
- chemical fallow prepared early in the season before nematodes have produced viable eggs

As with other nematodes, there is no effective or economically feasible means of controlling CCN through chemical application. Chemical nematicides are expensive to use and toxic to humans, and the success of applications are often highly variable. Cereal cyst nematodes are best controlled through effective rotation management. Only 70–80% of eggs hatch each season, regardless of the crop host. As a result, it can take several years for high CCN levels to be reduced by rotation with resistant or non-host crops. The use of a break crop (e.g. canola, lupins, chickpeas) ensures a large proportion of the CCN population is removed. In serious outbreaks of CCN, it may be important to avoid cereals for two years to ensure an adequate reduction in the population.

Ryegrass, wild oats and other grasses are also good hosts for CCN, although reproduction rates may be lower than on the cropping species. For this reason, it is important to realise that during a pasture phase in a rotation, the existence of grass weeds will assist the development of a CCN population. Likewise, if there are also grasses present following summer rains or around paddock borders, it provides a carryover for the nematode population.

Ensuring optimum soil fertility is maintained helps to minimise the effects of CCN. Allowing the emerging crop access to adequate nutrition allows the root systems to establish and 'get ahead' of any potential nematode infections. Although this does not decrease the nematode population, losses associated with CCN infections will be minimised.

Finally, where there is a known population of cereal cyst nematodes in a paddock, and the planting of a cereal cannot be avoided, it is important to choose cultivars displaying CCN tolerance and preferably resistance as well.  $^{36}$ 

#### 8.3 Nematodes and crown rot

While all winter cereals host the crown rot fungus, the degree of yield loss due to infection will vary depending on cereal type. The approximate order of increasing yield loss is cereal rye, oats, barley, bread wheat, triticale and durum wheat. <sup>37</sup>

Many trials concentrate on crown rot, and it is becoming more important to build a picture of the interaction of crown rot with other factors, especially in combination with *Pratylenchus thornei (Pt)* levels. As well as reducing yield, *Pt* reduces grain quality and nitrogen use efficiency, and increases the severity of crown rot infections. <sup>38</sup>

There have been numerous field trials since 2007 evaluating the impact of crown rot on a range of winter-cereal crop types and varieties. This work has greatly improved the understanding of crown rot impact and variety tolerance, but also indicates we may be suffering significant yield losses from another 'disease' that often goes unnoticed.



<sup>36</sup> A Wherrett, V Vanstone (2016) Cereal cyst nematode. Soil Quality. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

<sup>37</sup> GRDC (2016) Tips and Tactics: Crown rot in winter cereals—Southern Region. <a href="https://grdc.com.au/"/media/Documents/Resources/Publications/Tips-and-Tactics/GRDC\_Tips\_and\_Tactics\_Crown\_Rot\_SOUTHERN\_WEB.PDF">https://grdc.com.au/"/media/Documents/Resources/Publications/Tips-and-Tactics/GRDC\_Tips\_and\_Tactics\_Crown\_Rot\_SOUTHERN\_WEB.PDF</a>

<sup>38</sup> T Dixon (2013) Balancing crown rot and nematodes in wheat. Ground Cover 104: May—June 2013. Grains Research and Development Corporation, 06/05/2013. <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Balancing-crown-rot-and-nematodes-in-wheat">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Balancing-crown-rot-and-nematodes-in-wheat</a>

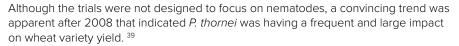




**VIDEOS** 

WATCH: <u>GCTV9: Crown rot and</u> root-lesion nematodes.





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Where Pt combines with high levels of crown rot (a common scenario), yield losses can be exacerbated if varieties are susceptible to Pt. Instead of a 10% yield loss from Pt in a susceptible variety, a 30 to 50% loss could occur if crown rot is combined with a Pt-intolerant variety (Photo 8).

The research has also shown that not only does Pt cause high yield loss in susceptible varieties, but Pt numbers can increase much faster than in an area in which tolerant varieties are growing. These increased Pt numbers can lead to even greater damage in future crops. <sup>40</sup>



**Photo 8:** Grass plant showing both parasitic nematode damage to roots and crown rot in above ground tissues.

Source: NCSU

# 8.3.1 Management

While variety choice is the key management option when it comes to managing Pt risk, rotation and stubble management are by far our most important management tools when it comes to crown rot management. Root-lesion nematodes, especially Pt, need to be taken far more seriously and better factored into crop rotation considerations as well as variety choice. <sup>41</sup>

# Soil testing

## PreDicta B

Cereal root diseases cost grain growers in excess of \$200 million a year in lost production. Much of this can be prevented.



<sup>39</sup> R Daniel (2013) GRDC Update Paper: Managing root lesion nematodes: how important are crop and variety choice? Grains Research and Development Corporation, 16/07/2013. <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice</a>

<sup>40</sup> B Freebairn (2011) Nematodes and crown rot: a costly union. Ground Cover 91, March–April 2011. Grains Research and Development Corporation, 01/03/2011. <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-91-March-April-2011/Nematodes-and-crown-rot-a-costly-union">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-91-March-April-2011/Nematodes-and-crown-rot-a-costly-union</a>

B Freebairn (2011) Nematodes and crown rot: a costly union. Ground Cover 91, March—April 2011. Grains Research and Development Corporation, 01/03/2011. <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-91-March-April-2011/Nematodes-and-crown-rot-a-costly-union">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-91-March-April-2011/Nematodes-and-crown-rot-a-costly-union</a>







<u>PreDicta B</u> (B = 'broadacre') is a DNA-based soil testing service that identifies soil-borne pathogens that pose a significant risk to broadacre crops prior to seeding (Photo 9).

SOUTHERN



Photo 9: Sampling for PreDicta B

Source: GRDC

PreDicta B includes tests for:

- Take-all (Gaeumannomyces graminis var tritici [Ggt] and G. graminis var avenae [Gga]).
- Rhizoctonia barepatch (Rhizoctonia solani AG8).
- Crown rot (Fusarium pseudograminearum and F. culmorum).
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PreDicta B is not intended for in-crop diagnosis. See the <u>crop diagnostic webpage</u> for other services.

#### 8.3.2 Varietal choice

Crop rotation and variety choice are the important factors in protection against both diseases. Choosing a variety solely on crown rot resistance is not critical, especially if appropriate management techniques have been carried out, but choice of variety is crucial when it comes to RLN tolerance.

Further research into varietal tolerance to crown rot and nematodes has revealed that choosing a variety is difficult. Determining the relative tolerance of varieties to crown rot is complex as it can be significantly influenced by background inoculum levels, RLN populations, differential variety tolerance to *Pn* versus *Pt* and varietal interaction with the expression of crown rot. Other soil-borne pathogens such as *Bipolaris sorokiniana*, which causes common root rot, also need to be accounted for in the interaction between crown rot and varieties. Starting soil water, in-crop rainfall, relative biomass production, sowing date and resulting variety phenology in respect to moisture and/or temperature stress during grainfill can all differentially influence the expression of crown rot in different varieties. <sup>42</sup>

The approximate order of increasing yield loss to crown rot is: cereal rye, oats, barley, bread wheat, triticale and durum wheat.  $^{43}$ 



S Simpfendorfer, M Gardner, G Brooke, L Jenkins (2014) Crown rot and nematodes—are you growing the right variety? GRDC Update Papers 6 March 2014, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Crown-rot-and-nematodes">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Crown-rot-and-nematodes</a>

<sup>43</sup> GRDC. (2016). <u>Tips and Tactics: Crown rot in winter cereals.</u> Southern region.







# **Diseases**

# Key messages

Triticale can be less susceptible to the common fungal diseases of cereals, which
makes it suitable for use in rotations where stubble is retained.

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- Some varieties have good resistance to stem, leaf and stripe rusts, mildew and Septoria tritici blotch as well as both resistance and tolerance to cereal cyst nematode (CCN).
- Soil testing is essential for diagnosing many cereal diseases.
- Keeping consistent paddock records and implemented crop rotations are some
  of the most important and simple strategies in fighting crop diseases.

In the early development stages of triticale in Australia, the crop was relatively free of disease compared with other winter cereals. As the crop expanded in the 1980s, a range of fungal and other diseases became more important and began to require active management. The main diseases have been the three rusts (leaf, stem and stripe rust), crown rot, Barley Yellow Dwarf Virus (BYDV), and nematodes. <sup>1</sup>

Many growers use triticale as a disease break in their rotations and value the benefits of triticale for its vigourous root growth. Triticale is considered resistant to Root-lesion nematodes and Cereal Cyst nematodes making it a useful crop rotation in managing these diseases. Other favoured characteristics of triticale are its resistances to BYDV, mildew and rusts, which may cause significant yield reductions in wheat, barley and oats. <sup>2</sup> Triticale is tolerant to rusts, *Septoria tritici*, smuts, bunt, powdery mildew, takeall, root rots, Wheat mosaic virus and Barley stripe mosaic virus. <sup>3</sup> Triticale has vastly superior tolerance over wheat to *Septoria tritici* blotch. <sup>4</sup>

Table 1 shows the reaction to diseases by different varieties of triticale grown in the southern region.  $^{\rm 5}$ 



<sup>1</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Rethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/IA-102">http://www.apri.com.au/IA-102</a> Final Research Report pdf

<sup>2</sup> KV Cooper, RS Jessop, NL Darvey (2004) Triticale in Australia. In M Mergoum, H Gómez-Macpherson (eds), Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="mailto:ftp://ftp.fao.org/docrep/fao/009/y555802.pdf">ftp://ftp.fao.org/docrep/fao/009/y555802.pdf</a>

Varughese, Pfeiffer and Pena (1996) in Mergoum, M., & Macpherson, H. G. (2004). Triticale improvement and production (No. 179). Food & Agriculture Org. ftp://ftp.fao.org/docrep/fao/009/y5553e/y5553e02.pdf

<sup>4</sup> P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf. See also GRDC. Field Peas: The Ute Guide. App. GRDC, <a href="https://grdc.com.au/Resources/Apps">https://grdc.com.au/Resources/Apps</a>

Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary">http://agriculturevic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary</a>







**Table 1:** Triticale variety agronomic guide and disease reaction.

Variety	Maturity	Height	Head colour	Stem rust	Stripe rust	Leaf rust	Yellow leaf spot	Septoria tritici	CCN resistance	Pratylenchus neglectus resistance	P. thornei resistance
Astute(b	М	M-T	W	RMR	RMR#	RMR	MRMS	-	R	RMR	MS
Berkshire()	E-M	Т	W	R	MRMS#	R	MR	RMR	_	MR	MS
Bison(b	М	Т	W	RMR	R#	RMR	MR	MR	R	MR	RMR
Canobolas(1)	E-M	M-T	W	R	MRMS#	RMR	MR	RMR	_	MR	MSS
Chopper(1)	Е	S-M	W	MR	MRMS#	R	MR	RMR	R	MRMS	MSS
Endeavour(1)	L		W	R	RMR#	R	MR	R	_	MR	SVS
Fusion(b	М	M-T	W	R	RMR#	R	MRMS	R	R	RMR	MS
Goanna	E-M	Т	W	R	RMR#	R	MR	R	R	MRMS	SVS
KM10	E-M			R	R#	MRMS	MRMS	MR	_	MR	MSp
Rufus	М	Т	W	R	MRMS#	R	MR	RMR	R	MSS	MSS
Tahara	М	Т	W	R	MRMS#	R	MR	RMR	R	MR	S
Tobruk(D	M-L	_	W	R	MR#	R	MR	R	_	MR	SVS
Tuckerbox	М	Т	W	MR	MR#	R	MR	RMR	_	MRMS	S
Yowie	М	M-T	W	R	MR#	R	MR	RMR	R	MR	MSS

Maturity: E = early, M = mid-season, L = late, VL = very late

 $\label{eq:height: M = medium, T = tall} \begin{tabular}{ll} Colour: W = white, Br = brown \\ Disease resistance order from best to worst: R > RMR > MRMS > MS > MSS > S > SVS > VS \\ \end{tabular}$ 

p = provisional ratings—treat with caution. R = resistant, M = moderately, S = susceptible, V = very. # Varieties marked may be more susceptible if alternative strains are present.

Source: Agriculture Victoria

#### 9.1 General disease-management strategies

#### Key points:

- Use resistant or partially resistant varieties.
- Use disease-free seed.
- Use fungicidal seed treatments to kill fungi carried on the seed coat or in the seed.
- Have a planned in-crop fungicide regime.
- Conduct soil testing to determine the severity of potential disease infestations. This can be used as a tool to determine what crop is grown in what paddock the following year.
- Send plant or stubble samples away for analysis to determine the pathogen or strain you are dealing with or the severity of the disease.
- Keep the farm free of weeds, which may carry over some diseases. This includes cereals over summer that may act as a green bridge.
- Rotate crops. 6
- Stay up to date with local disease guides: Cereal disease guide 2016–SA and Cereal disease guide 2016-Vic.

### Cereal root disease management in the Southern region

Cereal root diseases can have serious impacts on grain yield if they are not adequately controlled. The key to preventing root diseases is to identify paddocks at risk by inspecting the roots of previous cereal crops or taking a PreDicta B soil test before sowing. Knowledge of the potential root diseases in a paddock enables the most appropriate control strategies to be implemented prior to and/or at



SOUTHERN

DAF QId (2015) Wheat:diseases, physiological disorders and frost. DAF QId, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/ broadacre-field-crops/wheat/diseases



**TABLE OF CONTENTS** 



sowing. Management must be implemented prior to sowing as there are no in-crop management options available for the control of root diseases, compared with many foliar diseases. <sup>7</sup> To protect the paddock environment and maximise yields:

SOUTHERN

- Minimise losses associated with root diseases by inspecting plant roots in the previous crop or using a PreDicta B soil test prior to sowing to identify atrisk paddocks.
- Crown rot can an major disease if inoculum levels are high from the previous season. Reduce risk by rotating to non-cereal crops
- In paddocks with high numbers of root-lesion nematodes (RLNs), yield losses can
  be minimised by selecting partially tolerant cultivars and avoiding late sowing.
  Resistant cultivars can reduce nematode densities and therefore reduce losses
  in subsequent intolerant crops.
- Cereal cyst nematode is a very damaging nematode if numbers are allowed to increase by growing susceptible cereals.
- Rhizoctonia root rot will likely be a low risk if there is a wet summer with multiple rainfall events, provided summer weeds are controlled.
- Take-all will be a low risk if there is a dry spring, limiting inoculum build up.

# 9.1.1 Tools for diagnosing cereal diseases

# Crop Disease Au app





The app Crop Disease Au, developed by the National Variety Trials, allows the user to quickly:

- Identify crop diseases.
- Compare disease-resistance ratings for cereal, pulse and oilseed varieties.
- Potentially, facilitate the early detection of exotic crop diseases.

The app brings together disease-resistance ratings, disease information and also features an extensive library of quality images that make it easier for growers to diagnose crop diseases and implement timely management strategies. Live feeds from the Australian National Variety Trials (NVT) database means the apps is always up to date with the latest varieties.

If a disease cannot be identified there is also a function that allows the user to take a photo of their crop and email it to a friend or an adviser.

The precursor for this app was the Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR) Crop Disease app developed by a team of grains pathologists. Crop Disease Au functions similarly to the old app, but provides information for all Australian grain-growing regions.

#### MyCrop







Released by DAFWA and funded by the GRDC, MyCrop is a collection of interactive tools that can be accessed online or via apps that enable users to diagnose **cereal** production constraints while in the field. The apps cover wheat, barley, canola and pulses.

The main feature is an intuitive diagnostic key, which quickly diagnoses a range of possible constraints based on real-time crop and paddock symptoms. Covering a broad range of disease, pest and other agronomic issues, MyCrop can help users to accurately identify constraints and determine possible management solutions. Key features include:



<sup>7</sup> G Hollaway, J Fanning, F Henry, A McKay (2015) Cereal root disease management in Victoria. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Cereal-root-disease-management-in-Victoria">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Cereal-root-disease-management-in-Victoria</a>



**TABLE OF CONTENTS** 





# **MORE INFORMATION**

Field Crop Diseases Manual online

MyCrop

GRDC, <u>Cereal root and crown</u> diseases: Back pocket quide

- Extensive image library and constraint factsheets.
- Selecting paddock and plant clues to easily identify the likely cause of cropping problems.
- Over 150 constraints ranging from pests and diseases to soil deficiencies, environmental and management factors.
- Online diagnostic tools.

# CropPro

## Web-based

The online tool CropPro, developed by DEDJTR and GRDC, has diagnostic and economic features that allow growers to efficiently identify and manage constraints to both crop productivity and profitability. The core functions of CropPro are to:

- Diagnose the cause of wheat and canola crop problems.
- Support risk analysis.
- Provide evidence-based information for management of crop constraints.

It combines paddock and crop symptoms in one resource, enabling users to work through a simple process of elimination. CropPro also has an economic feature allowing growers to compare return-on-investment outcomes for different management options and an Agronomist Toolkit that includes an extensive list of resources, online decision-support tools and apps.

Through CropPro, the Field Crop Diseases Manual is available online. The manual provides an all-in-one resource for disease identification, biology and management information for cereal, pulse and oilseed crops.

A series of economic videos also feature on CropPro, providing growers with clear information about how management decisions might influence their profitability.

# **9.2 Rust**

In Australia, there are three rust diseases of triticale and wheat:

- stripe rust
- stem rust
- leaf rust

They are caused by three closely related fungi all belonging to the genus *Puccinia*.

The rusts are so named because the powdery mass of spores which erupt through the plant's epidermis have the appearance of rusty metal. These spores can be spread over considerable distances by wind but may also be spread on clothing and equipment.

Rusts have a number of features in common. They can only infect a limited number of specific host plants (mostly volunteer triticale, wheat and barley) and can only survive on green, growing plant tissue. Biotrophic pathogens (including stem rust, stripe rust and leaf rust) require a living plant host and, since they cannot survive on soil, seed or dead tissue, need a 'green bridge', grassy weeds or overlapping crops to persist. Plants that facilitate the survival of rust fungi through the summer are known as the 'green bridge'. <sup>8</sup>

Stripe rust reached epidemic levels in eastern Australia during 2009, resulting in widespread fungicidal spraying. Given favourable conditions rust can cause large losses in susceptible varieties. However, growers have shown that by planning to manage this disease they can effectively minimise its effects.

The University of Sydney's 2016 Cereal Rust Report warns growers to monitor crops carefully. Reports on wheat leaf rust, barley leaf rust and wheat stripe rust in the



SOUTHERN

<sup>8</sup> DAF QId (2015) Wheat: diseases, physiological disorders and frost. DAF QId, <a href="https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases">https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases</a>





FEEDBACK



# **MORE INFORMATION**

The Rust Bust

Cereal rust situation, September 2016

eastern states suggest that these diseases are starting to gain momentum in crops. Recent weather conditions across large areas of the cereal-growing regions are likely to favour rust development. Monitoring of crops for all cereal rusts is advised and samples of all rusts observed in cereal crops should be submitted for pathotype analysis to the Australian Cereal Rust Survey. 9

SOUTHERN

The Rust Bust is an initiative of the Australian Cereal Rust Control Program (ACRCP) Consultative Committee, with support from the GRDC. The Rust Bust aims to raise awareness of wheat rust-management strategies that reduces risk of disease outbreak.

# 9.2.1 Varietal resistance or tolerance

Some triticale varieties have good resistance to stem, leaf and stripe rusts (Tables 2 and 3).  $^{10}$ 

**Table 2:** Triticale variety Rust disease susceptibility ratings.

Variety	Stem rust	Stripe rust	Leaf rust
Astute(D	RMR	RMR#	RMR
Berkshire(b	R	MRMS#	R
Bison(b	RMR	R#	RMR
Canobolas(1)	R	MRMS#	RMR
Chopper(D	MR	MRMS#	R
Endeavour(1)	R	RMR#	R
Fusion(D	R	RMR#	R
Goanna	R	RMR#	R
KM10	R	R#	MRMS
Rufus	R	MRMS#	R
Tahara	R	MRMS#	R
Tobruk(D	R	MR#	R
Tuckerbox	MR	MR#	R
Yowie	R	MR#	R

 $\label{eq:maturity: E = early, M = mid-season, L = late, VL = very late} \\ Height: M = medium, T = tall \\$ 

Colour: W = white. Br = brown

Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > VS p = provisional ratings—treat with caution. <math>R = resistant, M = moderately, S = susceptible, V = very. # Varieties marked may be more susceptible if alternative strains are present

Source: Agriculture Victoria



W Cuddy, R Park, D Singh (2016) Cereal rust situation, September 2016. Cereal Rust Report (14) 7. University of Sydney, <a href="http://sydney.edu.au/agriculture/documents/pbi/cereal\_rust\_report\_2016\_14\_7.pdf">http://sydney.edu.au/agriculture/documents/pbi/cereal\_rust\_report\_2016\_14\_7.pdf</a>

Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/">http://agriculture.vic.gov.au/</a> agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary



Variety	Stripe Tobruk() Pathotype	Stripe YR17-27 Pathotype
Breakwell▲	SVS	MR
Endeavour(1)	RMR	RMR
Yukuri	RMR	RMR
Crackerjack▲	MS∘	RMR
Tobruk(b▲	MSS∘	MR
Canobolas(b▲	MSS	MRMS
Chopper(b▲	MSS	MRMS
Berkshire(b▲	MS	MRMS
Bogong(D▲	MS	MRMS
Rufus▲	MS	MRMS
Tahara▲	MS	MRMS
Fusion(b	MR•	RMR
Yowie§	MRMS, MS•	MR
Tuckerbox	MRMS	MR
Goanna§	MRMS	RMR
Hawkeye(D	MR, MSS•	MR,MS•
Jaywick(D	MR, MRMS•	RMR, MS•
Cartwheel	-	R
Astute(D§	-	RMR
Bison(b§	-	R
KM10§	-	R

VS = Very susceptible, SVS = Susceptible to very susceptible, S = Susceptible, MSS = Moderately susceptible to susceptible, MS = Moderately susceptible, MRMS = Moderately resistant, RMR = Resistant to moderately resistant, R = Resistant.

Source: Rust Bust.

# 9.2.2 Symptoms

Table 4 outlines the symptoms of common diseases of cereals.  $^{\mbox{\scriptsize 1}}$ 



**SOUTHERN** 

 $<sup>\</sup>$  Limited data available on Astute(b, Bison(b, Goanna, KM10 and Yowie in NSW.

<sup>▲</sup> Outclassed.

Mixed population, some plants are more susceptible to stripe rust.

o Susceptible to head infection.

<sup>11</sup> DAF Qld (2015) Integrated disease management of wheat rusts and yellow leaf spot. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts</a>



Table 4: Diagnosing leaf diseases in wheat.

Disease	Spore colour	Symptoms	Plant part affected
Stripe rust	Yellow-orange	Small closely packed circular pustules during the vegetative stage, becoming stripes along leaves of older plants	Upper surface of leaf, leaf sheaths, awns and inside glumes
Stem rust	Reddish-brown	Random, oblong pustules with torn margins	Both sides of leaf, leaf sheaths, stems and outside of head
Leaf rust	Reddish-orange	Random, circular to oval pustules	Upper surface of leaf and leaf sheaths
Yellow leaf spot	small tan (yellow brown) oval spots surrounded by a yellow margin	Spots up to 10 mm, varied shapes and may coalesce	Both sides of leaf, leaf sheaths, stems and outside of head

Source: DAF Qld

# 9.2.3 Stripe rust

Stripe rust has become more damaging in recent years owing to new races arriving in eastern Australia.

Stripe rust is caused by the fungus *Puccinia striiformis*. It is easily distinguished from other wheat rusts by the yellow-orange spores, which produce small, closely packed pustules that develop into stripes along the length of the leaf veins. The spores occur on the upper surface of the leaves, the leaf sheaths, awns and inside of the glumes (Photo 1).  $^{12}$ 



Photo 1: Stripe rust in a cereal plant.

Source: DAF Qld



<sup>12</sup> DAF Qld (2015) Integrated disease management of wheat rusts and yellow leaf spot. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts</a>



**TABLE OF CONTENTS** 



Stripe rust requires cool and wet conditions to infect the crop. Free moisture on the leaves and an optimal temperature of  $10-15^{\circ}$ C are required for infection. Pustules erupt 10-14 days after infection.

If the weather is conducive to stripe rust, the disease can cause up to 25% yield loss on varieties scoring moderately susceptible (MR–MS) or lower. This is provided there is inoculum from a neglected green bridge or from an infected crop.

There are several fungicides recommended for the control of stripe rust. Fungicides can be incorporated with the fertiliser or applied as seed dressings to delay the onset of disease. Later on, if the if the main leaves (the flag, flag 1, -2 and -3 leaves) leaves require protection, recommended foliar fungicides can be applied for the control of stripe rust.

See the APVMA website for up-to-date fungicide registrations.

#### Stripe rust in southern Australia

There have been two introductions of stripe rust into Australia. They probably came in on clothing. The first arrived in Victoria in 1979, and it rapidly spread across eastern Australia. It mutated, and a number of pathotypes (also known as races or strains) developed, enabling the rust to attack more varieties over time. Even though it became widespread in eastern Australia, it did not move to Western Australia.

The second introduction occurred in Western Australia in 2002. By 2003, this pathotype was in eastern Australia. This one, known as the WA pathotype, quickly became dominant in eastern Australia. It has undergone several mutations in eastern Australia, and there are now many pathotypes of stripe rust that are common in southern Australia. The resistance ratings provided in disease guides often represent the most important of the pathotypes. <sup>13</sup>

The Plant Breeding Institute at the University of Sydney received samples in 2016 of stripe rust in Victoria: a sample off Derrimut from Nullawil, and a sample off Scepter from Rupanyup. Stripe rust has also been reported by Dr Hugh Wallwork around the Northern Yorke Peninsula in South Australia, but no samples have yet been received to confirm its presence. <sup>14</sup>

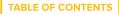
Severe symptom development on Tobruk(to triticale was reported in November 2009. Experiments confirmed that isolates collected from Tobruk(to were capable of causing more severe infection on Tobruk(to in adult plants compared to the 'Jackie' pathotype in greenhouse tests. This lead to the naming of a new pathogenic variation caused by the 'Tobruk(to') pathotype, which was responsible for the poor performance of Tobruk(to in 2009. Photo 2 shows the contrast in infection types between the 'Jackie' and 'Tobruk(to') pathotypes on Tobruk(to) and Endeavour(to) triticale.



<sup>13</sup> G Holloway (2016) Stripe rust of wheat. Note AG1167. Revised, Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stripe-rust-of-wheat">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stripe-rust-of-wheat</a>

<sup>14</sup> W Cuddy, R Park, D Singh (2016) Cereal rust situation, September 2016. Cereal Rust Report (14) 7. University of Sydney, <a href="http://sydney.edu.au/agriculture/documents/pbi/cereal\_rust\_report\_2016\_14\_7.pdf">http://sydney.edu.au/agriculture/documents/pbi/cereal\_rust\_report\_2016\_14\_7.pdf</a>









Stripe rust



WATCH: GCTV1: Cereal rust





SOUTHERN

**Photo 2:** Paired leaves of triticale cultivars Tobruk() and Endeavour() compared to the susceptible Jackie, inoculated with the 'Jackie' pathotype (left) and 'Tobruk()' pathotype (right).

Source: Cereal Rust Report, 2010.

## Managing stripe rust

Avoid growing highly susceptible varieties: replace susceptible varieties with a moderately or highly resistant variety. Growers should check to ensure their current variety has adequate field resistance to both the Jackie and Tobruk() pathotypes of stripe rust (See Table 3 in section above) or consider using foliar fungicides to control the disease in the crop if required.

There are now options available to treat seed to provide seedling protection against the disease. <sup>15</sup> Seed treatment should be considered for controlling seedling stripe rust in susceptible varieties, especially those sown early for grazing. <sup>16</sup>

Newer varieties generally have improved stripe-rust resistance. Varieties with at least an MR–MS (moderately resistant—moderately susceptible) should be used. Usually changing to a more resistant variety also gives a yield advantage. For example, changing from Jackie to Endeavour() makes good sense. Endeavour() offers a 15% yield increase over Jackie, has excellent dry-matter production for early grazing, and is resistant to all current strains of stripe rust.

Seek local advice on managing stripe rust in triticale. Remember that just because a variety is rust resistant does not mean it will be completely free of stripe rust.

Under very high disease pressure, isolated leaves of resistant varieties can be infected. This does not automatically mean the resistance has broken down or that the crop needs spraying. <sup>17</sup> In these cases rust samples should be sent to: Australian Cereal Rust Survey

Plant Breeding Institute Private Bag 4011 Narellan, NSW 2567



<sup>15</sup> Agriculture Victoria (2012) Growing triticale. Note AG0497. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. DPI NSW, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

<sup>17</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/1A-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>



# 9.2.4 Stem rust (black rust)

Triticale is thought to have good resistance against stem rust. <sup>18</sup> All the present commercial varieties have been screened for the current races of stem rust and they have adequate levels of resistance, although if new races arrive varieties will require screening for them as the levels of resistance to new races are unknown. <sup>19</sup>

Stem rust is caused by the fungus *Puccinia graminis* f. sp. *tritici*. Stem rust will infect all cereals. It produces reddish-brown spore masses in oval, elongated or spindle-shaped pustules on the stems and leaves. Unlike leaf rust, pustules erupt through both sides of the leaves (Photo 3). <sup>20</sup> Ruptured pustules release masses of stem rust spores, which are disseminated by wind and other carriers.



Photo 3: Stem rust in a cereal plant.

Source: DAF Qld

Stem rust develops at higher temperatures than the other wheat rusts, within a range of 18–30°C. Spores require free moisture (i.e. dew, rain or irrigation) and take up to six hours to infect the plant. Pustules can be seen 10–20 days after infection.

Some cereal varieties have reasonable resistance to stem rust (rating 5 or higher). However, in the past, stem rust has had the ability to cause significant economic damage (50–100% of yield). This has happened when conditions are conducive for the disease and susceptible varieties are grown, or a new pathotype has developed which has overcome a variety's resistance.

Inoculum must be present for the disease to develop. Practicing crop hygiene by removing volunteer wheat, which forms a green bridge for the fungus through the summer, can eliminate or delay the onset of stem rust.

Foliar fungicides to control stem rust are presented in Tables 4 and 5 in section: Managing cereal rusts.



Adhikari, K. N., & McIntosh, R. A. (1998). Inheritance of wheat stem rust resistance in triticale. Plant breeding, 117(6), 505–513.

<sup>19</sup> Jessop RS, Fittler M. (2009). Triticale production Manual—an aid to improved triticale production and utilisation. <a href="http://www.apri.com.au/IA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/IA-102\_Final\_Research\_Report\_pdf</a>

<sup>20</sup> DAF QId (2015) Integrated disease management of wheat rusts and yellow leaf spot. DAF QId, <a href="https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts">https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts</a>









**MORE INFORMATION** 

Stem rust



WATCH: <u>GCTV5</u>: <u>Green bridge control</u> <u>for less stem rust</u>



#### Stem rust in southern Australia

Conditions that favour stem-rust epidemics are rare and occur on average once every 16 years in southern Australia. However, when conditions are conducive, the disease can cause complete crop loss in susceptible varieties.

SOUTHERN

Historically, the most severe epidemics occurred (in descending order of severity) in 1973, 1947, 1934 and 1955. In 1973, stem rust reduced the southern cereal harvest by 25%. It is unlikely that stem-rust losses will ever be as severe as in 1973, due to the increased cultivation of stem-rust-resistant varieties, and the greater availability of effective foliar fungicides. In recent years, there have been a few localised occurrences of stem rust.

Following the exceptionally wet January of 2011 there was a large amount of inoculum carryover that resulted in widespread stem rust in southern Australia during 2011. Despite this, the widespread use of chemicals helped minimise losses from this disease. <sup>21</sup>

# 9.2.5 Leaf rust (brown rust)

The current commercial triticale varieties have good resistance to leaf rust and newer varieties should maintain this attribute. <sup>22</sup>

Leaf rust is caused by the fungus *Puccinia triticinia* (previously called *Puccinia recondite* f. sp. *tritici*). The disease can infect triticale, rye and wheat. It produces reddish-orange spores which occur in small, 1.5 mm, circular to oval-shaped pustules. These are found on the top surface of the leaves, distinguishing leaf rust from stem rust (Photo 4). <sup>23</sup>

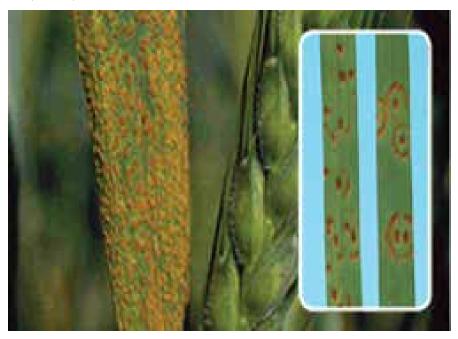


Photo 4: Leaf rust in wheat.

Source: DAF Qld

In most parts of southern Australia leaf rust is effectively controlled with resistant varieties, but it can cause problems in areas where susceptible varieties are grown. Cereal varieties mostly have reasonable resistance (rating of MR–MS,5 or higher).



<sup>21</sup> Hollaway G. (2014). Stem rust of wheat, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stem-rust-of-wheat">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stem-rust-of-wheat</a>

<sup>22</sup> Jessop RS, Fittler M. (2009). Triticale production Manual—an aid to improved triticale production and utilisation. http://www.apri.com.au/IA-102\_Final\_Research\_Report\_pdf

<sup>23</sup> DAF Qld (2015) Integrated disease management of wheat rusts and yellow leaf spot. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts</a>



**TABLE OF CONTENTS** 



The spores require temperatures of  $15-20^{\circ}$ C and free moisture (i.e. dew rain, irrigation) on the leaves to successfully infect cereal. The first signs of the disease, sporulation, occur 10-14 days after infection. Removal of volunteer cereal plants, which form a green bridge for the fungus through the summer, can eliminate or delay the onset of leaf rust.

SOUTHERN

See the APVMA website for up-to-date fungicide registrations.

The Plant Breeding Institute at the University of Sydney received samples of leaf rust in 2016 from all wheat-growing states except Tasmania (Figure 1). One was from Lismore in Victoria, and samples from South Australia have been received from Port Neill off the variety Mace, and off other wheats from Paskeville and Roseworthy in late August and early September. <sup>24</sup>

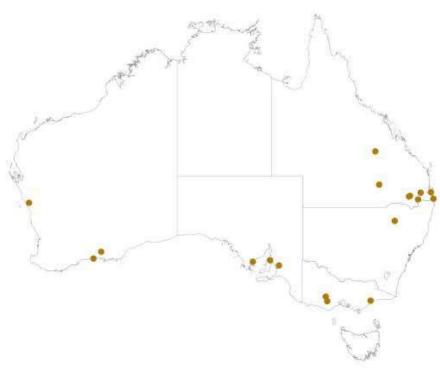


Figure 1: Reported detections of leaf rust in 2016.

Source: University of Sydney

# 9.2.6 Managing cereal rust

Rust diseases of cereals can be eliminated or significantly reduced by removing the green bridge. This should be done well before the new crop is sown, allowing time for any herbicide to work and for the fungus to stop producing spores.

Rust fungi change continuously, producing new pathotypes. These are detected when disease is found on a previously resistant variety. Even if a resistant variety has been sown, the crop should be monitored on a regular basis, starting no later than growth stage 31 (first node detectable) and continue to at least growth stage 49 (first awns visible). This is because the main leaves (the flag, flag-1, flag-2 and flag-3 leaves) are the main factories contributing to yield and quality. It is very important that these leaves are protected from any diseases. <sup>25</sup> However, the importance of maintaining these leaves completely disease free diminishes as crops are grown into the more arid, lower yielding and higher spring temperature finishing regions. <sup>26</sup>



<sup>25</sup> DAF Old (2015) Wheat:diseases, physiological disorders and frost. DAF Old, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases</a>



Leaf rust

CSIRO, Cereal rusts

The Rust Bust

How to manage rust, SA



DAF Qld (2015) Integrated disease management of wheat rusts and yellow leaf spot. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts</a>









WATCH: GCTV Extension files: Rust sampling



WATCH: <u>GCTV18</u>: <u>Adult plant</u> resistance—fungicide



WATCH: <u>GCTV9: Cereal rust—adult</u> plant resistance



WATCH: GCTV18: Triple rust resistance



See the APVMA website for up-to-date fungicide registrations.

# **IN FOCUS**

SOUTHERN

# Breeding cereals for rust resistance in Australia

Rust diseases have caused significant losses to Australian cereal crops, and continue to pose a serious threat. Because Australian cereal-crop yields are generally low, genetic resistance remains the most economical means of controlling rust. Resistant cultivars also contribute significantly to reducing over-summer rust survival.

The Australian Cereal Rust Control Program conducts annual pathogenicity surveys for all cereal rust pathogens, undertakes genetic research to identify and characterise new sources of resistance, and provides a germplasm screening and enhancement service to all Australian cereal-breeding groups. These three activities are interdependent and are closely integrated, with particular emphasis on linking pathology and genetics to develop more resistant varieties. Recent changes in the wheat rust pathogens, including the development of virulences for the Yr17, Lr24, Lr37 and Sr38 resistance genes, and the introduction of a new pathotype of the wheat stripe rust pathogen, have provided new and significant challenges for wheat rust resistance breeding. Similar challenges exist in breeding barley and oats for rust resistance. In future, as more markers linked to durable rust resistance sources become available, it is likely that the use of marker-assisted selection will become more common-place in rust resistance breeding. <sup>27</sup>

# 9.3 Yellow leaf spot (tan spot)

Yellow leaf spot, also known as tan spot, has become a widespread and important disease of cereals in southern Australia (Photo 5). It has been supported by stubble retention, intense wheat production in the rotation and wide spread cultivation of susceptible varieties. <sup>28</sup>



<sup>27</sup> RF Park (2008) Breeding cereals for rust resistance in Australia. Plant Pathology, 57 (4), 591–602.

<sup>28</sup> G Holloway (2014) Yellow leaf spot of wheat. Note AG1114. Revised. Agriculture Victoria, <a href="http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/yellow-leaf-spot-of-wheat">http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/yellow-leaf-spot-of-wheat</a>







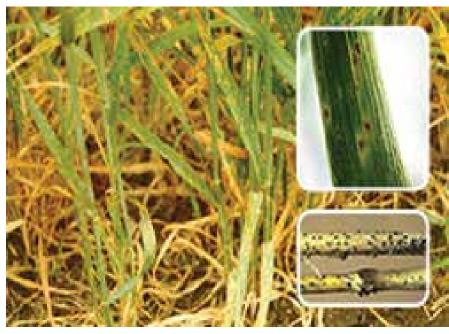


Photo 5: Yellow leaf spot in cereal crop.

Source: DAF Qld

Yellow leaf spot is caused by the fungus *Pyrenophora tritici-repentis*. It survives in wheat and, occasionally, triticale stubble. In rare cases, the fungus may survive in barley stubble. Wet spores (ascospores) develop in fungal fruiting bodies on wheat stubble, spread during wet conditions and infecting growing wheat plants.

As the crop develops, masses of a second type of spore (conidia) are produced on old lesions and dead tissues. Conidia result in rapid development of the epidemic within a crop and spread of the disease to other crops and areas. Again, wet conditions are necessary for spore production and infection. Strong winds are needed to spread the disease any great distance. <sup>29</sup>





**SOUTHERN** 

<sup>29</sup> DAF QId (2015) Wheat: diseases, physiological disorders and frost. DAF QId, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases</a>





## 9.3.1 Varietal resistance

Most triticale cultivars have moderate resistance to yellow leaf spot (Table 5). 30 However, it can still carryover the disease into following years. 31

Table 5: Triticale variety disease guide for yellow leaf spot.

Variety	Yellow leaf spot
Astute(b	MRMS
Berkshire(b	MR
Bison(b:	MR
Canobolas(b:	MR
Chopper(b	MR
Endeavour(b	MR
Fusion(D	MRMS
Goanna	MR
KM10	MRMS
Rufus	MR
Tahara	MR
Tobruk(D	MR
Tuckerbox	MR
Yowie	MR

Maturity: E = early, M = mid-season, L = late, VL = very late

Height: M = medium, T = tall Colour: W = white, Br = brown

Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS

p = provisional ratings—treat with caution, R = resistant, M = moderately, S = susceptible, V = very # Varieties marked may be more susceptible if alternative strains are present

Source: Agriculture Victoria

# 9.3.2 Damage caused by yellow leaf spot

Yellow leaf spot is most often observed in seedlings, but when conditions are suitable it can progress up the plant where it causes significant yield loss. <sup>32</sup> Grain yield can be reduced and losses of around 10% may occur in triticale under suitable conditions (e.g. high humidity after GS39). Only in extreme pressure situations would losses be greater than this in triticale in the southern region and unlikely to be greater than 20%. Pink grain with reduced value can result under severe yellow leaf spot epidemics.

# 9.3.3 Symptoms

Yellow leaf spot is characterised by tan-brown flecks turn into yellow-brown ovalshaped spots or lesions surrounded by yellow margins. They may expand to 10-12 mm in diameter. Large lesions coalesce, and develop dark brown centres or cause the tips of leaves to die. Spots develop on both sides of leaves (Photos 6 and 7). Severe yellow leaf spot may result in short, spindly plants with reduced tillering and root development. Where conditions are favourable to the disease, plants may be fully defoliated soon after flowering. 33



<sup>30</sup> Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, http://agriculture.vic.gov.au/ agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary

Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, http://www.farmtrials.com.au/trial/13801

G Holloway (2014) Yellow leaf spot of wheat. Note AG1114. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pestsdiseases-and-weeds/plant-diseases/grains-pulses-and-cereals/yellow-leaf-spot-of-wheat

DAF QId (2015) Wheat: diseases, physiological disorders and frost. DAF QId, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/ broadacre-field-crops/wheat/diseases





Photo 6: Yellow leaf spot in triticale.

Source: Thomas County Ag



**Photo 7:** Yellow leaf spot lesions may coalesce, causing the tip of the leaf to die. Source: Thomas County Ag

# 9.3.4 Conditions favouring development

Yellow leaf spot is likely to develop in wet years in fields where cereal residues remain on the soil surface. Temperatures of  $15-28^{\circ}$ C, with up to 12 hours of leaf wetness, are optimal condition for infection. <sup>34</sup>



<sup>34</sup> GRDC (2011) Management to reduce the risk of yellow leaf spot. Factsheet. GRDC, <a href="https://grdc.com.au/Resources/Factsheets/2011/08/Yellow-Leaf-Spot-Fact-Sheet">https://grdc.com.au/Resources/Factsheets/2011/08/Yellow-Leaf-Spot-Fact-Sheet</a>

**MORE INFORMATION** 

Management of yellow leaf spot in

wheat: decide before you sow







# 9.3.5 Management of disease

The impact of the disease can be reduced by:

- Planting partially resistant varieties.
- · Rotating with resistant crops such as barley, oats or chickpeas.
- Incorporating the stubble into the soil.
- Grazing or burning the stubble late in the fallow period.

Incorporation or burning of stubble is not recommended unless infestation levels are very high. The correct identification of the yellow leaf spot fungus in infected stubble should be carried out before the stubble is removed. Varieties partially resistant to yellow leaf spot offer the only long-term solution and should be considered for planting where yellow leaf spot could be a problem. <sup>35</sup>

# Minimising the risk of yellow leaf spot

- Avoid sowing cereal-on-cereal.
- If you are going to sow cereal-on-cereal consider a late (autumn) stubble burn, and/or select a wheat variety with some level of resistance to yellow leaf spot (however, consider tolerance/resistance to other diseases as well). Triticale-onwheat may be a reasonable option as triticale has better resistance and early vigour, potentially allowing it to establish before infection.
- Primary management decisions for yellow leaf spot need to be made prior to and/or at sowing. Fungicides are a poor last resort for controlling yellow leaf spot as they have reduced efficacy.

## In-crop fungicides and timing

Yellow leaf spot is difficult to control with fungicide.

Fungicides used against yellow leaf spot in Australia include:

- propiconazole
- tebuconazole
- azoxystrobin + cyproconazole
- propiconazole + cyproconazole

Identifying the disease and applying early control, before disease spreads up the plant, is crucial. (Table 6).

**Table 6:** Rate of fungicide (product formulation) recommended as foliar sprays for the control of yellow leaf spot in cereals.

Diseases	Foliar fungicides									
	Epoxi- conazole (125 g/L)	Flutriafol (250 g/L)	Propi- Triadimefon conazole (125 g/L) (250 g/L)		Tebu- conazole (430 g/L)	Prothio- conazole (210 g/L) + Tebu- conazole (210 g/L)	Azoxy- strobin (200 g/L) + Cypro- conazole (80 g/L)	Propi- conazole (250 g/L) + Cypro- conazole (80 g/L)		
Yellow leaf spot (tan spot)			250–500 mL/ha		145 or 290 mL/ha	150–300 mL/ ha	400 or 800 mL/ha	250–500 mL/ ha		
Withholding periods	6 weeks for grazing and harvest	7 weeks for grazing and harvest	4 weeks for harvest, 7 days for grazing	4 weeks for grazing and harvest	5 weeks for harvest, 14 days for grazing	5 weeks for harvest, 14 days for grazing	6 weeks for harvest, 21 days for grazing	6 weeks for harvest, 21 days for grazing		

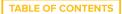
Source: <u>DAFF.</u>



<sup>35</sup> DAF QId (2015) Wheat:diseases, physiological disorders and frost. DAF QId, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases</a>

S Simpfendorfer (2013) GRDC Update Papers: Management of yellow leaf spot in wheat: decide before you sow, <a href="https://grdc.com.au/">https://grdc.com.au/</a>
<a href="https://grdc.com.au/">Research-and-Development/GRDC-Update-Papers/2013/03/Management-of-yellow-spot-in-wheat-decide-before-you-sow</a>









# **MORE INFORMATION**

Management to reduce the risk of yellow leaf spot: Southern region

Yellow leaf spot: Is it worth spraying?

The higher rate of application has been shown to provide longer protection under periods of high disease pressure. Fungicide effectiveness is greater on susceptible varieties and is reduced with increasing levels of resistance.

SOUTHERN

Information on fungicide effectiveness has been gathered from irrigated field trials and does not confirm the economic viability of such applications during the extreme pressure of large-scale epidemics. <sup>37</sup>

See the APVMA website for up-to-date fungicide registrations.

# 9.3.6 Integrated disease management of rusts and yellow leaf spot

Key points:

- Destroy volunteer plants by March, as they can provide a green bridge for rust carryover.
- Community efforts are required to eradicate volunteers from roadsides, railway lines, bridges, paddocks and around silos.
- Crop rotation is very important in the case of yellow leaf spot.
- Growing resistant varieties is an economical and environmentally friendly way of disease reduction.
- Seed or fertiliser treatment can control stripe rust up to four weeks after sowing, and suppress it thereafter.
- During the growing season active crop monitoring is very important for an early detection of diseases.
- Correct disease identification is very important; you can consult the department's fact sheets, charts, website and experts.
- When deciding if a fungicide spray is needed, consider crop stage and potential yield loss.
- Select a recommended and cost-effective fungicide.
- For effective coverage, the use of the right spray equipment and nozzles is very important.
- Read the label, wear protective gear, be safe to yourself and environment.
- Avoid repeated use of fungicides with the same active ingredient in the same season.
- Always check for withholding periods before grazing and harvesting a crop applied with any fungicide.
- If you suspect any severe disease outbreak, especially on resistant varieties, please inform your agronomist or local DPI.

Rust diseases occur throughout the cereal growing southern regions, frequently causing economic damage. Wherever possible, sow resistant varieties rated MR (Moderately Resistant) and above.

See the APVMA website for up-to-date fungicide registrations.

# 9.4 Take-all

Key points:

- Take-all (G. Graminis) is a fungal disease of the roots of cereals.
- Like cereal rye, triticale has good resistance to take-all, <sup>38</sup> and it is slightly less susceptible to take-all than wheat. Early sowing increases the risk. <sup>39</sup>



<sup>37</sup> DAF Qld (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/</a> broadacre-field-crops/wheat/diseases

<sup>8</sup> H Wallwork (1989) Screening for resistance to take-all in wheat, triticale and wheat-triticale hybrid lines. Euphytica, 40 (1–2), 103–109.

<sup>39</sup> P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. DPI NSW, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/ pdf\_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf



**TABLE OF CONTENTS** 





- Though triticale is less susceptible to take-all than wheat, it can still carryover the disease into following years. 41
- Grass-free pastures and break crops minimise G. graminis survival, e.g. pulses and canola.
- Monitor rainfall patterns (when and how much?), and adjust sowing times where possible.
- Control weeds during late summer and early autumn.
- Ammonium based nitrogenous fertilisers decrease take-all incidence through improved crop nutrition.
- In severe take-all outbreaks, grass free cropping may be a management strategy.

Take-all is a soil-borne disease of cereal crops and grasses and is most severe on crops in southern Australia, particularly in the higher-rainfall areas. The disease is caused by two variations of the fungus *Gaeumannomyces graminis*: *G. graminis* var. *tritici* (Ggt) and *G. graminis* var. *avenae* (Gga). 42

# 9.4.1 Symptoms

Initial indications of take-all in a crop are the appearance of indistinct patches of poor growth in the crop; these may be from a few metres across to significant areas of crop. Closer inspection of individual plants will show discolouration of the crown, roots and stem base. Blackening of the centre of the roots is symptomatic of an early take-all infection. Severely infected plants will have a blackened crown and stem base and be easy to pull from the soil, with no attached root system. Any remaining roots are brittle and break off with a square end.

The appearance of whiteheads later in the season is another indicator of a takeall (although frost and micronutrient deficiencies can also cause whiteheads), with severe infections causing the crop to hay-off early. Infected plants will produce pinched grain, with severe infections yielding little harvestable seed in the head (hence take-all) and in some cases infected areas may not be worth harvesting. <sup>43</sup>

#### What to look for in the paddock

- Patches (up to several metres in diameter and with indistinct and irregular edges) of white-coloured tillers and heads containing shrivelled or no grain (Photo 8).
- Affected plants can be individuals scattered among healthy plants or entire populations of plants over a large area.



<sup>40</sup> TW Hollins, PR Scott, RS Gregory (1986). The relative resistance of wheat, rye and triticale to take all caused by Gaeumannomyces graminis. Plant Pathology, 35 (1), 93–100.

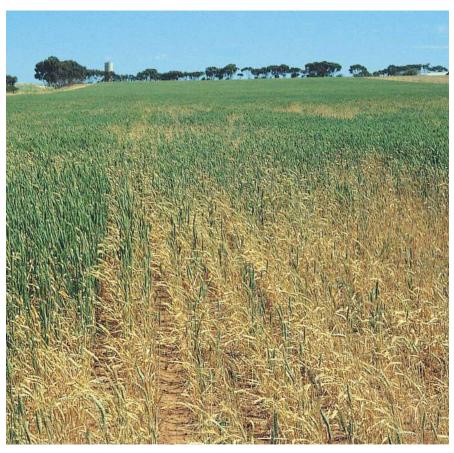
<sup>41</sup> Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, <a href="http://www.farmtrials.com.au/trial/13801">http://www.farmtrials.com.au/trial/13801</a>

 $<sup>42 \</sup>quad Soil quality.org \ (2016) \ Take-all \ disease: NSW. \ Factsheet. \ Soil quality.org, \ \underline{http://www.soil quality.org.au/factsheets/take-all-disease-nsw.}$ 

 $<sup>43 \</sup>quad \text{Soilquality.org.} \ (2016) \ \text{Take-all disease: NSW. Factsheet. Soilquality.org.} \ \underline{\text{http://www.soilquality.org.au/factsheets/take-all-disease-nsw.}} \ \\$ 

DAFWA (2015) Diagnosing take-all in cereals. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-take-all-cereals">https://www.agric.wa.gov.au/mycrop/diagnosing-take-all-cereals</a>

FEEDBACK



**Photo 8:** Patches with irregular edges of white coloured tillers and heads containing shrivelled or no grain.

Source: DAFWA

# What to look for in the plant

- First obvious aboveground signs of infection are seen after flowering, with the development of whiteheads.
- Roots of affected plants are blackened and brittle, and break easily. They are black to the core, not just on outer surface (Photo 9).



**Photo 9:** Roots of affected plants are blackened, brittle, break easily, and are black to the core (left). Severely affected plants can have blackened crowns and lower stems (right).

Source: DAFWA



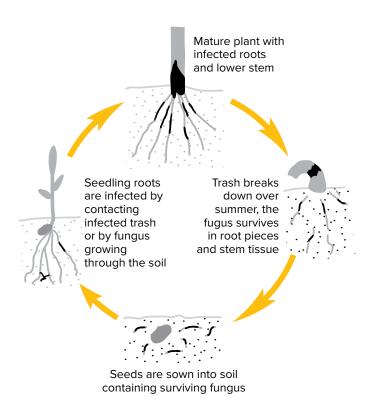


# 9.4.2 Conditions favouring development

*Gaeumannomyces graminis* survives the Australian summer in the residue of the previous season's grass host (Figure 2). <sup>45</sup> The arrival of cooler temperatures and rainfall in the autumn encourages the fungus into action, and it is in this period that it infects the roots of the emerging crop. Higher rainfall in winter is likely to increase take-all disease pressure. While lower soil moisture will decrease the chance of a severe outbreak of take-all, plants that are already infected will find it difficult to cope due to water stress.

SOUTHERN

Soil at field capacity (fully wet) encourages early-season infection of seedlings by both *G. graminis* var. *tritici* and *G. graminis* var. *avenae*. Greatest yield loss occurs on infected plants when moisture is limited post-anthesis.



**Figure 2:** Common life cycle of the take-all fungus (adapted from MacNish, 2005). Source: Soilquality.org

#### Hosts

All annual grasses can be infected by *G. graminis*, although some species are more susceptible than others. While wheat, barley and triticale are the most susceptible crops to take-all, barley grass is also an effective host to the disease. Brome grass, silver grass and ryegrass are all viable host species for take-all, too. Oats is one of the only cereal crop to offer resistance, although evidence of *G. graminis* strains capable of causing yield loss have been reported in areas where continual oat cropping occurs. The non-cereal crops (e.g. lupins, canola and clover) do not host take-all. <sup>46</sup>



 $<sup>45 \</sup>quad \text{Soilquality.org.} \ (2016) \ \text{Take-all disease: NSW. Factsheet, Soilquality.org.} \ \underline{\text{http://www.soilquality.org.au/factsheets/take-all-disease-nsw.}} \ \\$ 

<sup>46</sup> Soilquality.org (2016) Take-all disease: NSW. Factsheet, Soilquality.org, http://www.soilquality.org.au/factsheets/take-all-disease-nsw

**TABLE OF CONTENTS** 



# 9.4.3 Managing take-all

Key points:

- By far the most effective method of reducing take-all is to remove grasses in the year before the cereal crop with a grass-free pasture or break crop.
- Seed, fertiliser or in-furrow applied fungicides are registered for take-all control.
- Acidifying fertilisers can slightly reduce disease severity; conversely, the severity
  of take-all may increase following liming.
- Control volunteer grasses and cereals.
- Delay sowing following the opening rains by implementing a short chemical fallow. <sup>47</sup>

The most effective management strategy for take-all is to deny the fungus the ability to survive in the paddock, through the elimination of hosts. This is most effectively done through the use of a non-cereal break crop (i.e. lupin, canola, field peas, faba beans, chickpeas and vetch) and effective grass-weed control during autumn. Pastures containing low levels of grass species will also have reduced take-all carryover the following season. Where minimum tillage is practiced the time taken for residues to breakdown is increased, and this allows the disease to stay viable for longer. The use of break crops and activities to hasten residue breakdown may be beneficial. While burning does decrease the amount of surface residue infected with the fungus, it is generally not hot enough to affect the infected material below ground.

Fungicides, applied as either fertiliser or seed treatments, are registered for use against take-all, but are generally only economically viable where severe outbreaks have occurred. Registered fungicides provide useful protection in paddocks with low to medium disease risk. In many cases it is more practical to sow non-cereal crops or pasture to reduce take-all carryover.

Competition from other soil organisms decreases the survival of *G. graminis* in the soil. Summer rains or an early break in the season allows for such conditions. The effect of this can be negated by poor weed control during this period. This has a double effect:

- Cereal weeds become infected, thus enabling G. graminis to survive until crop establishment.
- Rapid drying of the topsoil due to weeds decreases the survival of competitive soil organisms, therefore slowing *G. graminis* decline.

### 9.5 Crown rot

Key points:

- Fusarium species are responsible for causing two distinctly different diseases in winter cereal crops: crown rot and Fusarium head blight.
- Triticale is susceptible to crown rot. 48
- Crown rot survives on infected stubble, from where it is passed onto the following crop.
- Use non-host crops (i.e. pulses, oilseeds and broadleaf pasture species) in rotation sequences to reduce inoculum levels.
- Control grass-weed hosts to reduce opportunities for Fusarium spp. to survive fallow or non-host rotations.
- Sow varieties with partial resistance or improved tolerance where available.

Information concerning the resistances of triticale varieties to *Fusarium* diseases is very limited. For crown rot (*Fusarium psuedograminearum*) most research has been completed in wheat, but data from 2007 included one triticale (Everest). Inoculation with the crown-rot fungus caused the greatest reduction in yield in durum wheat



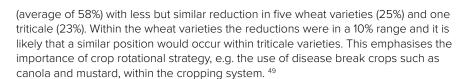
<sup>47</sup> DAFWA (2015) Diagnosing take-all in cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-take-all-cereals

<sup>48</sup> Matthews P, McCaffery D, Jenkins L. (2016). Winter crop variety sowing guide 2016. <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf



**TABLE OF CONTENTS** 





**OUTHERN** 

There are two types of disease caused by *Fusarium* species that affect cereal crops, Fusarium head blight (FHB) and crown rot.

Crown rot is very damaging disease in the Northern cropping region, but is less prevalent in the Southern region. A survey of 957 wheat crops during the period 1997 to 2009 estimated annual losses from crown rot to be approximately 2-3% with crop losses inversely correlated to growing season rainfall. Field experiments showed yield loss in wheat ranged from 0-51% and was related to spring rainfall and inoculum levels prior to sowing. less than 5%, with sporadic loss. <sup>50</sup>

FHB is usually caused by the fungus *Fusarium graminearum* but the crown rot fungus, *Fusarium pseudograminearum*, may cause the disease in wet years as rain splash distributes the fungus from lower stem nodes into grain heads.

While all winter cereals host the crown rot fungus, the amount of yield loss due to infection varies with cereal type. The approximate order of increasing yield loss is cereal rye, oats, barley, bread wheat, triticale and durum wheat. <sup>51</sup>

Both FHB and crown rot become apparent after flowering, however the conditions that encourage them are different: Fusarium head blight requires prolonged wet weather during flowering and grainfill, and crown rot expresses as whiteheads following periods of moisture and/or heat stress. Crown rot is sometimes first seen in patches or in wheel tracks, but is often not obvious until after heading. Then it becomes obvious with the appearance of dead heads that contain shrivelled or no grain are called whiteheads, although it is important to note that yield loss can occur even without the formation of whiteheads.

# 9.5.1 Update on the latest research

Key points:

- Managing the impact of crown rot on yield and quality means managing the balance between inoculum levels and the amount of soil water.
- Although most management strategies tend to focus solely on combating
  inoculum levels, sometimes to the detriment of soil-water levels, it is more
  important to maintain good levels of soil water so that triticale is not temperature
  or water stressed during grainfill.
- For crown rot, cultivation, even shallow cultivation, distributes infected residue more evenly across paddocks and into the infection zones below the ground for crown rot. This is not good!
- Some of the newer wheat varieties appear promising in that they provide improved tolerance to crown rot.
- PreDicta B is a good tool for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing. However, it requires a dedicated sampling strategy and is not a simple add-on to a soil nutrition test.

Crown rot is a significant disease of winter cereals. Infection is characterised by a light honey-brown to dark brown discolouration of the base of infected tillers, and the crown rot-induced production of whiteheads that causes major yield loss is related to the presence of the fungus and moisture stress post-flowering. It is critical that growers understand that there are three distinct and separate phases of crown



<sup>49</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Rethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.gu/h/102/Final Research Report\_pdf">http://www.apri.com.gu/h/102/Final Research Report\_pdf</a>

<sup>650</sup> G Holloway. (2007). GRDC Final reports: DAV00062 – Victorian cereal pathology support with emphasis on crown rot management. http://finalreports.grdc.com.au/DAV00062

<sup>51</sup> GRDC (2016). Tips and Tactics: Crown rot in winter cereals—Southern region





rot, namely survival, infection and expression. Management strategies are different for each phase.

OUTHERN

Survival—the crown-rot fungus survives as mycelium (cottony growth) inside winter cereal and grass-weed residues, which it has infected. The fungus will survive as inoculum inside the stubble for as long as the plant material remains intact, which varies greatly with soil and weather conditions as decomposition is a very slow process.

Infection—given some level of soil moisture, the crown-rot fungus grows out of stubble residues and infects new winter cereal plants through the coleoptile, subcrown internode or crown tissue, which are all below the soil surface. The fungus can also infect plants on the soil surface through the outer leaf sheaths. However, whatever the points of infection, direct contact with the previously infected residues is required. Infections can occur throughout the whole season, given the necessary moisture. Hence, wet seasons favour increased infection events by the crown-rot fungus, especially when combined with the production of greater stubble loads, which significantly build up inoculum levels.

Expression—yield loss is related to moisture and temperature stress around flowering and through grainfill. This stress is believed to trigger the crown rot fungus to proliferate in the base of infected tillers, restricting water movement from the roots through the stems, and producing whiteheads. The expression of whiteheads in plants infected with crown rot (i.e. they will still have basal browning) is restricted in wet seasons and increases greatly with increasing moisture and temperature stress during grainfill. Focus attention to crops around trees in a paddock or along tree lines. Even in good years, whiteheads associated with crown-rot infection are likely to be seen around trees. This is due to the extra competition for water. <sup>52</sup>

## 9.5.2 Damage caused by crown rot

The presence of crown rot in the plant stem limits water movement, which can result in premature death of the tiller and the presence of white (dead) heads (Photo 10). Crown rot survives from one season to the next on infected stubble, from where it is passed onto the following crop. The impact of a bad crown rot season can make or break a crop, with bread-wheat yield losses of up to 55% possible at high inoculum levels, and losses in durum up to 90%.



Photo 10: Scattered whiteheads in a cereal paddock.

Source: DAFWA



<sup>52</sup> S Simpfendorfer (2015) Crown rot: an update on latest research. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research">https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research</a>





# 9.5.3 Symptoms of crown rot

If the leaf bases are removed from the crowns of diseased plants, a honey-brown to dark-brown discolouration will be seen. In moist weather, a pinky-purple fungal growth forms inside the lower leaf sheaths and on the lower nodes.

The infection of plants with crown rot occurs at the base of the plant and spreads up the stem during the growing season. The onset of crown rot is often not obvious until after heading, when whiteheads appear with the onset of water stress. Plants infected with crown rot display a number of symptoms, including:

- Brown tiller bases, often extending up 2–4 nodes (Photo 11). <sup>53</sup> This is the most reliable indicator of crown rot, with browning often becoming more pronounced from mid to late grainfilling through to harvest.
- Whitehead formation, particularly in seasons with a wet start and dry finish (Photo 12). These are usually scattered throughout the crop, and do not appear in distinct patches. These may first appear in wheel tracks where crop-available moisture is more limited.
- A cottony fungal growth that may be found around the inside of tillers, and a
  pinkish fungal growth that may form on the lower nodes, especially during moist
  weather (Photo 13).
- Pinched grain at harvest. 54



Photo 11: Honey-brown discolouration of stem bases.

Source: DAFWA



<sup>53</sup> DAFWA (2016) Diagnosing crown rot of cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-crown-rot-cereals

 $<sup>54 \</sup>quad Soil quality.org. (2016) \ Crown \ rot: \ Qld. \ Factsheet, Soil quality.org, \underline{http://www.soil quality.org.au/factsheets/crown-rot-queensland}$ 







**Photo 12:** Scattered single tillers and whiteheads.

Source: DAFWA



SOUTHERN JANUARY 2018









**Photo 13:** Pink discolouration often forms around or in the crown or under leaf sheaths.

Source: DAFWA

# 9.5.4 Symptoms of Fusarium head blight

Fusarium head blight (FHB) is an infection of the head rather than root or crown as with crown. In wheat, FHB appears as premature bleaching of spikelets within a head. Frequently only part of the head (usually the upper half) is affected (Photo 14). <sup>55</sup> Salmon pink to orange spore masses (sporodochia) at the bases of infected spikelets can also be apparent during prolonged warm, humid weather. Infected wheat grains have a chalky white appearance and are usually shrivelled and lightweight; they may sometimes have pink staining, too. In barley, infected spikelets have a brown or a water-soaked appearance, rather than bleaching, and the grains have an orange or black encrustation on their surfaces.



**SOUTHERN** 

<sup>55</sup> DAFWA (2015) Diagnosing fusarium head blight in cereals. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-fusarium-head-blight-cereals">https://www.agric.wa.gov.au/mycrop/diagnosing-fusarium-head-blight-cereals</a>



**Photo 14:** FHB results in heads that are partly or fully bleached. Source: DAFWA

# 9.5.5 Conditions favouring development

## Crown rot

The effects of crown rot on yield tend to be most severe when there are good crop conditions in the first part of the season followed by a dry finish. This is because the moist conditions at the beginning of the season enable the fungus to grow from infected stubble to an adjacent seedling, while the dry conditions during flowering and grainfilling cause moisture stress, allowing rapid growth of the pathogen within the plant. A wet finish to the season can reduce the damage caused by crown rot, but will not prevent yield loss in all cases. <sup>56</sup>

Cultivation can also have a huge impact. Crown rot is a stubble-borne disease and for a plant to become infected it must come into contact with inoculum from previous winter cereal crops. So by cultivating soil, growers are actually helping to spread the crown rot inoculum to next year's crop. The best thing a grower can do with infected stubble is leave it alone.  $^{57}$ 

#### Interaction with root-lesion nematodes

Root-lesion nematodes (RLNs) are also a widespread constraint to wheat production across the region. RLNs feed inside the root systems of susceptible winter cereals and create lesions that reduce lateral branching. This reduces the efficacy of the root system to extract soil water and nutrients, which can subsequently exacerbate the expression of crown rot. Varieties with reduced tolerance to *Pratylenchus thornei* can



SOUTHERN

<sup>56</sup> Soilquality.org (2016) Crown rot: Qld. Factsheet, Soilquality.org, <a href="http://www.soilquality.org.au/factsheets/crown-rot-queensland">http://www.soilquality.org.au/factsheets/crown-rot-queensland</a>

<sup>57</sup> T Dixon (2013) Balancing crown rot and nematodes in wheat. Ground Cover. No. 104, May—June 2013. GRDC, <a href="https://grdc.com.au/">https://grdc.com.au/</a> Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Balancing-crown-rot-and-nematodes-in-wheat







suffer significantly greater yield loss from crown rot if both of these pathogens are present within a paddock.

SOUTHERN

See <u>Section 8.3 Nematodes and crown rot</u> in Section 8: Nematodes for more information.

#### **FHB**

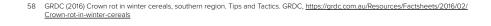
FHB is a fungal disease that affects cereals. It survives from one season to the next in the stubble remains of infected plants. The disease is more common on heavy clay soils.

Infection is favoured by high soil moisture in the two months after planting. Drought stress during elongation and flowering will lead to the production of deadheads or whiteheads in the crop. These heads contain pinched seed or no seed at all.

## 9.5.6 Management

Key points:

- Rotate crops—this is the most important management tool. A grass-free break from winter cereals is the best way to lower crown-rot inoculum levels.
- Test—a pre-sowing PreDicta B soil test will identify paddocks at risk of crown rot.
- Sow winter cereals into paddocks where the risk is lowest.
- Choose more resistant crop varieties, but variety choice needs to be combined with effective management.
- Observe—check plants for browning at the base of infected tillers as this is
  the most reliable indicator of crown rot. Don't rely solely on whiteheads as an
  indicator (Figure 3).
- Keep crown rot inoculum at low levels is the most effective way to reduce yield loss from this disease. 58





**TABLE OF CONTENTS** 

FEEDBACK



Figure 3: The GRDC's 'Stop the crown rot' campaign.

Source: GRD0

Crown rot may be controlled through planting more resistant varieties and by using crop rotation. If the disease is severe, rotation to a non-susceptible crop for at least two and preferably three years is recommended. A winter crop such as chickpea, oats or any summer crop may be used as a disease-free rotation crop.  $^{59}$ 

There is no treatment available in controlling FHB, only preventative measures. Avoid multiple winter cereal crops, which can promote the disease once it is established. Do not sow winter cereals into summer crop paddocks until all summer residues have broken down. Additionally, avoid sowing winter cereals adjacent to those paddocks. <sup>60</sup>

## Crop rotation

The most effective way to reduce crown rot inoculum is to include non-susceptible crops in the rotation sequence. The crown rot fungus can survive for two to three years in stubble and soil. Growing a non-host crop for at least two seasons is recommended to reduce inoculum levels. This allows time for decomposition of winter cereal residues that host the crown rot fungus. Stubble decomposition varies with the type of break crop grown: canopy density and rate of the canopy closure as well as row spacing, the amount of soil water they use and seasonal rainfall.

Because crown rot survives from one season to the next on infected stubble, the use of break crops can give stubble a chance to decompose and thus reduce soil



<sup>59</sup> DAF QId (2015) Wheat: diseases, physiological disorders and frost. DAF QId, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases</a>

<sup>60</sup> DAFWA. (2015). Diagnosing Fusarium head blight in cereals. https://agric.wa.gov.au/n/2138



**TABLE OF CONTENTS** 





WATCH: GRDC, <u>Grains research</u> <u>updates: Crown rot tolerance in new</u> <u>cereal cultivars</u>





<u>Tips and Tactics: Crown rot in winter</u> cereals, southern region

<u>Understanding crown rot underpins</u> <u>effective management, southern and</u> <u>western regions</u> inoculum levels. The use of break crops with dense canopies, such as canola, can be particularly effective, as these help to maintain a moist soil surface, which further promotes the breakdown of cereal residues.

SOUTHERN

The number or break crops required to sufficiently reduce crown rot levels will vary, depending on rainfall in the break year. In dry years, when residue breakdown is slower, a two-year break crop may be required to reduce crown rot to acceptable levels. In wetter seasons, a one-year break may be sufficient.

It should be noted that incorporating plant residues into the soil by cultivation during the break period can increase the rate of decay of residue. However, it also spreads infected residue, which may increase plant infection rates in following crops, thus counteracting any benefits from increased rate of breakdown.

Baling, grazing and/or burning crop residues are not effective solutions for the removal of crown rot, either. The majority of the crown rot inoculum is below ground and in the bottom 7 cm of the stem. Thus, the crown rot fungus can survive in belowground tissue even if above-ground material is removed.

#### Variety selection

All winter cereal crops host the crown-rot fungus. Yield loss varies between crops and the approximate order of increasing loss is oats, barley, triticale, bread wheat and durum.

Where growers are aware their paddocks are infected with crown rot, tolerant varieties can be used to limit yield loses. Growers need to be aware of the levels of crown rot disease in their paddocks, as even the most tolerant crops can suffer yield loss under high levels of the disease. At intermediate levels of disease, the grower can take a calculated risk about returns versus yield loss by growing only tolerant varieties. However, where high levels of disease are present even tolerant varieties may be affected, and a break crop may be required.

NSW DPI trials at 23 sites in 2013–14 indicate that susceptibility can represent a yield benefit of around 0.50 t/ha in the presence of high levels of crown rot infection. However, variety choice is NOT a solution to crown rot with even the best variety still suffering up to 40% yield loss from crown rot under high infection levels and a dry/hot seasonal finish.  $^{61}$ 

## Crop management

Stressed plants are most susceptible to the effects of crown rot. Thus the use of management practices to optimise soil water and ensure good crop nutrition can help reduce the impacts of crown rot. Effective strategies include:

- Reducing moisture stress in plants through good fallow management and avoiding excessively high sowing rates.
- Matching nitrogen fertiliser inputs to available soil water to avoid excessive early crop growth.
- Ensuring good crop nutrition. Zinc nutrition can be particularly important as the expression of whiteheads can be more severe in zinc-deficient crops.

#### Cultivation

The effect of cultivation on crown rot is complex, as it potentially impacts on all three phases of the disease cycle.

Survival—stubble decomposition is a microbial process driven by temperature
and moisture. Cultivating stubble in theory increases the rate of decomposition
as it reduces particle size of stubble, buries the particles in the soil where
microbial activity is greater and the soil environment maintains more optimal
moisture and temperature conditions compared to the soil surface or above
ground. However, cultivation also dries out the soil in the cultivation layer, which
immediately slows down decomposition. Decomposition of cereal stubbles is

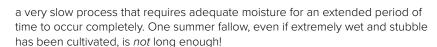


S Simpfendorfer (2015) Crown rot: an update on latest research. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-bevelopment/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research">https://grdc.com.au/Research-and-bevelopment/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research</a>









OUTHERN

- Infection—the cultivation of winter cereal stubble harbouring the crown-rot fungus breaks the inoculum into smaller pieces and spreads them more evenly through the cultivation layer across the paddock. Consequently, the fungus is given a much greater chance of coming into contact with seedlings when the next winter cereal crop germinates and starts to grow. In a no-till system the crown-rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheaths at the soil surface, thus greatly reducing infection. Cultivation or harrowing negates the option of inter-row sowing as a crown rot management strategy.
- Expression—extensive research has shown that cultivation dries out the soil to
  the depth of cultivation and reduces the water infiltration rate due to the loss of
  structure (e.g. macropores). The lack of cereal stubble cover can also increase
  soil evaporation. With poorer infiltration and higher evaporation, fallow efficiency
  is reduced for cultivated systems compared to a no-till stubble retention system.
  Greater moisture availability has the potential to provide buffering against the
  expression of crown rot late in the season.

### Stubble burning

As stubble burning removes the above-ground portion of crown rot inoculum but the fungus will still survive in infected crown tissue below ground, burning is **NOT** a quick fix for high-inoculum situations. The removal of stubble by burning increases evaporation from the soil surface and makes fallow less efficient. A 'cooler' autumn burn is preferable to an earlier hotter burn as it minimises the loss of soil moisture while still reducing inoculum levels.

#### Reducing water loss

Inoculum level is important in limiting the potential for yield loss from crown rot, but the factor that most dictates the extent of yield loss is moisture and temperature stress during grainfill. Any management strategy that limits the storage of soil water or creates constraints that reduce the ability of roots to access this water will increase the probability and/or severity of moisture stress during grainfill and exacerbate the impact of crown rot.

### **Grass-weed management**

Grass weeds should be controlled in fallows and in crops, especially in break crops, as they host the crown-rot fungus and can also significantly reduce soil-moisture storage. In pasture situations, grasses need to be cleaned out well in advance of a following cereal crop as they serve as a host for the crown-rot fungus.

### Sowing time

Earlier sowing within the recommended window for a given variety and region can bring the grainfill period forward and reduce the probability of moisture and temperature stress during grainfill. Earlier sowing can increase root length and depth and provide greater access to deeper soil water later in the season, which buffers against the expression of crown rot. However, earlier sowing can place a crop at risk of frost damage during its most susceptible time.

Sowing time is a balancing act between the risk of frost and heat stress. However, when it comes to crown rot, increased disease expression with delayed sowing can have just as big an impact on yield as frost. The big difference from NSW DPI trial work is the additional detrimental impact of later sowing on grain size in the presence of crown rot infection.











PreDicta B



#### Row placement

In a no-till system the crown rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheaths at the soil surface. This is why inter-row sowing with GPS guidance has been shown to provide around a 50% reduction in the number of plants infected with crown rot when used in a no-till cropping system. Further research has also demonstrated the benefits of row placement in combination with crop rotation and the placement of break crop rows and winter cereal rows in the sequence to limit disease and maximise yield. Sowing break crops between standing rows, which are kept intact, then sowing the following cereal crop directly over the row of the previous year's break crop, ensures four years between wheat rows being sown in the same row space. This substantially reduces the incidence of crown rot in cereal crops, improves establishment of break crops (especially canola), and chickpeas will benefit from reduced incidence of virus in standing stubble.

SOUTHERN

### Soil type

The soil type does not directly affect the survival or infection phases of crown rot. However, the water-holding capacity of each soil type does affect the expression of crown rot by the degree to which it buffers triticale plants against moisture stress late in the season. Hence, yield loss can be worse on red soils than black soils due to the generally lower water-holding capacity of red soils. On top of this, other sub-soil constraints, e.g. sodicity, salinity or shallower soil depth, can also reduce the level of plant-available water, which can increase the expression of crown rot. <sup>62</sup>

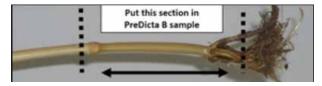
### Soil testing

In addition to visual symptoms, the DNA-based soil test PreDicta B can be used to assess the level of crown rot in the paddock. Soil samples that include plant residues should be tested early in late summer to allow results to be returned before seeding. This test is particularly useful when sowing susceptible varieties, and for assessing the risk after a non-cereal crop.  $^{63}$ 

PreDicta B has been developed for broadacre cropping regions in Australia and includes tests for:

- cereal cyst nematode (CCN)
- take-all
- Rhizoctonia barepatch
- crown rot
- · root-lesion nematode
- stem nematode

PreDicta B samples are processed weekly from February to mid-May (prior to crops being sown) to assist with planning the cropping program. The test is not intended for in-crop diagnosis. That is best achieved by sending samples of affected plants to your local plant pathology laboratory. In order to get an accurate result, it is important to follow the PreDicta B sampling protocol (Photo 15). <sup>64</sup>



**Photo 15:** It is important to follow the PreDicta B sampling protocol precisely. Source: GRDC.



<sup>62</sup> S Simpfendorfer (2015) Crown rot: an update on latest research. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-pevelopment/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research">https://grdc.com.au/Research-and-pevelopment/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research</a>

Soilquality.org (2016) Crown rot: Qld. Factsheet, Soilquality.org, <a href="http://www.soilquality.org.au/factsheets/crown-rot-queensland">http://www.soilquality.org.au/factsheets/crown-rot-queensland</a>

<sup>64</sup> D Lush (2014) PreDicta B sampling strategy. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2014/04/PreDicta-B-sampling-strategy">https://grdc.com.au/Media-Centre/Media-News/South/2014/04/PreDicta-B-sampling-strategy</a>



TABLE OF CONTENTS



### 9.6 Common root rot

Common root rot (Bipolaris spp.) is a soil-borne fungal disease which attacks cereals. It survives from one season to the next through fungal spores that remain in the cultivated layer of the soil. The disease increases in severity with continuous cereal sequences. The symptoms of common root rot are:

- a dark-brown to black discolouration of the stem just below the soil surface
- black streaks on the base of stems
- slight root rotting

# 9.6.1 Damage caused by disease

Common root rot can cause yield losses of between 10–15% in susceptible varieties.

# 9.6.2 Symptoms

### What to look for in the paddock

Affected plants tend to be scattered over a paddock, and they may be slightly stunted, have fewer tillers and produce smaller heads.

### What to look for in the plant

- Browning of roots and sub-crown internode (the piece of stem emerging from the seed to the crown) (Photo 16). 65
- Blackening of sub-crown internode in extreme cases.



Photo 16: Blackening of sub-crown internode in an extreme case of common root rot.

Source: DAFWA



<sup>65</sup> DAFWA (2015) Diagnosing common root rot of cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-common-root-rot-







# 9.6.3 Conditions favouring development

- The disease can occur from tillering onwards, but is most obvious after flowering.
- There are no distinct paddock symptoms, although the crop may lack vigour.
- Severe infections can lead to stunting of plants.
- Common root rot appears to be more prevalent in paddocks that are N deficient.
   When N is not limiting, yield loss occurs through a reduction in tillering due to poor N use efficiency.
- Affected plants are usually scattered through the crop.
- The disease is widespread through the grain belt, and is often found in association with crown rot.
- The fungus that causes common root rot survives on the roots of grasses and as dormant spores in the soil. It can build up to damaging levels in continuous wheat rotations <sup>66</sup>

Infection is favoured by high soil moisture for six to eight weeks after planting.

# 9.6.4 Management

The disease may be controlled by planting the more resistant varieties and using crop rotation. Where the disease is severe, rotation to non-susceptible crops for at least two years is recommended. <sup>67</sup> It is important to:

- Reduce levels of the fungus in your paddocks by rotating with crops such as field peas, faba beans and canola.
- Keep susceptible crops and pasture grass-free.
- Sow more resistant wheat or barley varieties.
- If moisture permits, reduce sowing depth to limit the length of the sub-crown internode (SCI).
- Ensure adequate nutrition, especially of phosphorus, which reduces severity.
- Reconsider stubble burning, as it does not decrease spore levels in the soil. 68

#### 9.7 Smut and bunt

Triticale is not usually prone to infection from smuts and bunt. However, it is good insurance for better yields to apply a seed dressing to the grain when it is being graded. <sup>69</sup>

# 9.7.1 Bunt or stinking smut

Bunt or stinking smut (*Tilletia* spp.) affects mature triticale, durum and wheat ears. A mass of black fungal spores replaces the interior of a grain with what is known as a bunt ball. Compared with healthy plants, infected plants are shorter and have darker green ears and gaping glumes (Photo 17). <sup>70</sup> Bunt is usually only noticed at harvest when bunt balls and fragments are seen in the grain. It is important to manage this disease, as AWB will not accept grain deliveries with traces of bunt balls.



35

<sup>66</sup> K Moore, B Manning, S Simpfendorfer, A Verrell (n.d.) Root and crown diseases of wheat and barley in northern NSW. NSW DPI. <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0019/159031/root-crown-rot-diseases.pdf

<sup>67</sup> DAF Qld (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases</a>

<sup>68</sup> Moore K, Manning B, Simpfendorfer S, Verrell A. NSW DPI. Root and crown diseases of wheat and barley in Northern NSW. <a href="http://www.dpi.nsw.qov.au/">http://www.dpi.nsw.qov.au/</a> data/assets/pdf\_file/0019/159031/root-crown-rot-diseases.pdf

<sup>69</sup> Agriculture Victoria. (2012). Growing Triticale. <a href="http://agriculturevic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculturevic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

<sup>70</sup> DAFWA (2016) Smut and bunt diseases of cereal: biology, identification and management. DAFWA, <a href="https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-biology-identification-and-management?page=0,1">https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-biology-identification-and-management?page=0,1</a>



**TABLE OF CONTENTS** 





SOUTHERN

**Photo 17:** Common bunt in cereal head showing glumes containing bunt balls. Source: DAFWA

The spores germinate with the seed when it is planted, and infect the young seedling. The fungus then grows inside the developing wheat plant, finally replacing each normal grain with a mass of spores. If a bunt ball is crushed, a putrid, fishy odour is released. Spores released during harvest will contaminate sound grain.

#### Managing bunt

- All seed should be treated with a fungicidal seed dressing which will control bunt.
- Grain from a crop with bunt should not be used for seed. 71

Seed treatments are extremely effective in controlling bunt. However, seed treatments need to be applied every year, and a good coverage of grain is essential to prevent infection.

Following a bunt infection clean seed should be obtained. All machinery that handled infected grain should be thoroughly cleaned and wheat should not be sown back into an infected paddock for several years. <sup>72</sup>

# 9.7.2 Loose smut

Triticale is susceptible to loose smut, though it does not usually occur to a degree where control is warranted.  $^{73}$ 

Loose smut is a fungal disease that becomes evident at head emergence. A loose, powdery mass of fungal spores is formed in the head; these spores are readily blown away leaving a bare, ragged stalk (Photo 18). <sup>74</sup>



36

<sup>71</sup> DAF Qld (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases</a>

<sup>72</sup> G Holloway, F Henry. (2007). Bunts and smuts of cereals. Agriculture Victoria. <a href="http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bunts-and-smuts-of-cereals">http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bunts-and-smuts-of-cereals</a>

<sup>73</sup> P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets. <a hre

<sup>74</sup> DAFWA (2016) Smut and bunt diseases of cereal: biology, identification and management. DAFWA, <a href="https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-biology-identification-and-management?page=0,1">https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-biology-identification-and-management?page=0,1</a>



TABLE OF CONTENTS





Photo 18: Close-up view of barley heads affected with loose smut.

Source: DAFWA

If the spores settle on healthy flowers, they may germinate and infect the embryo of the developing seed. When this seed is planted, the smut grows inside the plant until flowering, when the disease appears. Because loose smut is carried inside the seed, systemic seed dressings are needed to control it. These are more expensive than the others and should be used only when a high incidence of loose smut is expected. 75

#### Managing smut

The disease is controlled by pickling seed with a systemic fungicide which penetrates the developing seedling to kill the internal infection. Seed-dressing fungicides for cereals differ in their efficacy for smut management with trial research demonstrating that some seed dressings can reduce the incidence of loose smut in heavily infected seed to nearly zero. The correct application of seed dressings is critical to ensuring adequate prevention and control. 76

# 9.8 Rhizoctonia barepatch

- The presence of *Rhizoctonia* fungal disease is most evident as bare patches in a young crop. Close inspection of infected seedlings shows brown discolouration or rotting of the roots and evidence of 'spear tips'.
- In cereals, oats are most tolerant, followed by triticale, wheat and then barley, which is the most intolerant. 77
- Adequate nutrition during crop emergence gives the crop a better chance of getting ahead of the disease.
- Fast-growing roots will push past the infected topsoil before *Rhizoctonia* infects
- Poor weed management prior to seeding allows Rhizoctonia solani to 'prime' itself for infection of the upcoming crop.



SOUTHERN

DAF Qld (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/

DAFWA (2016) Smut and bunt diseases for cereal. DAFWA, <a href="https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-">https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-</a> biology-identification-and-management?page=0%2C0

 $<sup>\</sup>mathsf{GRDC} \ (2008) \ What is \ Rhizoctonia \ bare \ patch? \ \mathsf{Factsheet}. \ \mathsf{GRDC}, \ \underline{\mathsf{https://grdc.com.au/uploads/documents/grdc\_fs\_rhizo.pdf}$ 









Karoonda break crops trails: soil biology and rhizoctonia disease



WATCH: Over the Fence: Improving soil health helps fight against Rhizoctonia



In severe paddock infections cultivation following late summer-early autumn rains can help to reduce infection by the fungus.

SOUTHERN

JANUARY 2018

Rhizoctonia barepatch is a fungal disease caused by Rhizoctonia solani (Kuhn). It affects a wide range of crops and has become more prevalent in light soils in recent years following the introduction of minimum-tillage practices. The traditional practice of tilling prior to planting encouraged the breakdown of the fungus in the soil before seedlings emerged. Minimum tillage decreases the rate of organic-matter breakdown, thereby providing a habitat for *Rhizoctonia solani* over summer. The disease affects most major crops to varying degrees, with barley being most susceptible and oat crops are least susceptible. Bare patch and root rot of cereals, and damping off and hypocotyl rot of oilseeds and legumes are all caused by different strains of R. solani. <sup>78</sup>

# 9.8.1 Symptoms

The characteristic symptom of Rhizoctonia barepatch is clearly defined bare patches in the crop (Photo 19). 79 The reason these patches are clearly defined relates to the susceptibility of young seedlings, and the placement of the fungus within the soil profile. Rhizoctonia solani tends to reside in the upper layers of soil, but not in the surface, and only infects seedlings through the root tip soon after germination. Older plants have a more developed root epidermis that does not allow the penetration of fungal hyphae into the root. For this reason, once the crop is fully established, plants have either perished due to seedling infection or are reasonably healthy. Some yield loss may be associated with plants on the margins of the bare patch. Roots of a plant infected with R. solani will typically be shorter and have a brown 'spear tip' where they have rotted. Plants within a patch remain stunted with stiff, rolled leaves and can be darker green than those outside the patch. 80

#### What to look for in the paddock

- Severely stunted plants occur in patches with a distinct edge between diseased and healthy plants.
- Patches vary in size from less than half a metre to several metres in diameter.
- Patches of uneven growth occur from mid-winter when seminal roots have established (Photo 19).



<sup>78</sup> Soilquality.org (2016) Rhizoctonia: NSW. Factsheet, Soilquality.org, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw

Soilquality.org (2016) Rhizoctonia: NSW. Factsheet, Soilquality.org, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw









**Photo 19:** Patches vary in size from less than a metre to several metres in diameter. Patches have a distinct edge.

Source: DAFWA

### What to look for in the plant

- Affected plants are stunted with stiff, rolled leaves and are sometimes darker green than healthy plants (Photo 20).
- Roots of affected plants are short with characteristic pinched ends called 'spear tips' (Photo 21).



SOUTHERN JANUARY 2018









**Photo 20:** Affected plants are stunted with stiff, rolled leaves which are sometimes darker than those of healthy plants.

Source: DAFWA

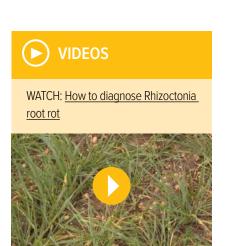


SOUTHERN JANUARY 2018



TABLE OF CONTENTS

FEEDBACK





**Photo 21:** Roots of affected plants are short with characteristic pinched ends or 'spear tips'.

Source: DAFWA

# 9.8.2 Conditions favouring development

Rhizoctonia solani survives best in organic matter just below the surface of undisturbed soil. The fungus benefits from summer rainfall by infecting and multiplying in weeds, and has a limited ability to survive on the residue of previous seasons crops. The break of season initiates the development of the fungus in soil, where it lies primed to infect germinating seeds. Infection by the pathogen is encouraged by factors that restrict root growth, such as low soil fertility and sulfonylurea herbicides. If there is a delay between the season break and seeding, it is imperative that weeds are controlled to minimise proliferation of the fungus. Good nitrogen nutrition helps to minimise the effects of the disease; bare patches are smaller and less severe.

In general, Rhizoctonia barepatch is most likely to be a severe problem where the plant is under stress from factors other than the disease, for example, low rainfall or poor nutrition.

### **Factors affecting Rhizoctonia**

There are certain soil conditions that favour *Rhizoctonia* development during and after seeding.

#### Soil nutrition

The disease is most common in light textured soils of poor fertility. Crops with access to sufficient nutrients for growth have a better ability to 'get ahead' of *Rhizoctonia* infections.









#### Soil disturbance

*Rhizoctonia* is sensitive to cultivation, with cultivation after rain and before sowing most effective at reducing infection. Disturbing the soil prevents the fungus from 'priming' itself for infection of the emerging crop.

#### Soil moisture

Under moisture stress the crop becomes more susceptible to *R. solani* infection and has a decreased ability to get ahead of the disease. Rhizoctonia appears worse in crops emerging in dry cold growing conditions in light textured low nutrient soils.

#### Weeds

Poor weed management following late summer and early autumn rain allows *Rhizoctonia* to infect grass weeds, thereby allowing the fungus to multiply in preparation for the crop.

#### Herbicides

Sulfonylurea herbicides, both residual and recently applied, can sometimes worsen *Rhizoctonia*, and this is attributed to minor herbicidal effects on the crop. <sup>81</sup> Ensure soil Zinc levels are adequate or apply foliar zinc to help alleviate Group B herbicide effects.

# 9.8.3 Managing Rhizoctonia

Where reduced tillage is practiced, Rhizoctonia bare patch is best controlled by effectively managing weeds and maintaining adequate nutrition for the establishing crop. Spraying weeds with a fast-acting knockdown herbicide will minimise the development of the fungus in the ground prior to seeding, and good nutrition gives the crop a better chance of getting ahead of the disease.

Best-tillage practices involve deep cultivation and shallow sowing, with minimal time between the two. In no-till systems the use of modified sowing points that provide some soil disturbance 5–10 cm below the seed can be useful in controlling the disease.

In the past, tilling was the most effective method of reducing the impact of *Rhizoctonia solani*. The establishment of the fungus in the topsoil late in autumn was negated as cultivation broke the network of fungal hyphae, and it did not have time to recover before seedling establishment. In severely infected paddocks, cultivation may be an important management strategy.

Currently there are no resistant crop varieties, but there are a number of products on the market with claims for Rhizoctonia barepatch control. Consult your local adviser for specific information.

In areas where the disease is known or suspected it is best practice to clean knife points once the seeding is complete, to eliminate movement of the fungus from one paddock to the next. In general, maintaining adequate nutrition (especially nitrogen) during crop establishment is the best way to reduce the impact from R. solani infection.  $^{82}$ 

## 9.9 Ergot

Triticale, like rye, is susceptible to ergot, a fungal disease, caused by *Claviceps purpurea*, that can ruin a year's crop. Careful crop rotation, the use of a clean seedbed, and diligent maintenance of field edges will minimise this chance, but triticale intended for human or animal consumption should be tested for toxins.



Management to minimise Rhizoctonia disease in cereals



<sup>81</sup> Soilguality.org (2016) Rhizoctonia: NSW. Factsheet. Soilguality.org. http://www.soilguality.org.au/factsheets/rhizoctonia-nsw

<sup>82</sup> Soilquality.org (2016) Rhizoctonia: NSW. Factsheet. Soilquality.org, <a href="http://www.soilquality.org.au/factsheets/rhizoctonia-nsw">http://www.soilquality.org.au/factsheets/rhizoctonia-nsw</a>







Ergot can make grain less palatable to livestock, as well as causing serious health problems.  $^{\rm 83}$ 

Ergot is relatively rare in Australian grains, however it is considered a constant threat as it contains toxic chemicals (alkaloids) that are very harmful to both animals and humans. For this reason, Ergot in grain could prove quite damaging to grain trade. <sup>84</sup>

# 9.9.1 Damage caused by disease

Ergot bodies contain alkaloid chemicals that can cause lameness, gangrene of the extremities and nervous convulsions (staggers) that can lead to death in both humans and other animals. Symptoms begin to occur after long periods of low level ingestion as toxins accumulate in the body. Yields of crops affected by ergot are generally not much diminished yield losses, but economic losses can be quite severe, because grain tendered by growers is likely to be rejected at receival. <sup>85</sup>

# Gangrenous ergotism of humans and cattle

In humans, gangrenous ergotism causes blockages of circulation to the extremities resulting first in tingling and then in gangrene in the fingers and toes, as well as vomiting, diarrhoea, and ulceration of the mouth. It is a dry form of gangrene, and limbs may fall off.

In cattle there is lameness, especially in the hindquarters, gangrene of feet, ears and tail. Pregnant cows may abort. There is a characteristic band where the gangrenous tissue ends.

### Convulsive ergotism

Symptoms are similar to those of gangrenous ergotism, and are followed by painful spasms of the limbs, epilepsy-like convulsions and delirium in humans. Cattle become excitable and run with a swaying, uncoordinated gait.  $^{86}$ 

## 9.9.2 Symptoms

#### What to look for in the plant

Characteristically ergot pieces have a purple—black surface with a white to grey interior (Photo 22). They are usually horn-like in shape and replace one or more grains in the heads of cereals and grasses. These ergot bodies can be up to four times larger than normal grain.

- Hard, dry purple—black fungal bodies (ergots) that replace the grain in the seed head.
- Yellow droplets of sugary slime in infected heads during flowering. 87



<sup>83</sup> UVM Extension Crops and Soils Team (2011) Triticale. University of Vermont, <a href="http://northerngraingrowers.org/wp-content/uploads/TRITICALE.pdf">http://northerngraingrowers.org/wp-content/uploads/TRITICALE.pdf</a>

<sup>84</sup> AWB (n.d.) Ergot. Factsheet. AWB, <a href="https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT\_factsheet.pdf">https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT\_factsheet.pdf</a>

<sup>85</sup> AWB (n.d.) Ergot. Factsheet. AWB, <a href="https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT\_factsheet.pdf">https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT\_factsheet.pdf</a>

<sup>86</sup> HerbiGuide (n.d.) Rye. HerbiGuide, <a href="http://www.herbiguide.com.au/Descriptions/hg\_Rye.htm">http://www.herbiguide.com.au/Descriptions/hg\_Rye.htm</a>

<sup>87</sup> DAFWA (2015) Diagnosing ergot. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-ergot">https://www.agric.wa.gov.au/mycrop/diagnosing-ergot</a>





Photo 22: Ergot bodies in cereal grain head.

Photo: C Wolinsky

#### What to look for in stock

Producers are encouraged to keep an eye on animals that may have eaten ergotinfected grain, especially in hot or sunny weather (Photo 23). Signs of ergot poisoning include animals seeking shade, being reluctant to move, and panting and distress following any exercise. Animals may also drool, have an increased respiratory rate, and reduced feed intake. 88



**Photo 23:** Producers need to be aware that even a small amount of ergot in grain can cause serious illness to their stock.

Photo: Michael Raine



<sup>88</sup> DAFWA (2015) Look out for ergots when selecting stock feed. DAFWA, https://www.agric.wa.gov.au/news/media-releases/look-out-ergots-when-selecting-stock-feed







# 9.9.3 Conditions favouring development

Key points:

- Ergots survive in the soil for up to one year, producing spores that infect plants during flowering.
- Infection is more likely when there is cool wet weather at flowering.
- It is spread by rain splash or by insects attracted to the sugary droplets.
- High levels of grass-weed contamination can increase ergot infection in cereals, or ergots produced in grasses can contaminate grain samples.

The development of ergot is promoted by moist soil surfaces during spring and early summer. In addition, wet conditions during the flowering of cereals and grasses increases the period of infection. The disease cycle of ergot consists of two stages. It begins in spring when the ergot bodies germinate in wet soils after winter and develop fruiting bodies that contain spores (ascospores). The spores can be spread to neighbouring, susceptible plants by wind and rain. To infect these plants, the spores must land on the florets. Within five days the second stage commences; this is referred to as the 'honeydew stage'. The infected florets exude a sugary slime that contains spores of a second type (conidia). These can infect other florets via insect vectors, rain splash and/or wind. This period of infection lasts for as long as the susceptible plants are in flower. The infected ovary in the floret then enlarges and is replaced by the purple–black ergot body, which can survive in soil for up to one year.

Crops are generally perceived to be at greatest risk when grass weed populations are high. Infected grasses usually produce slender ergots and in some cases can be fully responsible for the contamination of grain samples. <sup>90</sup>

Ongoing periods of spring and summer rain can increase occurrence of ergots in ryegrass; therefore, ergots in crops are more likely to develop in years of above-average rain when ryegrass is flowering. 91

# 9.9.4 Management of disease

Key points:

- Give contaminated paddocks a one-year break without cereals or grasses.
- Manage grass-weed contamination in crops.
- Clean seed. 92

For grain that is contaminated, grain-cleaning equipment can be used to remove the majority of ergot bodies (Photo 24). However, the grower will need to determine whether this is economically viable.



<sup>89</sup> DAFWA (2015) Diagnosing ergot. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-ergot

<sup>90</sup> AWB (n.d.) Ergot. Factsheet. AWB, <a href="https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-488D-8B6C-631A00F15478/0/ERGOT\_factsheet.pdf">https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-488D-8B6C-631A00F15478/0/ERGOT\_factsheet.pdf</a>

<sup>91</sup> DAFWA (2015) Look out for ergots when selecting stock feed. DAFWA, <a href="https://www.agric.wa.qov.au/news/media-releases/look-out-ergots-when-selecting-stock-feed">https://www.agric.wa.qov.au/news/media-releases/look-out-ergots-when-selecting-stock-feed</a>

DAFWA (2015) Diagnosing ergot. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-ergot">https://www.agric.wa.gov.au/mycrop/diagnosing-ergot</a>

**TABLE OF CONTENTS** 

FEEDBACK



Photo 24: Ergot-contaminated seed.

Source: DAFWA

To avoid the development of ergot in subsequent cereal crops, effective farmmanagement practices are required. One option available to growers is the use of crop rotations away from cereals for at least one year to reduce the number of viable ergot pieces in the soil to negligible levels.

During planting, clean seed must be used, as there are currently no effective treatments against ergot. For growers using conventional tillage, ergot pieces need to be buried to a minimum depth of 4 cm. This prevents the fruiting bodies that are produced by the ergot from reaching the soil surface and releasing spores. This may have an effect on the usual sowing operations and guidance should be sought.

Finally, to eliminate the development of host reservoirs, growers may be able to mow or spray grass pastures to prevent flowering.  $^{93}$ 

Control of grasses within cereal crops will help prevent cross-infection. This is best achieved by preventing seedset in the season before cropping, by clear fallowing, hard grazing or hay cutting, together with the use of selective herbicides.  $^{94}$ 

The only practical control is to sow clean, year-old seed on land that hasn't grown cereal rye for at least a year. Mowing roadside and headland grass prior to seedset will reduce or eliminate this major source of ergot re-infestation. <sup>95</sup>

Strategies to reduce the risk of ergot infection:

• Use ergot-free seed if possible.



<sup>93</sup> AWB. Wheat Quality Factsheet—ERGOT. <a href="https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/">https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/</a> ERGOT\_factsheet.pdf

<sup>94</sup> Agriculture Victoria. (1999). Ergot of pasture grasses. <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ergot-of-pasture-grasses">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ergot-of-pasture-grasses</a>

<sup>95</sup> Alberta Gov. (2016). Fall Rye Production. <a href="http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/agdex1269/\$file/117\_20-1.pdf">http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/agdex1269/\$file/117\_20-1.pdf</a>



**TABLE OF CONTENTS** 





 As the source of ergot infection is often the grass in headlands or ditches, mowing this grass before flowering or seedset will greatly reduce or eliminate the chances of ergot infection.

SOUTHERN

- Ergots germinate at or near the soil surface. To prevent them from germinating, work the field to a depth greater than 4-5 cm to bury the ergot bodies.
- Seed at a uniform depth as shallow as possible for adequate moisture to obtain a uniform early emergence.
- Separate the seed collected from the first few combine rounds to prevent contamination of the entire lot, as most of the ergot infested grain will likely be concentrated in this region. 96

### Marketing options

Stockfeed intended for feedlot cattle has been limited to 0.1% ergot sclerotia (dormant, or vegetative, stage of ergot bodies) by weight since 2004.

Deliveries of grain with sclerote levels higher than 0.3% will be rejected by grain merchants, and higher than 0.1% will be rejected by cattle feedlotters. Most commonly, a sample containing 0.3% sclerotia will contain about 1 mg alkaloid/kg (1 ppm), but because the alkaloid concentration can vary, it will be advisable to minimise ergot wherever possible.

Although there is a 0.3% sclerote contamination limit for grain intended for livestock, some end-users will not accept ergot-contaminated grain at all. Grower pigs, chickens and laying hens are more tolerant of the alkaloids in sclerotia, and are a potential market for grain that contains 0.3% sclerotia. Grain with levels higher than the animal-feed limit can be mixed with clean grain to reduce the sclerote levels. Fortunately, the incidence of ergot contamination of bulk grain has been very low in the last decade. <sup>97</sup>

# 9.10 Septoria tritici blotch

Triticale has vastly superior tolerance over wheat to Septoria tritici blotch (Table 9). 98

Septoria tritici blotch (STB) is an important stubble-borne foliar disease of cereals in southern Australia. This disease has increased in importance in the high-rainfall cropping regions in recent years, even though it has been well controlled in Victoria for the last 30 years through the use of partially resistant varieties. The increase in STB in the high-rainfall zone has been favoured by stubble retention, intensive wheat production, susceptible cultivars and favourable disease conditions.

When susceptible and very susceptible varieties are grown, *Septoria tritici* blotch is likely to cause annual average losses of up to 20%, with much higher losses possible in individual crops.

# 9.10.1 Symptoms

The fungus causes pale grey to dark brown blotches on the leaves, and to a lesser extent stems and heads. The diagnostic feature of *Septoria tritici* blotch is the presence of black fruiting bodies (pycnidia) within the blotches (Photo 25). <sup>99</sup> These tiny black spots give the blotches a characteristic speckled appearance. When the disease is severe, entire leaves may be affected by disease lesions (Photo 26).



 $<sup>96 \</sup>quad \text{Alberta Gov. (2016). Fall Rye Production.} \\ \underline{\text{http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/agdex1269/\$file/117\_20-1.pdf} \\ 20.1.pdf \\$ 

<sup>97</sup> DAF Qld (2010) Ergot-affected and mouldy sorghum. DAF Qld, <a href="https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/disease-management/ergot-affected-and-mouldy-sorghum">https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/disease-management/ergot-affected-and-mouldy-sorghum</a>

P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

<sup>99</sup> G Hollaway (2014) Septoria tritici blotch of wheat. Note AG1336. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/">http://agriculture.vic.gov.au/agriculture/</a> pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/septoria-tritici-blotch-of-wheat





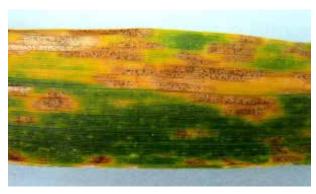


In the absence of the black fruiting bodies, which are visible to the naked eye, similar blotching symptoms may be caused by yellow leaf spot or nutritional disorders such as aluminium toxicity or zinc deficiency.

**SOUTHERN** 

JANUARY 2018

The only other disease that has black fruiting bodies within the blotches is *Septoria nodorum* blotch, but this disease is rare in Victoria.



**Photo 25:** The presence of black fruiting bodies within the blotches is a diagnostic feature of Septoria tritici blotch.

Source: Agriculture Victoria



Photo 26: Septoria tritici blotch can cause complete death of leaves.

Source: Agriculture Victoria









Table 7 lists the resistance of different varieties to Septoria tritici blotch. 100

**Table 7:** Triticale variety resistance ratings to Septoria tritici blotch.

Variety	Septoria tritici
Astute(D	_
Berkshire(1)	RMR
Bison(D	MR
Canobolas(b	RMR
Chopper(1)	RMR
Endeavour(1)	R
Fusion(b	R
Goanna	R
KM10	MR
Rufus	RMR
Tahara	RMR
Tobruk(b	R
Tuckerbox	RMR
Yowie	RMR

Maturity: E = early, M = mid-season, L = late, VL = very late Height: M = medium, T = tall Colour: W = white, Br = brown

Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS  $\rho = \text{provisional ratings}$ —treat with caution. R = resistant, M = moderately, S = susceptible, V = very. # Varieties marked may be more susceptible if alternative strains are present

Source: Agriculture Victoria

# 9.10.3 Conditions favouring development

Septoria tritici blotch, also called Septoria leaf spot or speckled leaf blotch of wheat is caused by the fungus Mycosphaerella graminicola (asexual stage Zymoseptoria tritici, synonym Septoria tritici).

Septoria tritici blotch survives from one season to the next on stubble. Following rain or heavy dew in late autumn and early winter, wind-borne spores (ascospores) are released from fruiting bodies (perithecia) embedded in the stubble of previously infected plants. The spores can be spread over large distances.

Early ascospore infections cause blotches on the leaves. Within these blotches a second type of fruiting body, pycnidia, are produced. Asexual spores ooze from pycnidia when the leaf surface is wet and spores are dispersed by rain splash to other leaves where they cause new infections. This phase of disease development depends on the rain splash of spores; therefore, Septoria tritici blotch will be most severe in seasons with above-average spring rainfall. A combination of wind and rain provides the most favourable conditions for spread of this disease within crops.

# 9.10.4 Management

An integrated approach that incorporates variety selection, cultural practices, crop rotation and fungicides is the most effective way to manage Septoria tritici blotch.



49

SOUTHERN

<sup>100</sup> Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/">http://agriculture.vic.gov.au/</a> agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary

**TABLE OF CONTENTS** 





### Variety selection

The majority of commercially grown varieties now have partial resistance (i.e. they are moderately susceptible) to *Septoria tritici* blotch. This resistance has to date been durable, and sufficient to effectively control this disease in Victoria.

It is important to avoid very susceptible varieties as they will build up inoculum levels. This will cause yield loss in that variety, and in adjacent moderately susceptible wheat crops. For information on the resistance status of varieties consult the current Victorian Cereal Disease Guide.

### **Cultural practices**

Following an outbreak of *Septoria tritici* blotch do not sow wheat into infected stubble and avoid early sowing as a high number of ascospores are released early in the season. If this is not possible, destroying stubble by grazing or cultivation will reduce the number of spores available to infect the new season's crop. Such practices will have more effect if undertaken on a district basis. This practice is not, however, practicable in light soil areas where stubble must be kept to prevent erosion.

#### **Crop rotations**

Crop rotations are important to ensure wheat is not sown into paddocks with high levels of stubble-borne inoculum. A one-year rotation out of wheat is generally effective to provide disease break. However, the fungus may survive for over 18 months on stubble during very dry seasons.

### **Fungicides**

Some seed-applied fungicides can suppress early infection and should be used in areas where *Septoria tritici* blotch is known to occur. Effective foliar fungicide sprays are available if necessary. However, it is important to correctly identify *Septoria tritici* blotch before spraying with a fungicide as nutritional disorders such as aluminium toxicity or zinc deficiency can be confused with *Septoria tritici* blotch.

In high-risk areas, the timing of fungicides will be important to achieve adequate disease control. In early sown susceptible varieties, a fungicide application at growth stage 31–32 may be required to suppress the disease and protect emerging leaves. Once the flag leaf has fully emerged, at GS39, another fungicide application may be required to protect the upper canopy.

Since STB is prone to developing resistance to fungicides, and resistance has been detected in Australia, it is important that fungicide strategies to reduce the likelihood of resistance developing are adopted.

#### Fungicide resistance

Increasing resistance of *Zymoseptoria tritici* to some triazole (Group 3) fungicides was recently detected in Victoria by Dr Andrew Milgate, of the NSW Department of Primary Industries. Two mutations of *Septoria tritici* blotch giving resistance to triazole fungicides were identified. These mutations reduce the effectiveness of fungicides, rather than making them completely ineffective. However, continued use of triazole fungicides will put further selection pressure on the pathogen, and potentially new mutations will be selected.

Fungicides with reduced effectiveness against *Septoria tritici* blotch include triadimefon, triadimenol, tebuconazole, propiconazole and epoxiconazole. Epoxiconazole is not registered for control of *Septoria tritici* blotch in Australia.

Dr Milgate found that resistance may not be causing reduced spray efficacy at present, but a strategy to prolong fungicide effectiveness will prolong the life of this fungicide group.  $^{101}$ 

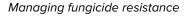


<sup>101</sup> A Milgate. (2014). Septoria fungicide resistance detected. Ground Cover Issue 110- Cereal foliar fungal diseases. <a href="https://grdc.com.au/media-Centre/Ground-Cover-Supplements/GCS110/Septoria-fungicide-resistance-detected">https://grdc.com.au/media-Centre/Ground-Cover-Supplements/GCS110/Septoria-fungicide-resistance-detected</a>









There are a number of methods thought to reduce the selection rate for further mutations.

The first method is to alternate different triazoles, as not all triazole fungicides are affected equally by mutations of the *Septoria tritici* blotch fungus. This means not using the same traizole fungicide more than once in a crop, if multiple sprays are required during the season.

The second is to used fungicides that combine triazoles, such as Tilt Xtra® (propiconazole and cyproconazole) or Impact Topguard® (tebuconazole and flutriafol), which are registered for use on *Septoria tritici* blotch.

The third is to use fungicides with different modes of action. However, in Australia there is a limited choice in this regard. Products that combine a strobilurin (Group 11) fungicide with a triazole fungicide may reduce the risk of resistance development. Custodia® (tebuconazole and azoxystrobin) is registered for *Septoria tritici* blotch in Australia.

Strobilurins on their own are considered to be at high risk of developing resistance due to their single site mode of action. In the United Kingdom, resistance to strobilurins is so widespread in *Septoria tritici* blotch populations they are no longer effective, even in mixtures. Resistance of *Septoria tritici* blotch to strobilurins has been recently detected in New Zealand, too. While not yet registered in Australia, SDHI (Group 7) carboxamide fungicides mixed with triazole (Group 3) fungicides are being used in New Zealand and the United Kingdom to manage *Septoria tritici* blotch.

When using fungicides, it is important that growers always follow label guidelines and ensure maximum residue limits are adhered to.

## Biosecurity

As resistant mutations of the *Septoria tritici* blotch fungus have been identified in other countries, including New Zealand, the United Kingdom and mainland Europe, it will be important to not accidentally introduce these resistant mutations into Australia after travelling overseas.

The risk of introducing exotic diseases or new mutations of a pathogen into Australia can be minimised by having a biosecurity hygiene plan, and implementing it following overseas travel.

Basic <u>biosecurity hygiene</u> includes washing clothes and cleaning footwear before returning to Australia. If high risk areas have been visited, consider leaving clothing and footwear behind. Remind family members, employees or others travelling to also take these precautions. <sup>102</sup>

# 9.11 Cereal fungicides

All of the diseases addressed so far are caused by different fungi. Fungal disease is a major disease threat to all Australian crops, and keeping paddocks (and farms) healthy and disease loads low requires thoughtful management.

- Fungicides are only one component of a good management strategy.
- Correct identification of the cause of plant symptoms is essential, and an understanding of the growth and spread of any pathogen will assist in any decision making.
- Cultivar resistance is the best protection against fungal diseases. Ideally, when suitable varieties are available, opt for moderately resistant (MR) to resistant (R) varieties in disease-prone environments.
- Disease control using fungicides is an economic decision. Does the yield potential justify the return on investment in applying the fungicide?



Septoria tritici blotch, southern region





**TABLE OF CONTENTS** 

**VIDEOS** 

WATCH: GCTV9: Banding fungicide in





 For cereal rusts and mildew, remove the green bridge between crops to prevent rusts from over-seasoning.

SOUTHERN

JANUARY 20<u>18</u>

- Monitor crops throughout the season.
- Spray if disease threatens key plant parts (flag to flag-2) of varieties that are
  moderately susceptible (MS) or susceptible (S). Note that if the disease has
  already reached this part of the plant it is too late to control the disease.
   Effective fungicide management relies on good identification and early control.
   Management should be pre-emptive if environmental conditions are suitable for
  disease growth and if a variety is susceptible.
- Fungicides do not increase yield; they protect yield potential and cannot retrieve lost yield if applied after infection is established.
- Fungicide resistance is a major emerging issue. Do not use tebuconazole-based products; e.g. on barley if there is any chance of powdery mildew occurring, and select varieties that are resistant to powdery mildew (Table 8).

**Table 8:** Modes of action registered for control of foliar diseases in Australian cereals.

_	A		- " (F) 1 (O)
Group	Active Ingredient	Example Product Name	Foliar (F), seed (S) or in-furrow (IF)
	Triadimefon	Triad®	F and IF
	Propiconazole	Tilt®	F
	Propiconazole + cyproconazole	Tilt® Xtra	F
	Tebuconazole	Folicur®	F and S
	Flutriafol	Impact®	F and IF
3 - DMI	Tebuconazole + flutriafol	Impact® Topguard	F
	Tebuconazole + prothioconazole	Prosaro®	F
	Epoxiconazole	Opus®	F
	Triadimenol	Baytan®	S
	Fluquinconazole	Jockey®	S
3 + 11 (Strobilurins)	Azoxystrobin + cyproconazole	Amistar® Xtra	F
	Pyraclostrobin + epoxiconazole	Opera®	F

Source: R Oliver, Curtin University. In <u>GRDC</u>



There have been a number of pathogens, including *Septoria tritici* blotch, which have recently developed a level of fungicide insensitivity or resistance in Australia. The occurrence of these highlights the important role all growers play in fungicide resistance.

To help achieve fungicide-resistance management and disease management, there are three important steps growers need to implement.

- 1. Remove the source of infection:
- For many pathogens, stubble is the source of the infection each year. By removing stubble before sowing, there is a substantial reduction of pathogen population size.



<sup>103</sup> GRDC (2013) Managing cereal fungicide use, southern region. Factsheet. GRDC, <a href="https://grdc.com.au/Resources/Factsheets/2013/05/Careal-fungicides">https://grdc.com.au/Resources/Factsheets/2013/05/Careal-fungicides</a>



**TABLE OF CONTENTS** 





GRDC, Cereal fungicides

This reduces all forms of the pathogen irrespective of resistance, and reduces

SOUTHERN

- To avoid rapid disease build up, do not sow wheat on wheat or barley on barley.
- 2. Variety choice:
- Under high disease pressure, a variety rated MR-MS can reduce the leaf area loss substantially. Where possible, choose a more resistant variety.
- Host resistance reduces all forms of the pathogen irrespective of resistance, and reduces the need for multiple canopy fungicide applications.
- But resistance ratings do change, so crops must still be monitored in season for higher than expected reactions and check each year for updates to disease ratings.
- 3. Fungicide choice and use:
- Do not use the same triazole active ingredient more than once in a season. Do
  not use a strobilurin or succinate dehydrogenase inhibitors (SDHIs) more than
  once in a season.
- Aim for early control of necrotrophic diseases in high-rainfall years. Reducing the disease in the lower canopy slows the upward movement of disease and ultimately the leaf area lost.
- Follow label instructions at all times.

the initial establishment of disease.

The timing of application in the disease epidemic is critical to getting the most out of these products.  $^{104}$ 

# 9.12 Barley yellow dwarf virus

The yellow dwarf diseases of cereals have now been divided into two groups: Barley yellow dwarf virus (BYDV) and Cereal yellow dwarf virus (CYDV). They are the most important virus diseases of cereals worldwide. They have a wide host range which includes wheat, barley, oats, triticale and over 150 non-commercial grass species.

The virus is usually spread by aphids from infected grasses to crops. Wet summers and autumns promote growth of host grasses and build up of aphid vectors, resulting in early crop infection, severe symptoms and yield losses. Yellow dwarf viruses (YDVs) tend to be more serious in the high-rainfall cropping regions in southern Australia, but can occur in all cropping regions. The virus is best controlled by monitoring and spraying for aphids early in the season.

#### **Economic importance**

Work in 1984 estimated yield losses caused by BYDV in Victoria to be 2%, with up to 20% in individual crops. Trial data has shown that yield losses of 9-79% can occur when plants are infected early in the growing season (before the end of tillering) and losses of 6-9% may occur when plants are infected late (after tillering).  $^{105}$ 

# 9.12.1 Symptoms

After infection, symptoms take at least three weeks to appear. They usually appear as patches of yellow or red stunted plants. The symptoms first appear where aphids have landed. Flying aphids may infect individuals or groups of plants dotted throughout the crop. If the aphids colonise the crop, rings or patches develop which increase in size with time (Photo 27). <sup>106</sup> If crawling aphids move into the crop from adjoining pastures or crops then symptoms will appear along the fence line first.



<sup>104</sup> A Milgate (2016) Cereal disease update and risks for southern NSW crops in 2016. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/">https://grdc.com.au/</a> Research-and-Development/GRDC-Update-Papers/2016/07/Cereal-disease-update-and-risks-for-southern-NSW-crops-in-2016

<sup>105</sup> Agriculture Victoria (2011) Barley yellow dwarf virus. Note AG1113. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus</a>

DAFWA (2015) Managing barley yellow dwarf virus and cereal yellow dwarf virus in cereals. DAFWA, <a href="https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-and-cereal-yellow-dwarf-virus-cereals?page=0,1">https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-and-cereal-yellow-dwarf-virus-cereals?page=0,1</a>



**TABLE OF CONTENTS** 





Photo 27: Patches where aphids have landed and transmitted the virus.

Source: DAFWA

YDV symptoms can be variable and can differ with host species, cultivar and time of infection. Sometimes, infection of cereals may occur without visible symptoms. Distinct symptoms usually occur on cereals although many infected grasses are symptomless. 107

Infected wheat plants develop a slight to severe yellowing or pale striping between veins (interveinal chlorosis) in young leaves (Photo 28). Leaf tips can also die (necrosis). Reddening of the leaf tips (particularly of the flag leaf) can often be seen and is the most characteristic symptom of virus infection in wheat. If a sensitive variety is infected before tillering, the plant is usually stunted, has fewer tillers and more sterile ones. Grain matures early, yield is greatly reduced and grain is shrivelled. Effects are milder with a late infection. 108



**SOUTHERN** 

<sup>107</sup> Agriculture Victoria (2011) Barley yellow dwarf virus. Note AG1113. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus</a>

<sup>108</sup> DAFWA (2015) Managing barley yellow dwarf virus and cereal yellow dwarf virus in cereals. DAFWA, <a href="https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-and-cereal-yellow-dwarf-virus-cereals">https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-and-cereal-yellow-dwarf-virus-cereals</a>



SOUTHERN

JANUARY 2018

**Photo 28:** Barley yellow dwarf virus infection of a cereal plant.

Source: DAFWA

# 9.12.2 Conditions favouring development

Because the YDVs have a such wide host range in the grass family (Poaceae), they survive between cropping seasons in volunteer cereals, annual and perennial pasture grasses, and wild grasses. In Victoria, perennial ryegrass is the main reservoir of YDVs in the high-rainfall areas. The virus and vectors can survive in small pockets of surviving grass even in the low-rainfall areas. The aphid vectors of the viruses tend to build up in autumn and spring on the grasses, and then move into cereal crops where they often develop colonies. High rainfall areas have a greater build-up of the grasses, virus and vectors.

There are at least six serotypes of the YDVs which are spread predominantly by different aphid vectors. The distribution and relative importance of the different types are largely dictated by the abundance of the aphid vector species. If samples are being tested, tests should include serotype PAV, MAV, RMV for (BYDV) and RPV for (CYDV).

The most common vectors found in Victoria are the oat aphid (*Rhopalosiphum padi*), the corn aphid (*R. maidis*), the English grain aphid (*Sitobian miscanthi*) and the rosegrain aphid (*Metopolophium dirhodum*). The viruses are not transmitted by any other insects and are not transmittable through seed, soil or sap. The aphids need to feed on an infected plant for at least 15 minutes, which is followed by a latent period of 12 hours, before the virus will transmit to a healthy plant. Aphids remain infected for the rest of their life.

See Section 7: Insect control for more information on aphids.

YDV outbreaks are likely to be worse in years when wet, cool summers allow larger than normal numbers of aphids and alternate hosts to survive summer, followed by a mild winter which favours the build up of aphid numbers. Early sown crops or long season crops sown in high rainfall areas are particularly vulnerable to this disease. <sup>109</sup>

## 9.12.3 Management

Where it is not possible to grow resistant varieties, YDV can be reduced by controlling aphid activity in crops, especially early in the season to prevent the spread of the disease, and or delayed sowing to avoid the main aphid flights in the autumn.



<sup>109</sup> Agriculture Victoria (2011) Barley yellow dwarf virus. Note AG1113. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/">http://agriculture.vic.gov.au/agriculture/</a> pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus









Barley Yellow dwarf virus, southern region

Crop diseases after drought

Later sowing will reduce the incidence of YDV, but this needs to be weighed up against possible yield reduction from delayed sowing.

Resistant varieties, when available, are the preferred option for management. There are a number of oat and a couple of wheat and barley varieties with varying levels of resistance.

SOUTHERN

#### Chemical treatments

It is vital to prevent spread of the virus by aphids during the first 8–10 weeks after crop emergence by using insecticides. In situations where aphids are likely to be a problem in the first few weeks after sowing, a seed treatment containing imidacloprid could be used for protection. This action requires a follow-up pyrethroid spray. <sup>110</sup>

Foliar sprays can be used soon after crop emergence if aphids are easily found. There are a number of products registered for control of aphids in cereals. The active ingredient pirimicarb only effects aphids, and will have less effect on any beneficial insects present at the time of spraying. Synthetic pyrethroids are also registered for use on aphids in cereals, but will have a detrimental effect on many beneficial insects. You will need to discuss with your agronomist the insecticide best suited to your situation. <sup>11</sup> If using pyrethroids, the first spray is three weeks after emergence (or at the 2-leaf stage if aphids easily found), and the second at seven weeks after emergence.

# 9.13 Disease following extreme weather

# 9.13.1 Cereal disease after drought

Drought reduces the breakdown of plant residues. This means that inoculum of some diseases does not decrease as quickly as expected, and will carry over for more than one growing season, such as with crown rot. The expected benefits of crop rotation may not occur or may be limited. Inversely, bacterial numbers decline in dry soil. Some bacteria are important antagonists of soil-borne fungal diseases such as common root rot. These diseases can be more severe after drought.

During the drought year, inoculum of some diseases favoured by a wet season may not increase as expected.

Large amounts of seed produced in abandoned crops, or seed pinched as a result of drought stress, will fall to the ground. If there are summer rains, large numbers of volunteers will provide a summer green bridge and autumn green ramp. Low stock numbers make it difficult to control volunteers, which provide a green bridge for rusts, viruses and virus vectors, and many other pathogens.

Weeds that harbour diseases are harder to kill.

Soil water and nitrogen may be unbalanced and these are likely to impact on diseases.  $^{\mbox{\scriptsize 112}}$ 

### 9.13.2 Cereal disease after flood

For disease to occur, the pathogen must have virulence to the particular variety, inoculum must be available and easily transported, and there must be favourable conditions for infection and disease development.

The legacy of the floods and excess rain include the transport of inoculum (e.g. of crown rot, nematodes, leaf spots through movement of infected stubble and soil) (Photo 29), development of sexual stages (e.g. in leaf spots, head blights), survival of



<sup>110</sup> DAFWA. (2015). Managing Barley yellow dwarf virus and cereal yellow dwarf virus in cereals. <a href="https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-cereal-yellow-dwarf-virus-cereals">https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-cereal-yellow-dwarf-virus-cereals</a>

<sup>4111</sup> Agriculture Victoria (2011) Barley yellow dwarf virus. Note AG1113. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus">http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus</a>

<sup>112</sup> G Murray, T Hind-Lanoiselet, K Moore, S Simpfendorfer, J Edwards (2006) Crop diseases after drought. Primefacts. No. 408. NSW DPI, http://www.dpi.nsw.qov.au/\_data/assets/pdf\_file/0004/123718/crop-diseases-after-drought.pdf







volunteers (unharvested material and self-sown plants in double-crop situations), and weather-damaged seed. 113

SOUTHERN



**Photo 29:** Yellow leaf spot-infected stubble following flood.

Photo: Rachel Bowman, Seedbed Media



DAF QId (2013) Winter cereals pathology. DAF QId, <a href="https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology">https://www.daf.qid.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology</a>





# Plant growth regulators and canopy management

#### Key messages

- In Australian cereal production, plant growth regulators (PGRs) are mostly used
  with the intention of producing a smaller plant that is resistant to lodging, or
  they are applied with the intention of reducing excessive growth in irrigated
  broadacre crops.
- Trials have revealed mixed responses in crop yield following the application of PGRs.
- Canopy management includes a range of crop management tools to manage crop growth and development to maintain canopy size and duration to optimise photosynthetic capacity and grain production
- Canopy management starts at seeding—sowing date, variety, plant population and row spacing are fundamental. It is more than purely delaying nitrogen (N).
- So far, the best results for canopy management have been seen in early sownlong season varieties with high yield potential, which are very responsive to high nitrogen fertiliser inputs. <sup>1</sup>

# 10.1 Plant growth regulators

A plant growth regulator (PGR) is an organic compound, either natural or synthetic, that modifies or controls one or more physiological processes within a plant. They include many agricultural and horticultural chemicals that influence plant growth and development. PGRs are intended to accelerate or retard the rate of growth or maturation, or otherwise alter the behaviour of plants or their produce. <sup>2</sup> This influence can be positive, e.g. larger fruit or more pasture growth, or negative, e.g. shorter stems or smaller plant canopies. <sup>3</sup>

#### 10.1.1 PGRs and triticale

The growth of triticale seedlings from seeds treated with three concentrations of the PGRs tetcyclacis and chlormequat, with or without drying after soaking has been investigated. Both tetcyclacis and chlormequat inhibited shoot growth. They reduced shoot-to-root ratios: first by restricting shoot growth (one week after treatment), and later by boosting root growth (eight weeks after transplanting). At the concentrations used, tetcyclacis was a more active PGR than chlormequat, and it promoted tiller production. Drying after soaking promoted root growth, retarded the elongation growth of seedlings, and enhanced some of the effects of the PGRs. <sup>4</sup>

In another study, seeds of triticale and barley were soaked in a range of dilutions of chlormequat. Germination was monitored and the growth of seedlings assessed for up to five weeks. Some concentrations of chlormequat produced seedlings with significantly more leaves on the main stem, more primary tillers, a greater leaf lamina area and a higher shoot dry weight. It is argued that these modifications could lead to an increased yield potential. <sup>5</sup>



G McMullen (2009) Canopy management in the northern grains region: the research view. NSW Department of Primary Industries, http://www.nga.org.au/results-and-publications/download/31/australian-grain-articles/general-1/canopy-management-tactical-nitrogenin-winter-cereals-july-2009.pdf

PG Lemaux (1999) Plant growth regulators and biotechnology. Presentation, Western Plant Growth Regulator Society, <a href="http://ucbiotech.org/resources/biotech/talks/misc/regulat.html">http://ucbiotech.org/resources/biotech/talks/misc/regulat.html</a>

<sup>3</sup> D Jones (2014) Plant growth regulators. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators</a>

<sup>4</sup> W Yang, REL Naylor (1988) Effect of tetcyclacis and chlormequat applied to seed on seedling growth of triticale cv. Lasko. Plant growth regulation 7(4), 289–301.

<sup>5</sup> REL Naylor, PS Brereton, L Munro (1989) Modification of seedling growth of triticale and barley by seed-applied chlormequat. Plant growth regulation 8(2), 117–125.

**TABLE OF CONTENTS** 





#### 10.1.2 PGRs in Australia

The use of PGR products in Australia has generally been relatively low. The principle reason for this is simply that crop responses are viewed as variable, and growers have not seen enough benefit in incorporating them into their cropping programs.

The use of PGR products in Australia has generally been relatively low. The principle reason for this is simply that crop responses are viewed as variable, and growers have not seen enough benefit in incorporating them into their cropping programs.

The most widely used PGRs in Australia have a negative influence on plant growth; i.e. they are applied with the intention of producing a smaller plant that is resistant to lodging or with the intention of reducing excessive growth in irrigated broadacre crops. Currently, there are four broad groups of PGRs in use in Australian crops. They are:

- 1. Ethephon, e.g. Ethrel®.
- 2. Onium-type PGRs, e.g. Cycocel®, the active ingredient of which is chlormequat (and Pix®, which is registered only for cotton).
- Triazoles, e.g. propiconazole (which is registered as a fungicide, and not for use as a PGR).
- 4. Trinexapac-ethyl, e.g. Moddus®, Moddus® Evo.

The four groups of PGRs act by reducing plant cell expansion, resulting in, among other things, shorter and possibly thicker stems. If the stems are stronger and shorter, the crop is less likely to lodge.

Ethephon is applied from the stage of the flag leaf emerging (Z37) to booting (Z45), and reduces stem elongation through the increase in concentration of ethylene gas in the expanding cells.

The PGRs in groups two to four reduce crop height by reducing the effect of the plant hormone gibberellin. These are applied at early stem elongation (Z30–32).

The manufacturers of these products claim other benefits, too, including:

- Better root development that allows for increased root anchorage.
- Better root development that provides greater opportunity for water and nutrient scavenging.
- Possible improved grain quality.
- Reduction in shedding in barley.
- Increased harvest index (HI), the ratio between grain and total dry matter.
- Faster harvest speeds and reduced stress at harvest.

A combination of trinexapac-ethyl and chlormequat applied at growth stage 31 has been found to provide significant and consistent yield gains in wheat (11%) and barley (9%) under dry spring conditions. They also significantly reduced plant height, lessening the possibility of lodging in wetter seasons. <sup>6</sup> Overseas, chlormequat chloride has been found to inhibit gibberellin production, and has been recommended in winter and spring rye, wheat, oats, triticale and winter barley. <sup>7</sup>

Moddus® is registered for ryegrass seed crops, poppies and sugar cane. Moddus Evo®, an enhanced dispersion concentrate of Moddus®, is not currently registered but has been submitted to the Australian Pesticides and Veterinary Medicines Authority (APVMA) for registration to be used in Australian cereals.

An alternative to the chemical PGRs is grazing. It was demonstrated in the <u>Grain and Graze project</u>, which had study sites at a number of mixed-farming locations, that



<sup>6</sup> W Long (2005) AC0003: Plant growth regulators and their agronomic and economic benefits to high yield potential cereal, pulse and oilseed crops. Final Report. Project ACC00003. GRDC, <a href="https://finalreports.grdc.com.au/ACC00003">http://finalreports.grdc.com.au/ACC00003</a>

<sup>7</sup> BASF. How do PGR's work? <a href="http://www.agricentre.basf.co.uk/agroportal/uk/en/crop\_solutions/cereals\_5/lodging\_canopy\_management/canopy\_management\_in\_cereals.html">http://www.agricentre.basf.co.uk/agroportal/uk/en/crop\_solutions/cereals\_5/lodging\_canopy\_management\_in\_cereals.html</a>









Plant growth regulators

grazed treatments were regularly shorter than the non-grazed treatments, and grazed crops were less prone to lodging.  $^{\rm 8}$ 

SOUTHERN

# 10.1.3 Considering mixed results

In Australia, there have been mixed results in terms of PGRs' ability to increase yield and profits.

Take home messages:

- Crop responses to the use of plant growth regulators can be inconsistent.
- In general, yield responses, if any, are produced by the reduction in lodging rather than as a direct effect of PGRs (Photo 1).
- Plant growth regulators must be applied at the correct crop growth stage according to product directions, which can be well before any lodging issues are apparent.



Photo 1: Severe lodging of a cereal crop (left).

Source: Syngenta

The main commercial triticale varieties are relatively tall compared with newer wheat varieties, increasing the likelihood of lodging. In most of the newer varieties, however, lodging is not considered a problem. The likelihood of lodging is increased by high rates of nitrogen (N) fertiliser and under irrigated conditions. <sup>9</sup> PGRs may help to decrease the risk of lodging in triticale, but this has not yet been explored in Australia.

Attempting to grow high yielding irrigated crops requires high levels of inputs; this includes water and fertiliser, which can promote large vegetative crops with an increased risk of lodging. Lodging can result in reduced yields and difficult harvest. Plant growth regulators have been around for many years but results can be variable, even having negative effects on yield. The Irrigated Cropping Council (ICC) conducted trials in 2003 and 2004 that saw some reduction in lodging but little yield response. At the same time, trials on nitrogen management in cereals demonstrated that to achieve high yields, crops do not necessarily need heavy sowing rates and large amounts of nitrogen at sowing, with corresponding lush crop in early season prone to lodging. This has seen many growers adopt a topdressing strategy that supplies the crop with N when it needs it; i.e. from stem elongation onwards. Less vegetation at stem elongation promotes stronger stems, which can support a crop yielding 8 tonnes/ha.

A trial conducted at the ICC trial block in 2012 which aimed to grow 10 t/ha of wheat and barley was deliberately sown heavily and fertilised early, and sprayed with the plant growth regulator, Moddus® Evo, as lodging was likely to occur. The effect of the PGR was mixed: barley yields increased, but wheat yields did not, despite the crops not actually lodging. A repeat trial sown in 2013 saw some lodging control and, once again, a yield increase in barley.



D Jones (2014) Plant growth regulators. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators</a>

<sup>9</sup> RS Jessop, M Fittler (2009) Triticale production manual: an aid to improved triticale production and utilization, in Improved triticale production through breeding and agronomy, Cooperative Research Centre for an Internationally Competitive Pork Industry, <a href="http://www.apri.com.au/IA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/IA-102\_Final\_Research\_Report\_pdf</a>









# **MORE INFORMATION**

Mixed bag—dual purpose crops, PGRs and other local research— Tasmania Institute of Agriculture

GRDC: Plant growth regulators

GRDC: <u>Plant growth regulators in</u> broad acre crops

GRDC: PGRs and their agronomic and economic benefits to high yield potential cereal, pulse and oilseed crops

Online farm trials: Good things come in small packages: plant growth regulators in barley

#### Conclusions: The value of PGRs

PGRs may have a place in the management of high yielding crops. Unfortunately their effects are not consistent and the decision on whether to apply a PGR has to be made approximately three months before the lodging would be expected.

SOUTHERN

Alternative PGRs are available but are not yet registered for use on all crops or at rates and timings that would have a growth regulatory effect.

The yield improvements seen in barley in the ICC trials need further investigation, as the reason behind the increase is not clear.  $^{10}$ 

# 10.1.4 Case study: Moddus® Evo

Key points:

- Moddus® Evo reduces lodging and can increase yields.
- Application timing and concentration of Moddus® Evo is critical.
- Moddus® Evo should not be applied to plants under stress.
- Moddus® Evo has improved formulation stability and plant uptake.

Lodging is considered one of the biggest barriers to reliably achieving high yields in intensive cereal production in Australia. When favourable season conditions combine with traditional management practices in high input cereal production systems, lodging can result in significant reductions in yield and grain quality.

Moddus® (250 g/L trinexapac-ethyl) is used by cereal growers in a range of overseas countries including New Zealand, UK and Germany to reduce the incidence and severity of lodging and optimise the yield and quality of high yielding wheat, barley and oat crops. Moddus® Evo is an enhanced dispersion concentrate (DC) formulation, which has been developed to provide greater formulation stability and more effective uptake in the plant. With improved mixing characteristics and the potential to provide better consistency of performance, Moddus® Evo is currently submitted to the Australian Pesticides and Veterinary Medicines Authority (APVMA) for registration in Australian cereals.

GRDC and Syngenta, the manufacturer of Moddus®, undertook research to investigate the value of Moddus® applications to Australian cereals to reduce lodging and improve yields.  $^{\rm 11}$ 

#### Methods

The researchers conducted field trials across Australia from 2004 to 2011. They used a number of varieties, climatic conditions and geographical locations. They established small plots, typically 20–120 m² using a randomised complete block design, and incorporating three to six replicates.

They measured the effect of Moddus® application on plant growth, stem strength, stem-wall thickness, lodging, lodging score, and yield, and took grain-quality measurements.

#### Results

In the trials, overall improvements in yield were often correlated with a reduction in stem height, irrespective of whether lodging had occurred. Yield improvements through the reduction of lodging are well documented. What is less understood is the often-positive impact on yields with the use of Moddus® Evo in the absence of lodging.

Conversely during the course of the evaluation of Moddus® Evo on the yield enhancement and reduction in lodging, a few trials gave anomalous results, in



<sup>10</sup> D Jones (2014) Plant growth regulators. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators</a>

<sup>11</sup> LM Forsyth and K McKee (2013) Moddus Evo: controlling plant growth for reduced lodging and improved cereal yields. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Moddus-Evo-Controlling-plant-growth-for-reduced-lodging-and-improved-cereal-yields">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Moddus-Evo-Controlling-plant-growth-for-reduced-lodging-and-improved-cereal-yields</a>



**TABLE OF CONTENTS** 

FEEDBACK



# **MORE INFORMATION**

GRDC: Moddus® Evo: Controlling plant growth for reduced lodging and improved cereal yields

which the application of Moddus® Evo did not improve yield. When the researchers examined these trials, they found that either environmental conditions during the lead-up to the application of the chemical were poor—with extensive frosting, drought, poor subsoil moisture—or there were nutrient deficiencies in the crop. As a result, they recommended that Moddus® Evo should only be applied to healthy crops with optimum yield potential. As well, the timing and concentration of Moddus® Evo applications is critical to produce the optimal yield improvements.

SOUTHERN

Moddus® Evo offers growers in environments conducive to lodging an in-season option to reduce the impact of lodging while allowing them to manage crops for maximal yields.

# 10.2 Canopy management

Key points:

- Canopy management starts at seeding: sowing date, variety, plant population and row spacing are fundamental. It is more than just delaying nitrogen.
- Correct identification of the key growth stages for input application is essential, particularly during early stem elongation when the key leaves of the crop canopy emerge.
- Knowledge of soil moisture status and soil nitrogen reserve and supply need to be taken into account in order to match canopy size to environment.
- Crop models can help integrate crop development, environmental conditions and nutrient status in order to make better canopy management decisions.

#### What is canopy management?

The concept of canopy management has been primarily developed in Europe and New Zealand—both distinct production environments similar to those typically found in most grain producing regions of Australia.

Canopy management includes a range of crop management tools to manage crop growth and development to maintain canopy size and duration to optimise photosynthetic capacity and grain production. One of the main tools for growers to manage the crop canopy is the rate and timing of applied fertiliser N. The main difference between canopy management and previous N topdressing research is that all or part of the N inputs is tactically delayed until later in the growing season. This delay tends to reduce early crop canopy size but this canopy is maintained for longer, as measured by green leaf retention, during the grainfilling period. <sup>13</sup>

If the canopy is too thin, nitrogen timing is brought forward, if it is too thick nitrogen timing is delayed (Photo 2). Much of the change brought about by canopy management has been due to the adoption of lower plant populations and a greater proportion of nitrogen being applied later in the season.



<sup>12</sup> GRDC (2009) Canopy management fact sheet, Grains and Research Development Corporation, <a href="https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf">https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf</a>

<sup>13</sup> G McMullen (2009) Canopy management in the Northern grains region—the research view. NSW DPI, <a href="http://www.nga.org.au/results-and-publications/download/31/australian-grain-articles/general-1/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-pdf">http://www.nga.org.au/results-and-publications/download/31/australian-grain-articles/general-1/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-pdf</a>

**TABLE OF CONTENTS** 

FEEDBACK





**Photo 2:** Example of controlled canopy cover—Kellalac wheat treated with the same level of nitrogen, sown 11 June at Gnarwarre (Geelong region) in Victoria (in high rainfall zone). The thinner crop canopy (left) yielded 6.18 t/ha and 12% protein; the thicker crop canopy (right) yielded 6.20 t/ha and 10.6% protein.

Source: GRDC

Adopting canopy management principles and avoiding excessively vegetative crops may enable growers to ensure a better match of canopy size with yield potential as defined by the water available.

Other than sowing date, plant population is the first point at which the grower can influence the size and duration of the crop canopy, <sup>14</sup> and one of the main tools for managing the crop canopy is the rate and timing of applied fertiliser N.

If the canopy becomes too big, it competes with the growing heads for resources, especially during the critical 30-day period before flowering. This is when the main yield component (grain number per unit area) is set. Increased competition from the canopy with the head may reduce yield by reducing the number of grains that survive for grainfill.

After flowering, temperature and evaporative demand increase rapidly. If there is not enough soil moisture, the canopy dies faster than the grain develops, and results in small grain. Excessive N application and high seeding rates are the main causes of excessive vegetative production. Unfortunately, optimum N and seeding rates are season dependent. Under drought conditions, N application and seeding rates that would be regarded as inadequate under normal conditions may maximise yield, whereas higher input rates may result in progressively lower yields. Alternatively, in years of above average rainfall, yield may be compromised with normal input rates. The extreme of this scenario of excessive early growth is haying-off, where a large amount of biomass is produced, using a lot of water and resources. Then, later in the season, there is insufficient moisture to keep the canopy photosynthesising, and not enough stored water-soluble carbohydrates to fill the grain. Therefore, grain size and yield decrease.

To attain maximum yield, it is important to achieve a balance between biomass and resources. The main factors that can be managed are:

- plant population
- row spacing
- inputs of N
- sowing date
- weed, pest and disease control
- plant growth regulation, with grazing or specific plant growth regulator products



<sup>14</sup> GRDC (2005) Cereal growth stages. Grains Research and Development Corporation, September 2005, <a href="https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf">https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf</a>



**TABLE OF CONTENTS** 

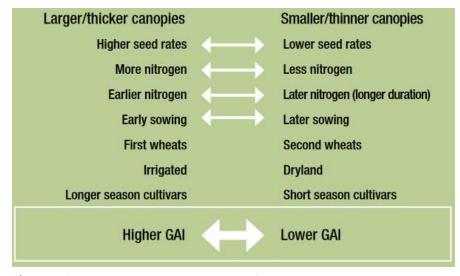


Of these, the most important to canopy management are N, row spacing and plant population.  $^{\rm 15}$ 

SOUTHERN

Applying N or fungicide at stem elongation increases the opportunity to match input costs to the potential yield for that season. While seeding applications may still be required for healthy establishment, crop models help support decisions on application timing. Models such as APSIM and Yield Prophet® simulate growth stage and season.

Canopy management is not about a delayed N strategy, however, but starts at seeding by determining the correct plant establishment for the chosen seeding date and row spacing. This must also take into account available soil moisture and nutrients (Figure 1). <sup>16</sup>



**Figure 1:** Factors under grower control that influence canopy density, size and duration. GAI = Green area index (amount of green surface area).

Source: GRDC

While N timing and rate are key components of successful canopy management, it is essential that they are considered in conjunction with the inter-related factors of:

- soil moisture
- soil nitrogen reserves
- · seeding date
- · seed rate and variety

To practice canopy management, it is important to understand the principal interactions between plant growth stages, available water and nutrients, and disease pressure. These interactions are complex but tools from simple visual indicators through to crop models can assist.

# **IN FOCUS**

#### Canopy management—Inverleigh

Trials to inform canopy management guidelines were conducted in Inverleigh, Vic in 2007. Barley was sown on 13 June, following canola stubble. With high soil nitrogen reserves (203 kg/ha N, 0 = 90 cm) recorded at sowing, a small but significant response was observed to applied



<sup>15</sup> N Fettell, P Bowden, T McNee, N Border (2010) Barley growth and development. PROCROP Series. NSW Department of Industry and Investment, <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0003/516180/Procrop-barley-growth-and-development.pdf

<sup>16</sup> GRDC (2009) Canopy management fact sheet, Grains and Research Development Corporation, <a href="https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf">https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf</a>







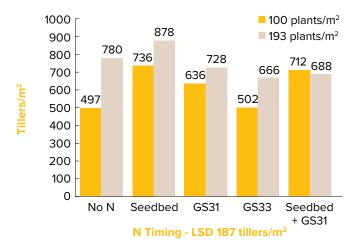
nitrogen (0.21 t/ha at 50 kg/ha N and 0.23 t/ha at 100 kg/ha N) (Figure 2). There was a significant advantage to nitrogen timed during stem elongation (GS31–33) over nitrogen applied in the seedbed (Figure 3).

There was also a non-significant trend for the higher populations (193 plants/m²) to be higher yielding than 100 plants/m² (0.21 t/ha mean advantage), with the highest yields in the trial recorded when the higher plant population was combined with GS31–33 nitrogen timings. At 50 kg/ha N, these timings produced malting grade qualities, with the exception of test weight, which was below 65 kg/ha in all treatments in the trial.

SOUTHERN

JANUARY 2018

The best margins (after nitrogen and seed costs had been deducted) came from 190 plants/m², with nitrogen timed at GS31–33 at 50 kg/ha N. Interestingly, there was a greater response to 100 kg/ha N over 50 kg/ha N with the thinner crop canopy, leading to a significant interaction between N rate and plant population. However, higher plant populations with 50 kg/ha N still produced better margins. This may have correlated to a need to boost tillers in the lower plant population, but not in the higher population.  $^{\rm 17}$ 



**Figure 2:** Influence of different nitrogen timings and plant population on tiller/m<sup>2</sup>.

Source: Online farm trials



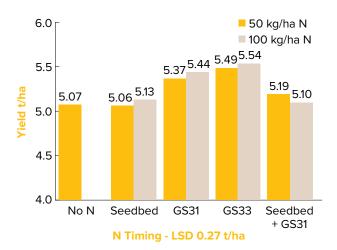
<sup>17</sup> N Poole (2007) Defining guidelines for canopy management in barley for the different climatic regions of Australia: June sown Gairdner, Inverleigh, Victoria. Crop Agronomy Trials, <a href="https://www.farmtrials.com.au/trial/15841">http://www.farmtrials.com.au/trial/15841</a>





**TABLE OF CONTENTS** 





SOUTHERN

**Figure 3:** Influence of different nitrogen timings and rates (mean of both plant populations) on yield (t/ha).

Source: Online farm trials

# 10.3 Cereal canopy management in a nutshell

- Select a target head density for your environment (350 to 400 heads per square metre should be sufficient to achieve optimum yield, even for a yield potential of 7 tonnes per hectare).
- 2. Adjust canopy management based on paddock nutrition, history and seeding time to achieve target head density.
- Established plant populations (for wheat) of between 80 and 200 plants/m<sup>2</sup> would cover most scenarios.
- 4. Lower end of range (80–100 plants/m²)—earlier sowings/high fertility and/or low yield potential low-rainfall environments.
- Higher end of the range (150–200 plants/m²)—later sowings, lower fertility situations and or higher rainfall regions.
- 6. During stem elongation (GS30–39), provide the crop with necessary nutrition (particularly N at GS30–33 pseudo stem erect–third node), matched to water supply and fungicides to:
  - » maximise potential grain size and grain number per head
  - » maximise transpiration efficiency
  - » ensure complete radiation interception from when the flag leaf has emerged (GS39)  $\,$
  - » keep the canopy green for as long as possible following anthesis

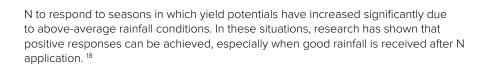
Keeping tiller number just high enough to achieve potential yield will help preserve water for filling grain and increase the proportion of water soluble carbohydrates. The timing of the applied N during GS30–33 window can be adjusted to take account of target head number and can be employed where tiller numbers and soil nitrogen seems deficient for desired head number. Conversely, where tiller numbers are high and crops are still regarded as too thick, N can be delayed further until the second or third node (GS32–33), which will result in fewer tillers surviving to produce a head. Much of the research on topdressing nitrogen has focused on the role of in-crop





**TABLE OF CONTENTS** 





**OUTHERN** 

# 10.3.1 Setting up the canopy

Research has shown that extra tillers produced by more plants per unit area are more strongly correlated to yield, than extra shoots stimulated by increased nitrogen at seeding. <sup>19</sup>

Boosting tiller numbers with seeding nitrogen results in greater tiller loss between stem elongation and grainfill. This specifically occurs in two situations: low rainfall, short environments and when soil moisture is limited. In these situations, moisture and nutrient resources are used prior to stem elongation to produce biomass, which fails to contribute to grain yield. Indeed, diverting these resources to unsuccessful tillers limits the potential of surviving tillers.

Therefore, identifying the correct population for a particular sowing date, soil nitrogen reserve and region is the basis for setting up the crop canopy.

#### 10.3.2 Soil moisture status

Under Australian conditions soil moisture has been identified as the biggest driver of the cereal crop canopy, both in terms of size and duration. Therefore, an understanding of how much water a soil can hold, and how much water a soil is holding at seeding and stem elongation is central to canopy management.

The start of stem elongation (GS30) is the pivotal point for managing the canopy with inputs, as from this point canopy expansion is rapid and soil nitrogen and water reserves can be quickly used.

If soil moisture is limited at the start of stem elongation, the ability to manipulate the crop canopy with nitrogen is limited; in many cases, the best canopy management is not to apply inputs such as nitrogen and fungicides.

By setting up a smaller crop canopy, modelling demonstrates that limited stored soil moisture can be reserved for use at grainfill, rather than being depleted by excessive early growth. However, in higher rainfall regions and in a good season, setting-up a small canopy may result in actual yield falling below potential.

Calculating potential yield and then plotting actual rainfall against decile readings for the region provides a broad picture of whether there will be sufficient soil moisture to consider additional nitrogen inputs at stem elongation.

The decision support tool Yield Prophet® and the Sirius Wheat Calculator (developed in New Zealand) offer simple tools to record and assess multiple options about the relationship between growing plants and the environment including available water and nutrients.

# 10.3.3 Soil nitrogen

It is important to have an understanding of soil N reserves to the depth of the rooting zone. Generally, 40-50~kg of N per hectare of soil-available N is required to feed a crop to stem elongation (GS30). Higher soil nitrogen reserves provide much more flexibility in managing the canopy, with tactical nitrogen applied during stem elongation.

Timing of deep-soil tests is important. Deep-soil nitrogen tests carried out in summer, several months before seeding may reveal less soil nitrogen than tests carried out after the autumn rain, when greater mineralisation will have occurred.



<sup>18</sup> N Poole, J Hunt (2014) Advancing the management of crop canopies, GRDC, http://www.grdc.com.au/CanopyManagementGuide

<sup>19</sup> GRDC (2009) Canopy management Factsheet, <a href="https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf">https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf</a>



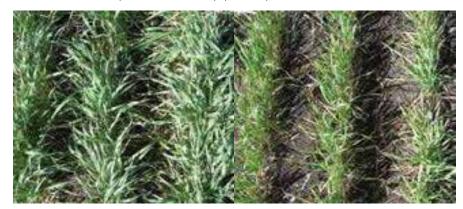


Providing soil moisture has not been limited or the crop has not been subject to waterlogging over winter, crop appearance at GS30–31 gives a reasonable indication of nitrogen reserves and the justification for nitrogen application at this stage.

SOUTHERN

JANUARY 2018

However, it is difficult to use visual appearance unless you have a benchmark. This has led to the concept of the N rich strip (Photo 3).  $^{20}$ 



**Photo 3:** A large difference in visual appearance: N-rich strip (110 kg N/ha at seeding) viewed at GS31, in trials planted on low soil N reserve (25 kg N/ha 0–90 cm). 443 tiller/m² under N-rich treatment (left) and 266 tillers/m² untreated (right).

Source: GRDC

A useful guide that requires no sophisticated equipment is to apply an excess of nitrogen at sowing, for example 50 to 100 kg N/ha, to a small area of the paddock, approximately  $2 \, \text{m}$  by  $10 \, \text{m}$ .

During winter and spring by comparing crop vigour (tiller number) and greenness in these small N-rich areas with the rest of the crop, an indication of N supply can be obtained. The advantage of using the plant rather than depending totally on a soil test is that the plant is directly registering soil N supply rather than soil nitrogen reserve, which crop roots may not always be able to access.

This visual difference can be quantified by using crop sensors that measure the light reflectance from the crop canopy. By measuring the reflectance at the red and near-infrared wavelengths, it is possible to quantify canopy greenness using a number of vegetative indices, the most common of which is termed the Normalised Difference Vegetative Index (NDVI). This index gives an indication of both biomass present and the greenness of that biomass. This canopy sensing can be done remotely from aircraft/satellites or with a hand-held or vehicle-mounted sensor.

#### 10.3.4 Seeding rate and date

Achieving the correct plant population is fundamental if sufficient tillers are to be set. Seeding rates need to be adjusted for seed size and planting date; if this does not occur the first step in controlling the canopy is lost.

How many plants are targeted depends on:

- region—as a general guide, drier regions sustain lower plant populations than wetter environments
- sowing date—earlier sowings require lower plant populations compared to later sowings, as the tillering window is longer and more tillers are produced per plant

Overall, earlier planting provides greater opportunities to manipulate the crop canopy during the stem elongation period: the plant's development periods are extended along with the earlier tillering period.



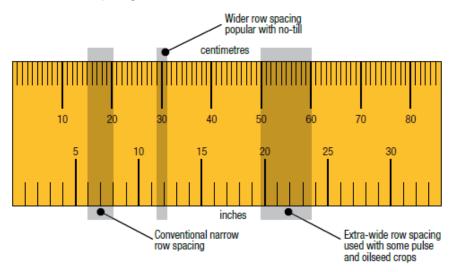
<sup>20</sup> GRDC (2009) Canopy management fact sheet, Grains and Research Development Corporation, <a href="https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf">https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf</a>

**TABLE OF CONTENTS** 



#### Row spacing

- Increased interest in no-till farming has created a trend for wider crop row spacing (Figure 4).
- In general, increasing row spacing up to 50 cm has minimal effect on cereal yield when yield potential is less than 2 tonnes per hectare.
- In higher rainfall areas, where cereal crops have higher potential yields, significant yield decreases have been recorded with wider row spacing (greater than 25 cm).
- The yields of broadleaf crops vary in their response to wider row spacing.
- $\bullet$  Precision agriculture allows for easier inter-row sowing and fertiliser applications at wider row spacing. <sup>21</sup>



**Figure 4:** Common row spacings in metric and imperial measurements.

Source: GRDC

#### Yield

- There are a number of reasons why growers might wish to pursue wider row spacing in cereals; for example, residue flow, inter-row weed and disease control. However, in all project trials (2007–10) on wheat covering a wide range of rainfall scenarios, increasing row width reduced yield.
- The yield reduction in wheat was particularly significant when row width exceeded 30 cm.
- Crop row spacing is an important factor for weed competition (Photo 4).
- At row widths of 30 cm, the reduction in wheat yield compared to narrower 20–22.5 cm row spacing was dependent on overall yield potential.
- At yields of 2–3 tonnes per hectare, the yield reduction was negligible.
- At yields of 5 tonnes per hectare, the yield reduction was between 5–7%, averaging about 6%.
- Data from a single site suggests that rotation position may influence the yield response in wider row spacing in wheat. In wheat, wheat-on-wheat suffered less yield reduction with wider rows than an equivalent trial at the same site which was in wheat after canola. <sup>22</sup>



<sup>21</sup> GRDC (2011) Crop placement and row spacing: southern region. Fact sheet. GRDC, <a href="https://grdc.com.au/Resources/Factsheets/2011/02/Crop-Placement-and-Row-Spacing-Southern-Fact-Sheet">https://grdc.com.au/Resources/Factsheets/2011/02/Crop-Placement-and-Row-Spacing-Southern-Fact-Sheet</a>

<sup>2</sup> N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC, http://www.grdc.com.au/CanopyManagementGuide



SOUTHERN

JANUARY 2018

**Photo 4:** Narrow row spacing (left) and wide row spacing (right). The higher the yield potential, the greater the negative impact of wider rows on crop yields.

Source: Weedsmart

#### Plant spacing

- Increasing row width decreases the plant-to-plant spacing within the row, leading
  to more competition within the row and reduced seedling establishment (for
  reasons that are not clearly understood).
- Increasing plant populations when using wider rows can be counterproductive with regard to yield, particularly where plant populations exceed 100 plants per square metre as a starting point.
- Limited data indicates that increasing seeding rates such that the average plantto-plant spacing in the row drops below 2.5 cm are either negative or neutral in terms of grain yield.
- Planting seed in a band (as opposed to a row) will increase plant-to-plant spacing, but may increase weed germination and moisture loss through greater soil disturbance.

#### Dry matter

- Wider row (30 cm and over) spacing reduced harvest dry matter relative to narrower rows (22.5 cm and under), with differences growing steadily (kilograms per hectare) from crop emergence to harvest, by which time differences were in the order of 1–3 t/ha depending on row width and growing season rainfall.
- The reduction in dry matter in wide rows was also significant at flowering (GS60–69), frequently 1 t/ha reduction when row spacing increased 10 cm or more over a 20 cm row spacing base. This could be important when considering harvesting for hay rather than grain.

#### **Grain quality**

- The most noticeable effect of row width on grain quality was on protein; wider rows reduced yield and increased grain protein.
- Differences in grain quality were typically small in terms of test weights and screenings, with very small benefits to wider rows over narrow rows on some occasions. <sup>25</sup>

#### Nitrogen management

Nitrogen management has not been found to interact with row spacing; optimum N regimes for narrow row spacing

(22.5 cm or less) can be the same as for wider row spacing (30 cm or more). The greater nitrogen efficiency observed with stem elongation applied nitrogen was more important with narrow row spacing since higher yields lead to a tendency for lower protein.  $^{26}$ 



<sup>23</sup> N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC, <a href="http://www.grdc.com.au/CanopyManagementGuide">http://www.grdc.com.au/CanopyManagementGuide</a>

<sup>24</sup> N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC, <a href="http://www.grdc.com.au/CanopyManagementGuide">http://www.grdc.com.au/CanopyManagementGuide</a>

 $<sup>25 \</sup>quad \text{N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC, } \underline{\text{http://www.grdc.com.au/CanopyManagementGuide}}$ 

 $<sup>26 \</sup>quad N \ Poole, \ J \ Hunt \ (2014) \ Advancing \ the \ management \ of \ crop \ canopies. \ GRDC, \ \underline{http://www.grdc.com.au/CanopyManagementGuide}$ 

**TABLE OF CONTENTS** 





Delaying N inputs from seeding to stem elongation (GS30–31) means they can be better matched to the season. In a dry spring, for example, no application may be warranted. In a spring with adequate rainfall to justify N application, project trials have shown stem elongation N to give yields equal or better than wheat crops grown with seeding N. However, applying N in advance of a rain front to ensure good incorporation has been found to be more important than exact growth stage. While GS31 should be the target growth stage for in-crop N application, the window can be expanded from GS25 to 31 in order to take advantage of rainfall. Even applications delayed until flag leaf can be successful where starting soil nitrogen is not too low (Figure 5).

Results from winter wheat cropping trials across Australia on the use of in-crop solid N at stem elongation show that where soil N reserves are low, N applied at stem elongation is not always the most appropriate strategy if yield is to be optimised.

Stem elongation N applications were found to be less appropriate with shorter season varieties and late sown crops. Drought conditions during the trial period (2006-08) has limited the results produced from trials. These trials assessed stem elongation N use in cereals grown on wider-row spacings: 300–350 mm compared to 175–200 mm. However, at the same seeding rate, moving to wider rows was found to reduce tillers per unit area and final ear population and yield, the latter by approximately 6% in the high rainfall zone. <sup>27</sup>

If high soil N reserve (over 100kg N/ha 0-60cm)

No N constraint on canopy at GS30 - 31

Advantage of applying tactical nitrogen as early growth driven by soil nitrogen reserves

Wet spring consider N application from pseudo stem erect up to booting GS30 - 45 dependent on crop status (colour) and rainfronts. For applications of nitrogen over 40-50kg N/ha consider splitting dose with 50-60% dose at GS30 -31 and a second dose at flag leaf dependent on rainfall during stem elongation.

TACTICAL N OK.

If moderate soil N reserve (50 -100kg N/ha 0-60cm)

Little constraint on canopy until GS30 - 31

Early growth driven by soil nitrogen reserves but need for N application during stem elongation unless crop water stressed and outlook dry

Use any timing in the window from GS30 - 32 to apply nitrogen based on reliable rainfall events. If no rainfall, consider delaying until flag leaf, if no rain by flag leaf stage, consider whether application is needed.

TACTICAL N OK.

If low soil N reserve (less than 50kg N/ha 0-60cm)

Constrained canopy

Better equipped where dry conditions more prevalent in the spring

Consider small applications of N at seeding 20-40kg N/ha then tactical N at stem elongation.

TACTICAL N OK.

If low soil N reserve (less than 50kg N/ha 0-60cm)

SOUTHERN

Constrained canopy

Wet spring conditions more probable (or irrigation), inadequate crop canopy to harness the potential of the season even with stem elongation nitrogen or high water holding capacity and no rain fronts for uptake.

Disadvantage in entire N applied as tactical N TACTICAL N NOT OK – CONSIDER UPFRONT N

SPLIT with GS30 - 31
Tactical N will be less successful where root disease is present. In these cases it may also not be appropriate.

Figure 5: Broad scenarios based on soil nitrogen level.

Source: GRDC

# 10.3.6 Limitations of tactical nitrogen application

The main limitation to tactical N application is the ability to reliably apply N before a rain event, to enable roots to access soluble N in the root-zone. Predicted rain fronts may pass without yielding anything; therefore, dependably applying N throughout the season is risky.

Foliar N application is gaining popularity; however, this is only suitable for relatively low rates of N addition. Where higher N input is required, an efficient system to apply N into the wet soil profile after a rainfall event needs to be devised.



<sup>27</sup> GRDC (2009) Canopy management fact sheet, Grains and Research Development Corporation, <a href="https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf">https://grdc.com.au/uploads/documents/GRDC\_CanopyManagement\_4pp.pdf</a>









# **MORE INFORMATION**

GRDC Fact Sheet: <u>Canopy</u> <u>management</u>

GRDC: Cereal growth stages guide

GRDC: <u>Advancing the management</u> of crop canopies

As technologies such as NDVI imaging and paddock management in zones become prevalent, the addition of N later in the crop cycle will become more relevant and will force the development of equipment to make such a system work.

**SOUTHERN** 

Based on sound trials and paddock experience, the aim of improving the economic outcome at the end of the season through manipulation of the most costly input is taking shape. Adoption of these techniques would be further aided by development of efficient, in-soil N-application equipment. <sup>28</sup>



<sup>28</sup> P McKenzie (2009) Canopy management in the northern grains region—the commercial view. Consultants Corner, Australian Grain, July 2009, <a href="https://www.nga.org.au/results-and-publications/download/31/australiangrain-articles/general-l/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-pdf">https://www.nga.org.au/results-and-publications/download/31/australiangrain-articles/general-l/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-pdf</a>









# Crop desiccation/spray out

SOUTHERN JANUARY 2018

Not applicable to this crop.







# **Harvest**

# Key messages

- Harvesting and storage management for triticale is generally similar to that for wheat. However, triticale for grain is a late-maturing crop, and is also more susceptible to sprouting conditions at harvest than wheat.
- Preferred harvest moisture to reduce damage due to heating caused by mould is 13% or less.<sup>1</sup>
- For best returns, aim to harvest crops at 12% moisture or less, produce grain with a minimum test weight of 65 kg/hl, and minimise other cereal grain contaminants.
- One of the drawbacks of triticale grown for grain is that it is prone to shattering.
- Harvester settings should be set similar to those for wheat, with care taken to slow the cylinder speed to minimise grain cracking and splitting.<sup>2</sup>
- Some varieties are difficult to thresh cleanly without either leaving intact
  head sections in the grain sample or causing grain cracking through tight
  concave settings. Conversely, some varieties are prone to shedding under
  windy conditions.

# 12.1 Harvesting issues

One of the drawbacks of triticale grown for grain is that it is prone to shattering (Photo 1). There is a spot about a quarter to a third of the way down from the tip on the rachis that is very weak.  $^3$ 



Photo 1: Shattered cereal grain.

Source: National Plant Germplasm System [USDA/ARS]

Triticale varieties vary strongly in thresh-ability. Some varieties are difficult to thresh cleanly without either leaving intact head sections in the grain sample or causing grain cracking through tight concave settings. Conversely, some varieties are prone to shedding under windy conditions.



SOUTHERN

M Mergoum and HG Macpherson (2004) Triticale improvement and production (No. 179). Food & Agriculture Org

Alberta Agriculture and forestry. (2016). Triticale crop production. http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571

<sup>3</sup> Alternative crops – Triticale in the US. <a href="http://pnw-ag.wsu.edu/AgHorizons/crops/csr2no1.htm">http://pnw-ag.wsu.edu/AgHorizons/crops/csr2no1.htm</a>



**TABLE OF CONTENTS** 



Most triticale varieties have inverted heads at maturity, which shed rain and therefore make the crop less liable to sprouting at maturity. This can be especially important in regions where storms can delay harvesting.

SOUTHERN

The level of carryover (hard seed) self-sown plants that occurs after a triticale crop appears to be higher than with other winter cereals. No data exists concerning any varietal differences in hard seed levels, but this will need careful management, especially where some seed shedding has occurred. <sup>4</sup>

Triticale grain generally matures later than wheat or rye and has a higher protein content, which makes it a good homegrown feed option. Care must be taken to ensure ergot levels are less than 0.1 %. Newer varieties have fewer ergot problems. Harvesting standing grain rather than windrowing first is advisable because triticale is more susceptible to sprouting in the windrow than wheat. <sup>5</sup>

# 12.2 Windrowing

Windrowing is a practice in high yielding crops to prevent excess shattering of grain. High yielding crops are not common in the Southern growing region except in unusual circumstances, therefore windrowing is not a common practice.

Windrowing or swathing involves cutting the crop and placing it in rows held together by interlaced straws, supported above the ground by the remaining stubble (Photo 2). It can be considered as an option where:

- the crop is uneven in maturity, or the climate does not allow for rapid drying of the grain naturally
- there is a risk of crop losses from shedding and lodging

High yielding crops may gain more from windrowing than low yielding crops. Generally, crops expected to yield less than 2 t/ha should not be windrowed. Picking up windrowed cereals is significantly slower than direct heading because of the large volume of material.

If the crop is too thin or the stubble too short to support the windrow above the ground, the crop should not be windrowed. Heads on the ground may sprout and attempts to pick up heads that are lying close to the soil surface will pick up soil. <sup>6</sup>



RS Jessop and M Fittler (2009) Triticale production Manual—an aid to improved triticale production and utilisation. <a href="http://www.apri.com.">http://www.apri.com.</a>
au/lA-102\_Final\_Research\_Report\_pdf

Albert Lea Seed. Triticale <a href="http://www.alseed.com/UserFiles/Documents/Product%20Info%20Sheets-PDF/Basics%20Triticale-2010.pdf">http://www.alseed.com/UserFiles/Documents/Product%20Info%20Sheets-PDF/Basics%20Triticale-2010.pdf</a>

<sup>6</sup> G Troup (2016) Oats: harvesting, swathing and grain storage, Swathing. DAFWA, <a href="https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1">https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1</a>

**TABLE OF CONTENTS** 

FEEDBACK



**Photo 2:** Directing chaff into a narrow windrow using a custom-made chute.

Source: GRDC

# **12.2.1 Timing**

Windrowing can begin when grain moisture content is below 35%—when grain is at the medium dough stage, hard but can still be dented with the thumbnail.

- It is better to windrow early to prevent losses from shedding and lodging, but not when the ground is wet after rain.
- Avoid windrowing too early as the grain is not fully developed and will result in small pinched grain.
- Although it may be easier to windrow later, the windrows of a ripe crop may not interlock well enough to withstand disturbance from strong wind.

# **12.2.2 Cutting**

- Cut across the sowing direction, or at 45 degrees for crops with wider row spacing, so the windrow sits-up on the stubble. Windrowing is not recommended for paddocks where the crop row spacing is over 25 cm.
- Avoid placing windrows in the same location each year so nutrients are not concentrated in one place.
- Windrow size or width of cut should match header capacity. A double-up attachment to the windrower or placing two windrows side by side requires a larger capacity header and concentrates the residue in a narrow band within the paddock.
- Cutting height should be adjusted to keep sufficient straw on the head to hold the windrow together (minimum 30 cm) and sufficient stubble height to support the windrow.
- Start the cutting height at 10–20 cm above the ground (one-third crop height)
  and adjust to produce an even windrow with well-interlaced straws that sit above
  the ground. This allows good air circulation and rapid drying should rain occur. 8



<sup>7</sup> G Troup (2016) Oats: harvesting, swathing and grain storage, Swathing. DAFWA, <a href="https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1">https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1</a>

G Troup (2016) Oats: harvesting, swathing and grain storage, Swathing. DAFWA, <a href="https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1">https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1</a>









Setting up at harvest for narrow windrow burning

# 12.2.3 Harvesting the windrow

Harvesting of the windrowed crop must be completed as soon as possible, ideally within 10 days of windrowing.

SOUTHERN

- If left too long and subjected to long periods of wetting (more than 25 mm of rain over 4–8 days), grain may sprout and become stained. The windrow may also become contaminated with bronze field beetle.
- When the windrow is picked up, the reel should be rotating slightly faster than ground speed, but not fast enough to knock the heads off the stems.
- The conveyor canvas should be revolving sufficiently fast to prevent the crop material banking up.
- Rows pick up best when the header follows the direction of the windrow (heads first).

One of the major sources of contamination in windrowed cereals is the stubble being torn out during the windrowing operation. This generally occurs when the windrower is operated at too high a ground speed or when trying to windrow when the straw is tough due to it being cool or damp. <sup>9</sup>

# 12.3 Harvest timing

Harvesting and storage management for triticale is generally similar to that for wheat. However, triticale for grain is a late-maturing crop, and is also more susceptible to sprouting conditions at harvest than wheat.

In dryland conditions, direct heading triticale is recommended where conditions allow. This is because direct heading can help reduce losses from pre-harvest sprouting, which triticale is much more susceptible to than is wheat.

Harvesting at 13% grain moisture is considered dry for triticale (Photo 3). In Australia, is it recommended that triticale be stored at 10% moisture content.



Photo 3: Harvesting of triticale grain with dry moisture content.

Source: <u>Capital press</u>

Moisture content lower than 13% is very desirable, as most moulds and insects tend to be inactive below this moisture level.



<sup>9</sup> G Troup (2016) Oats: harvesting, swathing and grain storage, Swathing. DAFWA, <a href="https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1">https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1</a>







For best returns, aim to harvest crops at 12% moisture or less, produce grain with a minimum test weight of 65 kg/hl, and minimise other cereal grain contaminants.

SOUTHERN
JANUARY 2018

Kernels with moisture content up to 20% can be harvested, and (if properly dried) will not lose quality. If drying triticale grain, maximum desirable temperatures are:

- 40°C for seed
- 65°C for commercial grain

Optimum harvest stage for forage is when the plant is at the flag leaf or boot stage before head emergence. Protein content at this stage will vary between 14–19%. Generally, forage yields and palatability will be higher than for either wheat or rye. <sup>10</sup>

One study found that triticale dry matter yield was higher and more nutritious when harvest was shifted from early heading to milk dough stage. <sup>11</sup>

For more information on storing triticale, see Section 13: Storage.

In high fertility situations, lodging can occur. Under such conditions, plan to harvest early.  $^{\rm 12}$ 

# 12.3.1 Lodging

Lodging occurs when portions of the crop 'fall over' due to strong wind, and occasionally in very high yielding crops and/or varieties with weak stems.

The lodged plants will then begin to deteriorate in nutritive value, and the grain may even begin to sprout if advanced enough in its formation (hard dough stage).

If possible, harvest the crop within days before its nutritive value deteriorates too much and mould and deleterious bacteria build-up occurs. Travelling in the opposite direction to the lodged plants will allow crop to better feed into harvester front, ensuring less difficulty in the harvest operation and minimal losses. <sup>13</sup>

# 12.3.2 Harvesting triticale for silage

The cutting and subsequent storage of triticale forage for silage is similar to that of any small-cereal forage. The harvest date of triticale for silage is very important. As plants develop beyond the boot stage and into early grain fill, the protein and energy levels drops while the fibre level rapidly increases. Although there is a general increase in dry-matter yield as the crop matures, the increased yield is more often offset by the reduction in forage quality. Consequently, the best time to cut triticale for silage is in the boot to early-heading stage. <sup>14</sup>

Timing of harvest should consider the following:

- end use of the silage; i.e. for animal production vs. maintenance rations
- · weather conditions at harvest
- soil types and soil moisture conditions at harvest
- $\bullet \hspace{0.5cm}$  if spring sowing, when the follow-up pasture is to be sown
- if double cropping, when the follow-up crop needs to be sown
- · availability of suitable harvesting machinery
- · effect on dry matter yield

Cereals can be harvested at two stages:

- 1. flag leaf/boot: early ear emergence stages
- soft dough stage



<sup>10</sup> Alberta Agriculture and forestry. (2016). Triticale crop production. http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571

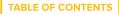
<sup>11</sup> CM McGoverin, F Snyders, N Muller, W Botes, G Fox and M Manley (2011) A review of triticale uses and the effect of growth environment on grain quality. Journal of the Science of Food and Agriculture, 91(7), 1155–1165.

 $<sup>12 \</sup>qquad \text{Albert Lea Seed. Triticale } \underline{\text{http://www.alseed.com/UserFiles/Documents/Product\%20Info\%20Sheets-PDF/Basics\%20Triticale-2010.pdf} \\$ 

<sup>13</sup> Agriculture Victoria (2008) Harvesting Forage Cereals, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/harvesting-forage-cereals">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/harvesting-forage-cereals</a>

M Mergoum and HG Macpherson (2004) Triticale improvement and production (No. 179). Food & Agriculture Org.









When to cut forage cereals

Triticale for silage

Triticale is particularly well adapted for high-forage yield production on heavily manured fields. Harvesting protocols and timing must be adjusted to accommodate the differences between triticale and barley in these situations. In high productivity systems where lodging is a problem, triticale should be compared to semi-dwarf barley, which also has special adaptation to high fertility conditions.

SOUTHERN

JANUARY 2018

When using triticale for silage, it has been recommended that the optimum time for harvest was at the soft dough stage in order to best balance potential quality and yield.  $^{15}$ 

# 12.4 Harvest equipment

Harvester settings should be set similar to those for wheat, with care taken to slow the cylinder speed to minimise grain cracking and splitting (Photo 4).  $^{16}$ 

Seed size can be of concern when harvesting triticale. Triticale varieties generally have a large seed, and a large embryo with an elongated beak, compared to bread wheat. Caution must be taken to ensure that any mechanical harvesters, such as modern harvesters, are appropriately set so there is no damage to the embryo. Embryo damage and seed cracking can have a significant impact on seed viability during storage. This can be a problem, since many triticale varieties are hard to thresh compared to wheat and rye.

In triticale without the wheat rachis, threshing frequently results in incomplete seed and chaff removal from the spike, and breakage may occur at the rachis nodes. In the wheat rachis types, breakage does not occur. Improvements in threshing will be an excellent improvement where mechanical threshing equipment is not readily available or economically feasible. <sup>17</sup>

Harvest triticale as you would wheat. The harvester speed should be slightly slower than for harvesting wheat. It is possible to windrow triticale before harvesting, but it is likely to begin sprouting in the windrow, so growers are advised to direct-harvest/head if possible. <sup>18</sup>



Photo 4: Triticale being harvested.

Source: Kaspar T in MCCC



 $<sup>15 \</sup>qquad \text{Alberta agriculture and forestry. (2016). Triticale for Silage.} \\ \underline{\text{www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10569}}$ 

<sup>16</sup> Alberta Agriculture and forestry. (2016). Triticale crop production. http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/fcd10571

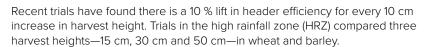
<sup>7</sup> M Mergoum and GH Macpherson (2004) Triticale improvement and production (No. 179). Food & Agriculture Org.

<sup>18</sup> UVM. Triticale. Northern grain growers. <a href="http://northerngraingrowers.org/wp-content/uploads/TRITICALE.pdf">http://northerngraingrowers.org/wp-content/uploads/TRITICALE.pdf</a>



**TABLE OF CONTENTS** 





Harvesting low will reduce stubble loads to manageable levels, and is achieved by baling or burning the windrows, or simply spreading trash and straw as evenly as possible across the header windrow.

Harvesting low and treating weed seeds also has the potential to reduce the soil weed seedbank over time, which can assist with weed control and herbicide resistance management.

The work in 2014 has shown how much slower harvesting is at a 15 cm height, and the additional fuel consumption required. When increasing the height to 50 cm, it was found that harvesting was around 25% faster than at 30 cm. A rule of thumb is a 10% efficiency increase for every 10 cm of harvest height. If a 100 ha crop is harvested at 15 cm it will take about 20% more time to harvest than a crop cut at 30 cm, or 38% more time than if it had been harvested at 50 cm. <sup>19</sup>

Ensure that all equipment is clean and free from potential contaminants to the harvested grain.

# 12.5 Fire prevention

Grain growers must take precautions during the harvest season, as operating machinery in extreme fire conditions is dangerous. They should take all possible measures to minimise the risk of fire. Fires are regularly experienced during harvest in stubble as well as standing crops. The main cause is hot machinery harvesting with combustible material. This is exacerbated on hot, dry, windy days. Seasonal conditions can also contribute to lower moisture content in grain and therefore a greater risk of fires.

# 12.5.1 Harvester fire reduction checklist

- Recognise the big four factors that contribute to fires: relative humidity, ambient temperature, wind, and crop type and conditions. Stop harvest when the danger is extreme.
- Focus on service, maintenance and machine hygiene at harvest on the days more hazardous for fire. Follow systematic preparation and prevention procedures.
- Use every means possible to avoid the accumulation of flammable material
  on the manifold, turbocharger or the exhaust system. Be aware of side and
  tailwinds that can disrupt the radiator fan airblast that normally keeps the
  exhaust area clean.
- 4. Be on the lookout for places where chaffing can occur, such as fuel lines, battery cables, wiring looms, tyres and drive belts.
- Avoid overloading electrical circuits. Do not replace a blown fuse with a higher amperage fuse. It is your only protection against wiring damage from shorts and overloading.
- Periodically check bearings around the harvester front and the machine.
   Use a hand-held digital heat-measuring gun for temperature diagnostics on bearings and brakes.
- Maintain fire extinguishers on the harvester and consider adding a water-type
  extinguisher for residue fires. Keep a well-maintained firefighting unit close-by to
  the harvesting operation ready to respond.
- 8. Static will not start a fire but may contribute to dust accumulation. Drag chains or cables may help dissipate electrical charge but are not universally successful



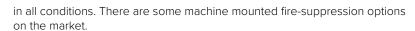
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<sup>9</sup> A Lawson (2015) Ground Cover Issue 118: Header efficiency increases with harvest height. <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Scaue-118-Sep-Oct-2015/Header-efficiency-increases-with-harvest-height">https://grdc.com.au/Media-Centre/Ground-Cover/Scaue-118-Sep-Oct-2015/Header-efficiency-increases-with-harvest-height</a>



**TABLE OF CONTENTS** 





- If fitted, use the battery isolation switch when the harvester is parked. Use vermin deterrents in the cab and elsewhere, as vermin chew some types of electrical insulation.
- 10. Observe the Grassland Fire Danger Index (GFDI) protocol on high fire risk days.
- 11. Maintain two-way or mobile phone contact with base and others, and establish a plan with the harvest team to respond to a fire if one occurs. <sup>20</sup>

#### Using machinery

To preventing machinery fires, it is imperative that all headers, chaser bins, tractors and augers be regularly cleaned and maintained. All machinery and vehicles must have an effective spark arrester fitted to the exhaust system. To prevent overheating of tractors, motorcycles, off-road vehicles and other mechanical equipment, all machinery needs to be properly serviced and maintained. Firefighting equipment must be available and maintained—it is not just common sense, it is a legal requirement.

Take great care when using this equipment outdoors:

- Be extremely careful when using cutters and welders to repair plant equipment.
   This includes angle grinders, welders and cutting equipment.
- Ensure machinery components, including brakes and bearings, do not overheat. These components can drop hot metal onto the ground and start a fire.

Use machinery correctly, as incorrect usage can cause it to overheat and ignite.

Be aware that when blades of slashers, mowers and similar equipment hit rocks or metal, they can cause sparks to ignite dry grass.

Avoid using machinery during inappropriate weather conditions of high temperatures, low humidity and high wind.

Do repairs and maintenance in a hazard-free, clean working area, such as on bare ground, on concrete, or in a workshop, rather than in the field.

Keep machinery clean and as free from fine debris as possible, as this can reduce onboard ignitions.  $^{\rm 21}$ 

#### Harvester fire research

With research showing an average of 12 harvesters burnt to the ground every year in Australia (Photo 5), agricultural engineers encourage care in keeping headers clean to reduce the potential for crop and machinery losses.

#### Key points

- Most harvester fires start in the engine or engine bay.
- Other fires are caused by failed bearings, brakes and electricals, and rock strikes. <sup>22</sup>



<sup>0</sup> R Barr (2015) Plant of attack needed for harvester fires. <a href="https://grdc.com.au/Media-Centre/Media-News/South/2015/10/Plan-of-attack-needed-for-harvester-fires">https://grdc.com.au/Media-Centre/Media-News/South/2015/10/Plan-of-attack-needed-for-harvester-fires</a>

<sup>21</sup> NSW Rural fire Service. Farm firewise. NSW Government, http://www.rfs.nsw.gov.au/dsp\_content.cfm?cat\_id=1161

<sup>22</sup> GRDC (2012) A few steps to preventing header fires. GRDC Ground Cover Issue 101, <a href="http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-101/A-few-steps-to-preventing-header-fires">http://www.grdc.com.au/Media-Centre/Ground-Cover-Issue-101/A-few-steps-to-preventing-header-fires</a>



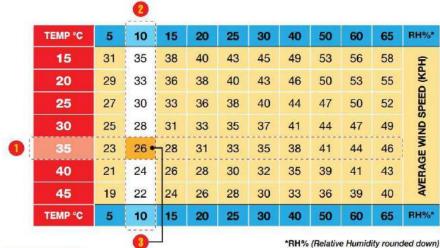
**Photo 5:** GRDC figures show that there are 1000 harvester fires in Australia each year.

Source: Weekly Times

# 12.5.2 Harvesting in low-risk conditions

Growers can use the Grassland Fire Danger Index (GFDI) to assess the wind speed at which harvest must cease (a GFDI of 35), depending on the temperature and relative humidity (Figure 1).

- Step 1: Read the temperature on the left-hand side.
- Step 2: Move across to the relative humidity.
- Step 3: Read the wind speed at the intersection. In the worked example, the temperature is 35°C and the relative humidity is 10 % so the wind speed limit is 26kph.



\*RH% (Relative Humidity rounded down)

\*Wind speed averaged over 10 minutes

**SOUTHERN** 

JANUARY 2018

Figure 1: Grassland Fire Danger Index guide.

Source: CFS South Australia



GRDC podcasts: Harvester Fires

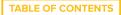


GRDC Reducing harvester fire risk:
The Back Pocket Guide

An investigation into harvester fires

<u>Plan of attack needed for harvester</u> <u>fires</u>









# **MORE INFORMATION**

<u>Grain Trade Australia—Cereal Rye</u> <u>and Triticale trading standards</u> 2016/2017

Grain Trade Australia, <u>Cereal rye and</u>
<u>Triticale trading standards 2016/2017</u>

# 12.6 Receival standards

Stay up to date with the Grain Trade Australia (GTA) national grain receival standards. The GTA Trading Standards are a critical tool for anyone purchasing, selling, trading, broking or operating in the commercial grain industry. The GTA Trading Standards cover all grains, oilseeds, pulses and other related commodities.

**SOUTHERN** 

JANUARY 2018

For triticale, there is no minimum variety specification, and a load may be delivered with a varietal mix at any level.

Any variety is eligible for delivery into the triticale grade.

Table 1: Triticale receival standards.

These receival standards are current as at 1/09/2016	TRI1
Infratec	
Protein	No Limit
Moisture content (maximum)	13
½ litre (weight)	
Weight (minimum kg/hl)	65
Weight (minimum grams)	325
½ litre (count)	
Type 1 seeds (maximum)	
Doublegees	1
Lupins	1
Saffron thistle	1
Variegated thistle	1
Field peas	1
Safflower	1
Sunflower	1
Sappy green grains/Sappy green material (maximum)	10
Storage mould/ bin burnt /heat-damaged grains (maximum)	1
Type 2 seeds (maximum)	
Barley, oats, drake seed, black/ brown or wild oats, radish pods, etc.	50
Field insects (maximum) Whole bodies, live or dead: grasshoppers, ladybirds, woodbugs, pea weevils, native weevils, bronzed field beetles and army worms.	15 of each
Whole Snail Shells (maximum) Live or dead, fragments acceptable.	1
Sprouted (maximum)	10
1 Level BPM	
Speargrass (maximum)	5
Type 3 Seeds (maximum) Wheat and cereal rye	10
% by Weight	
Screenings/Unthreshed Heads harvested (maximum)	6
½ Litre after Screening	
Ryegrass ergot (maximum)	5 cm
Dead grain insects (maximum)	10
Source: GIWA	

Source: GIWA





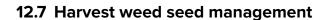






IWM manual section on harvest weed management

IWM manual section on narrow windrow burning



Controlling weeds after harvest may be more difficult in southern regions as there can be several months of good growing conditions for weeds.

In the southern cropping region's high rainfall zone (HRZ), an important question needs to be answered: how can harvest weed seed practices be adopted to reduce soil weed seed banks to address herbicide resistance? And more specifically, how can growers get weed seeds into the header?

Southern Farming Systems (SFS) is answering these questions through its Grains Research and Development Corporation-funded HRZ harvest weed seed control (HWSC) project. Paddock-scale trials will demonstrate to growers the suitability and effectiveness of a number of HWSC measures, using commercial equipment to highlight the potential of these management practices to complement large scale trials.

Trial plots have been established at SFS's Lake Bolac site in western Victoria, and in Tasmania.  $^{\rm 23}$ 

Trials in both south-eastern and western Australian grain-growing regions have found a 55-58% reduction, overall, in the emergence of annual ryegrass across the three main harvest weed-seed control (HWSC) systems being practised by growers. <sup>24</sup>

# 12.7.1 Harvest weed seed control strategies

Weed seed capture and control at harvest can assist other tactics to put the weed seed bank into decline. Up to 95% of annual ryegrass seeds that enter the harvester exit in the chaff fraction. If it can be captured, it can be destroyed or removed.

Western Australian farmers and researchers have developed several systems to effectively reduce the return of annual ryegrass and wild radish seed into the seedbank, and help put weed populations into decline.

A key strategy for all harvest weed seed control operations is to maximise the percentage of weed seeds that enter the header. This means harvesting as early as possible before weed seed is shed, and harvesting as low as is practical; e.g. 'beer can height.'

#### Narrow windrow burning

During traditional whole paddock stubble burning, the very high temperatures needed for weed seed destruction are not sustained for long enough to kill most weed seeds. By concentrating harvest residues and weed seed into a narrow windrow, fuel load is increased and the period of high temperatures extends to several minutes, improving the kill of weed seeds.

#### Windrow burning for weed control—WA fad or a viable option for the east?

- Continued reliance on herbicides alone is not sustainable in our continuous cropping systems. Rotating herbicides alone will not prevent the development of resistance.
- Early implementation of windrow burning will prolong the usefulness of herbicides, not replace them.
- Windrow burning is the cheapest non-chemical technique for managing weed seeds present at harvest.
- Windrow burning is an effective weed management strategy, even in the absence of resistance.



S Watt (2016) Weed seed project aims to keep growers out of the woods. <a href="https://grdc.com.au/Media-Centre/Media-News/South/2016/03/Weed-seed-project-aims-to-keep-growers-out-of-the-woods">https://grdc.com.au/Media-Centre/Media-News/South/2016/03/Weed-seed-project-aims-to-keep-growers-out-of-the-woods</a>

<sup>24</sup> S Clarry (2015) Trials measure harvest weed-seed control. <a href="https://qrdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-115-MarApr-2015/Trials-measure-harvest-weed-seed-control">https://qrdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-115-MarApr-2015/Trials-measure-harvest-weed-seed-control</a>



**TABLE OF CONTENTS** 

FEEDBACK



# **MORE INFORMATION**

Windrow burning for weed control— WA fad or a viable option for the east?

IWM manual section on chaff carts

IWM manual section on bale direct systems

 Growers need to begin experimenting now on small areas to gain the experience needed to successfully implement the strategy.

Narrow windrow burning is extremely effective—destroying up to 99% of annual ryegrass and wild radish seeds—but it must be done properly. For ryegrass, a temperature of 400°C for at least 10 second is needed to destroy the seeds' viability. For wild radish, the temperature needs to be 500°C for at least 10 seconds. <sup>26</sup>

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JANUARY 2018

#### **Chaff Carts**

Chaff carts are towed behind headers during harvest to collect the chaff fraction (Photo 6). Collected piles of chaff are then either burnt the following autumn or used as a source of stock feed.



Photo 6: Chaff cart in action.

Photo: A. Storrie

Chaff carts will collect and remove up to  $85\,\%$  of annual ryegrass and wild radish seeds that pass through a header. Collected chaff must be managed to ensure the seeds are then removed from the cropping system. This can be done by burning in the following autumn or by removing the chaff from the paddock and using it as a livestock feed.  $^{27}$ 

#### Bale direct systems

The bale direct system uses a baler attached to the harvester to collect all chaff and straw material. This system requires a large baler to be attached to the back of the harvester. As well as removing weed seeds, the baled material has an economic value as a livestock feed source. (See <a href="http://www.glenvar.com/">http://www.glenvar.com/</a> for the story and development of header-towed bailing systems).

#### **Harrington Seed Destructor**

The integrated Harrington Seed Destructor (iHSD) is the invention of Ray Harrington, a progressive farmer from Darkan, WA (Photo 7). Developed as a trail behind unit, the iHSD system comprises a chaff processing cage mill, and chaff and straw delivery systems. The retention of all harvest residues in the field reduces the loss and/or banding of nutrients and maintains all organic matter to protect the soil from wind and



<sup>25</sup> M Street, G Shepherd (2013) Windrow burning for weed control—WA fad or a viable option for the east? <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Windrow-burning-for-weed-control-WA-fad-or-viable-option-for-the-east">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Windrow-burning-for-weed-control-WA-fad-or-viable-option-for-the-east</a>

<sup>26</sup> S Clarry (2015) Trials measure harvest weed-seed control. <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-115-MarApr-2015/Trials-measure-harvest-weed-seed-control">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-115-MarApr-2015/Trials-measure-harvest-weed-seed-control</a>

<sup>27</sup> S Clarry (2015) Trials measure harvest weed-seed control. <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-115-MarApr-2015/Trials-measure-harvest-weed-seed-control">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-115-MarApr-2015/Trials-measure-harvest-weed-seed-control</a>









# **MORE INFORMATION**

<u>IWM manual section on Harrington</u> seed destructor

Section on the Harrington Seed Destructor in GRDC's <u>Tactics for</u> <u>managing weed populations</u>

<u>Chaff deck concentrates weeds in</u> <u>controlled traffic</u>



WATCH: <u>Harvest weed seed control</u> for the high rainfall zone.



WATCH: <u>Harvest – the time to get on top of resistant weeds.</u>

University of Adelaide
weed management expert
Dr Chris Prepare alls on
growers to order about
pre-emerge
harvest-time control options,
to cope with growing
herbicide resistance issues.

WATCH: <u>A beginner's guide to harvest</u> weed seed control.



water erosion, as well as reducing evaporation loss when compared with windrow burning, chaff carts and baling.  $^{28}$ 

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The HSD, which renders seeds non-viable by collecting and impacting the chaff as it exits the harvester, can be 92–99% effective, depending on seed species. <sup>29</sup>



Photo 7: Harrington Seed Destructor at work.

Source: GRDC

The chaff deck places the chaff exiting the sieves of the harvester on to permanent wheel tracks. Growers using chaff decks have observed that few weeds germinate from the chaff fraction and believe that many weed seeds rot in it. A permanent tramline farming system is necessary to be able to implement the chaff deck system. <sup>30</sup>



<sup>28</sup> GRDC Integrated weed management hub. Section 6: Managing weeds at harvest, <a href="https://grdc.com.au/Resources/iWMhub/Section-6-Wanaging-weeds-at-harvest">https://grdc.com.au/Resources/iWMhub/Section-6-Wanaging-weeds-at-harvest</a>

<sup>29</sup> S Clarry (2015) Trials measure harvest weed-seed control, <a href="https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-115-MarApr-2015/Trials-measure-harvest-weed-seed-control">https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-115-MarApr-2015/Trials-measure-harvest-weed-seed-control</a>

<sup>30</sup> Roberts P. (2014). New systems broaden harvest weed control options. GRDC. <a href="https://grdc.com.au/Media-Centre/Media-News/West/2014/11/New-systems-broaden-harvest-weed-control-options">https://grdc.com.au/Media-Centre/Media-News/West/2014/11/New-systems-broaden-harvest-weed-control-options</a>

**TABLE OF CONTENTS** 



# **Storage**

# Key messages

- Long-term on-farm storage of triticale will be a problem unless the storage facility is sealed silos.
- Triticale grain is softer than wheat and barley grain. Soft grain is more prone to attack from weevils and other grain storage insects.
- Maintain grain at low (<10%) moisture content to minimise insect infestation.
- Fumigation prior to storage in sealed silos effectively reduces the risk of insect damage when storing triticale.<sup>1</sup>
- Storing grain at levels less than 12% moisture content does not eliminate the need for treating it with insecticide, however it does avoid spoilage from mould and fungus growth.
- It is recommended to use a protectant when storing triticale post-harvest.
   Aeration is recommended when storing triticale.

Drying and storing triticale is similar to the process for wheat or rye. However, more care must be taken, especially for long-term storage, since triticale is extremely sensitive to grain insect infestations, far more so than wheat, and even more so than barley (Photo 1).  $^{2}$ 



Photo 1: Rust-red flour beetle on cereal grain.

Source: DAFWA.

Triticale has a very soft-textured kernel and is subject to damage from insect infestations during storage. It should be stored in a dry, well-ventilated area to reduce potential damage from moisture. Preferred harvest moisture to reduce damage due to heating caused by moulding is 12% or less. <sup>3</sup>

Triticale should be less than 12% moisture when stored, but the lower the moisture content (MC) the better. Storing grain at less than 12% does not eliminate the need



M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-v5553e/v5553e00.pdf">http://www.fao.org/3/a-v5553e/v5553e00.pdf</a>

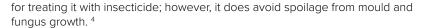
<sup>2</sup> DAFWA (2016) Insect pests of stored grain. DAFWA, <a href="https://www.agric.wa.gov.au/pest-insects/insect-pests-stored-grain">https://www.agric.wa.gov.au/pest-insects/insect-pests-stored-grain</a>

<sup>3</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/v5553e00.pdf">http://www.fao.org/3/a-y5553e/v5553e00.pdf</a>









It is recommended to use a protectant and to use aeration when storing triticale after harvest. <sup>5</sup> When storing, it is critical to pay attention to:

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- · truck, auger, silo or storage bin hygiene
- grain temperature
- grain moisture content
- grain insecticide treatment
- · regular monitoring.

Seek professional advice about storing triticale to reduce the risk of insect infestation and, subsequently, significant grain losses.

Newer varieties generally have harder seeds but they still require careful protection during storage. A maximum MC of 12% for triticale in grain storage combined with aeration cooling is one way to reduce insect problems. Chemical protectants are also usually needed when storing triticale. <sup>6</sup>

Triticale may also develop fungi. Some triticales show high levels of enzymatic activity, even in the absence of visual sprouting or spike wetting. In sprouted grain, this may promote fungal development during storage, or may have deleterious effects on the food-processing characteristics of grain. <sup>7</sup>

#### **GRDC Stored grain information hub**

Following the work already done through the Grain Storage Extension Project, the GRDC have funded another three years allowing grain storage extension to continue through to 2018.

The project aims to provide a stored grain information hub and equip growers with the skills and knowledge to enable best management practices of on-farm grain storage. Some exciting new resources to keep an eye out for under the new project will be an eLearning Manual, a smart phone App and an extension community of practice.

For more information on the grain storage extension project or to arrange a workshop in your area contact a member of the team.

- National Hotline 1800 weevil (1800 933 845)
- Southern NSW, VIC, SA and TAS, Peter Botta <u>pbotta@bigpond.com</u>
- QLD and northern NSW, Philip Burrill <a href="mailto:philip.burrill@daff.qld.gov.au">philip.burrill@daff.qld.gov.au</a>
- WA, Ben White <u>ben@storedgrain.com.au</u>
- Project coordinator Chris Warrick info@storedgrain.com.au

# 13.1 How to store product on-farm

Growers in the southern region are investing in on-farm storage for a range of reasons. In the eastern states, on-farm storage gives growers options for selling into domestic and export markets, while in South Australia, where the majority of grain goes to bulk handlers, growers tend to set up storage to improve harvest management.



Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102">http://www.porkcrc.com.au/1A-102</a> Triticale Guide Final Fact Sheets.pdf



Stored grain information hub



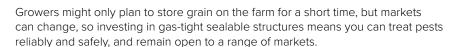
<sup>6</sup> RS Jessop, M Fittler (2009) Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler. Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/lA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/lA-102\_Final\_Research\_Report\_pdf</a>

M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="https://www.fao.org/3/a-v5553e/y5553e00.pdf">https://www.fao.org/3/a-v5553e/y5553e00.pdf</a>



**TABLE OF CONTENTS** 





Growers should approach storage as they would when purchasing machinery. Farmers spend a lot of time researching a header purchase to make sure it is fit for purpose; in the same way, because grain storage can also be a significant investment, and even a permanent one, it pays to do thorough research and develop a storage plan that adds value to your enterprise into the future.

Decide what you want to achieve with storage, critique existing infrastructure and be prepared for future changes. A good storage plan can remove a lot of stress at harvest-growers need a system that works so they capture a better return in their system. <sup>8</sup>

Agronomist's view

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JANUARY 2018

# 13.1.1 On-farm storage in Tasmania

- On-farm storage is becoming a popular option that helps growers manage risk on the farm.
- Tasmania has limited storage capacity compared to the mainland. Development
  in central storage will occur in Tasmania as the industry grows (although
  the industry needs to be careful that both producers and consumers don't
  build storage).
- Understand the capital cost, along with the further costs such as interest, hygiene, in/out loading, and opportunity costs.
- Work out what is the best fit for your business, Check that it aligns with your farming strategies and overall farm plan.

On-farm grain storage represents a significant investment. Many farms have older storage facilities that cannot be sealed for grain fumigation, but replacing these facilities with sealable silos may not be economically viable. In this case, a mixed-storage strategy could be the solution. The strategy is to purchase a small number of sealable silos and to use them to batch fumigate grain prior to sale.

There are several reason why growers might consider storing grain on the farm including:

- improving harvest logistics
- taking advantage of higher grain prices some time after harvest
- supplying a local market (e.g. feedlot, dairy)
- avoiding high freight costs at peak time
- adding value by cleaning, drying or blending grain
- retaining planting seed

In most cases, for on-farm storage to be economical it will need to deliver on more than one of these benefits. There are advantages and disadvantages with each of the four main storage systems: sealed silos, unsealed silos, storage bags, and storage sheds (Table 1). Under very favourable circumstances, grain-storage facilities can pay for themselves within a few years, but it is also possible for an investment in on-farm storage to be unprofitable. A grain storage cost—benefit <u>analysis template</u> is very useful tool in the decision-making process to test the viability of grain storage on your farm. <sup>10</sup>



<sup>8</sup> GRDC (2015) Extension tailored for regional challenges. Ground Cover. No. 119. GRDC, <a href="https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-119--Grain-storage/Extension-tailored-for-regional-challenges">https://grdc.com.au/Media-Centre/Ground-Cover-Issue-119--Grain-storage/Extension-tailored-for-regional-challenges</a>

<sup>9</sup> Stevens L. (2016). The grain industry in Tasmania harvest logistics. <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/08/The-grain-industry-in-Tasmania-harvest-logistics">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/08/The-grain-industry-in-Tasmania-harvest-logistics</a>

<sup>0</sup> GRDC (2015) Grain storage strategies in the northern region. GRDC, <a href="https://grdc.com.au/Media-Centre/Hot-Topics/Grain-storage-strategies-in-the-northern-region">https://grdc.com.au/Media-Centre/Hot-Topics/Grain-storage-strategies-in-the-northern-region</a>

TABLE OF CONTENTS



**Table 1:** Advantages and disadvantages of grain storage options.

Storage type	Advantages	Disadvantages
Gas-tight, sealable silo	Gas-tight, sealable status allows phosphine and controlled atmospheres to control insects Easily aerated with fans	Requires foundation to be constructed
		Relatively high initial investment required
	Fabricated on-site, or off-site and transported	Seals must be maintained regularly
	Capacity from 15 t to 3,000 t	Access requires safety equipment and infrastructure Requires and annual test to check gas-tight sealing
	25 years or more of service life	
	Simple in-loading and out-loading	
	Easily administered hygiene (cone-based silos particularly)	
	Can be used multiple times in a season	
Unsealed silo	,	Requires foundation to be constructed
	7–10% cheaper than sealed silos Capacity from 15 t to 3,000 t	Silo cannot be used for fumigation
	Up to 25 year service life  Can be used multiple times in a season	Insect control limited to protectants in eastern states and Dryacide® in WA
		Access requires safety equipment and infrastructure
Grain- storage bags	Low initial cost  Can be laid on a prepared pad in the paddock  Provide harvest logistics support  Can provide segregation options  Are ground operated	Requires purchase or lease of loader and unloader
		Increased risk of damage to grain beyond short-term storage (typically three months)
		Limited insect control options, with fumigation possible only under specific protocols
		Requires regular inspection and maintenance, which need to be budgeted for
		Aeration of grain bags currently limited to research trials only
		Must be fenced off
		Prone to attack by mice, birds, foxes, etc.
		Limited wet-weather access if stored in paddock
		Need to dispose of bag after use
		Single-use only











# **MORE INFORMATION**

Benefits flow from on-farm storage in the Mallee

<u>Cost–benefit analysis for grain</u> <u>storage</u>

Storage type	Advantages	Disadvantages
Grain- storage sheds	Can be used for dual purposes  30 years or more of service life	Aeration systems require specific design
	Low cost per stored tonne	Risk of contamination from dual purpose use
		Difficult to seal for fumigation
		Vermin control is difficult
		Limited insect control options without sealing
		Difficult to unload

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Source: Kondinin Group

# 13.1.2 Silos

As triticale is very prone to damage from insects during storage due to its soft kernel, the grain should be stored at less than 10% MC, preferably in sealed silos (Photo 2) to minimise insect attack. Treat the grain as it enters the silo and then check regularly (every 2–3 months) for reinfestation.



**Photo 2:** When using on-farm silos it is important to pressure test all silos, even those that are labelled as sealed.

Source: <u>GRDC</u>

Sealed silos offer a more permanent grain storage option than grain storage bags. Depending on the amount of storage required, they will have a higher initial capital cost than bags, and can be depreciated over a longer time frame than the machinery required for the grain bags. With a silo system, as stored tonnage increases, the capital cost of storage increases.

The potential advantages of using sealed grain silos as a method for grain storage include improved harvest management, reduced harvest stress, reduced harvest-freight requirements, minimal insecticide exposure for the grower and farm workers, and the opportunity to segregate and blend grain.











# **MORE INFORMATION**

Stored Grain Information Hub, Pressure testing sealable silos

GRDC, Silo buyer's guide



WATCH: GCTV2: Pressure testing sealed silos



The potential disadvantages include the initial capital outlay, the outlay required to meet occupational health and safety (OH&S) requirements, the additional on-farm handling required, and the additional site-maintenance requirements. <sup>11</sup>

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#### Pressure testing

- A silo sold as a sealed unit needs to be pressure tested to be sure it's gas-tight.
- It is strongly recommended that growers ask the manufacturer or reseller to
  quote the Standards Australia number AS2628 on the invoice as a means of
  legal reference to the quality of the silo being paid for.
- Pressure-test sealed silos upon erection, annually, and before fumigating by conducting a five-minute half-life pressure test.
- Maintenance is the key to ensuring a silo purchased as sealable can be sealed and gas-tight.

A silo is only truly sealed if it passes a five-minute half-life pressure test according to the Australian Standard AS2628. Often silos are sold as sealed but are not gas-tight—rendering them unsuitable for fumigation.

There is no compulsory manufacturing standard for sealed silos in Australia. Although a voluntary industry standard was adopted in 2010, it remains in the buyer's own interests to test silos before purchase. Watch this <u>GRDC Ground Cover TV</u> clip to find out more.

Even if a silo is sold as sealed it is not until it is proven to be gas-tight using a pressure test. The term 'sealed' has been used loosely in the past, and some silos may not have been gas-tight from the day they were constructed. However, even a silo that was gas-tight to the standard on construction will deteriorate over time, so it needs annual maintenance to remain gas-tight.

#### The importance of a gas-tight silo

The Kondinin Group's 2009 national agricultural survey revealed that 85% of respondents had used phosphine at least once during the previous five years, and of those, 37% had used phosphine every year. A Grains Research and Development Corporation survey during 2010 revealed that only 36% of growers using phosphine applied it correctly, i.e. in a gas-tight, sealed silo (Figure 1).

Research shows that fumigating in a storage that does not meet the industry standard does not achieve a high enough concentration of fumigant for a long enough period to kill pests at all life-cycle stages (Figure 2). For effective phosphine fumigation, a minimum gas concentration of 300 ppm for seven days, or 200 ppm for 10 days, is required. Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3 ppm close to the leaks. In the rest of the silo gas levels are also too low. <sup>12</sup>



J Francis (2006) An analysis of grain storage bags, sealed grain silos and warehousing for storing grain. Holmes Sackett and Associates, <a href="https://grdc.com.au/uploads/documents/Final%20report%20Grain%20Storage%20Bags%2021%20Jul%20061.pdf">https://grdc.com.au/uploads/documents/Final%20report%20Grain%20Storage%20Bags%2021%20Jul%20061.pdf</a>

P Botta, P Burrill, C Newman (2010) Pressure testing sealable silos. Factsheet, GRDC, <a href="https://grdc.com.au/"/media/0218DA4A22264A31B6202718043758DE.pdf">https://grdc.com.au/"/media/0218DA4A22264A31B6202718043758DE.pdf</a>



# **MORE INFORMATION**

Fumigating with phosphine, other fumigants and controlled atmospheres



WATCH: <u>Stored grain: Managing</u> sealed and unsealed storage



WATCH: <u>GCTV2</u>: <u>National standards</u> for sealed silos



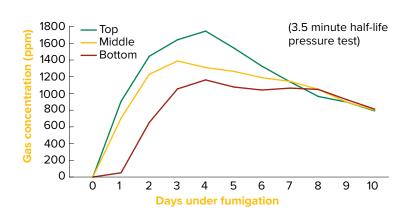


Figure 1: Gas concentration in gas-tight silo.

Source: GRDC

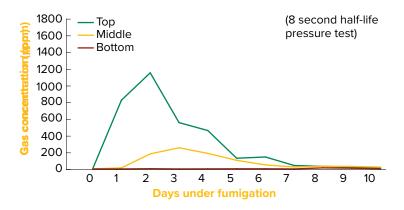


Figure 2: Gas concentration in non-gas-tight silo.

Source: GRDC

It is recommended to pressure-test silos that are sealable once a year to check for damaged seals on openings. Storages must be able to be sealed properly to ensure effective fumigation.

# 13.1.3 Grain bags

Grain-storage bags are a relatively new technology, and offer a low-cost alternative to silos for the temporary storage of grain on the farm. Grain-storage bags are made of multilayer polyethylene material similar to that used in silage fodder. Bags typically store 200–220 t of cereal grain, and are filled and emptied using specialised machinery (Photo 3). The bags are sealed after filling, producing a relatively airtight environment which, under favourable storage conditions, protects grain from insect damage without the use of insecticides.

The potential advantages of using grain-storage bags include the low capital set-up costs, improved harvest management, less harvest stress, reduced harvest-freight requirements, minimal cost for OH&S requirements, reduced grain-insecticide requirements, and the opportunity to segregate and blend grain.

The potential disadvantages include the need to dispose of used bags, and the relatively short period of storage before bags begin to deteriorate and management



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WATCH: GCTV extension files: Grain bags—best practice



WATCH: GCTV extension files: Grain bags—a grower's perspective



becomes necessary to ensure bag integrity. Another potential disadvantage of this system, when compared to permanent structures, is that once the storage period is complete there is no asset value in the storage system other than the bagging machinery. <sup>13</sup>

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**Photo 3:** A 100 m bag can be filled in 30 minutes when there is a constant supply of grain.

Source: StarTribune

# 13.1.4 Hygiene

Always thoroughly clean trucks, augers and storages prior to storing triticale. Dust and grain from previous years' grain should all be completely removed to avoid rapid infestation with stored-grain insects. <sup>14</sup>

#### 13.1.5 Insecticide treatment

There are three options for insecticide treatment:

- Chemical protectant—applied directly to the grain; used to treat uninfested grain; protects for three to nine months depending on product.
- Fumigation—applied only in a sealed silo; fumigant sits in tray or sachet in headspace of silo and is not in contact with the grain; residue-free; minimises insect resistance to chemicals if used with a gas-tight silo.
- Aeration cooling—residue-free; lowers temperature of grain; reduces potential for insect infestation.

# 13.1.6 Monitoring stored grain

Check the grain regularly during storage for signs of insect activity, and be prepared to deal with an infestation if it occurs. <sup>15</sup> When monitoring grain temperature and moisture content, take note of the following:

- Pests and grain moulds thrive in warm, moist conditions. Monitor grain moisture content and temperature to prevent storage problems.
- Use a grain-temperature probe to check storage conditions and aeration performance (Photo 4).
- When checking grain, smell the air at the top of storages for signs of high grain moisture or mould problems.



<sup>13</sup> J Francis (2006) An analysis of grain storage bags, sealed grain silos and warehousing for storing grain. Holmes Sackett and Associates, <a href="https://grdc.com.au/uploads/documents/Final%20report%20Grain%20Storage%20Bags%2021%20Jul%20061.pd">https://grdc.com.au/uploads/documents/Final%20report%20Grain%20Storage%20Bags%2021%20Jul%20061.pd</a>

<sup>14</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102">http://www.porkcrc.com.au/1A-102</a> Triticale\_Guide\_ Final\_Fact\_Sheets.pdf

Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/1A-102">http://www.porkcrc.com.au/1A-102</a> Triticale Guide Final\_Fact\_Sheets.pdf







 Aeration fans can be used to cool and dry grain to reduce problems of the storage environment.

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It is vital to monitor grain moisture content to prevent pests and grain moulds from thriving.  $^{\rm 16}$ 



**Photo 4:** Monitor moisture and temperature using a digital probe from both the top and the bottom of silos, if safe to do so.

Source: Plant Health Australia

# 13.1.7 Grain storage: get the economics right

As growers continue to expand their on-farm grain storage, the question of economic viability gains in significance. There are many examples of growers investing in on-farm grain storage and paying for it in one or two years because they struck the market at the right time, but are these examples enough to justify greater expansion of on-farm grain storage for most farmers?

The grain-storage extension team conducts approximately 100 grower workshops every year Australia wide, and it's evident from these that no two growers use on-farm storage in the exact same way: like many other economic comparisons in farming, the viability of grain storage is different for each grower. Depending on the business's operating style, the location, the resources, and the most limiting factor to increase profit, grain storage may—or may not—be the next best investment. For this reason, everyone needs to do a simple cost—benefit analysis of their own operation.

# Comparing on-farm grain storages

To make a sound financial decision, growers need to make two comparisons. The first is to compare the expected returns from using storage with expected returns from other farm-business investments, such as more land, a chaser bin, a wider boomspray, a second truck, or paying off debt. The other comparison is to determine if they can store grain on the farm cheaper than paying a bulk handler to store it.

Calculating the costs and benefits of on-farm storage will give the grower a return on investment (ROI) figure, which can be compared with other investment choices and the total cost of storage with bulk handlers.



<sup>16</sup> Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, <a href="http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/Monitoring-stored-grain-on-farm.pdf">http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/Monitoring-stored-grain-on-farm.pdf</a>



**TABLE OF CONTENTS** 





The key to a useful cost—benefit analysis is identifying which financial benefits to plan for, and costing an appropriate storage to suit that plan. People often ask, 'What's the cheapest form of storage?' The answer is the storage that suits the planned benefits. Short-term storage for harvest logistics or freight advantages can be suited to grain bags or bunkers. If flexibility is required for longer-term storage, gas-tight, sealable silos with aeration cooling allow quality control and insect control.

#### Benefits

To compare the benefits and costs in the same form, work everything out on the basis of dollars per tonne. On the benefit side, the majority of growers will require multiple financial gains for storing grain to make money out of it. These might include harvest logistics or timeliness, market premiums, freight savings or cleaning, blending, or drying grain to add value.

#### Costs

The costs of grain storage can be broken down into fixed and variable. The fixed costs are those that don't change from year to year and have to be covered over the life of the storage. Examples are depreciation and the opportunity or interest cost on the capital. The variable costs are all those that vary with the amount of grain stored and the length of time it's stored for. Interestingly, the costs of good hygiene, aeration cooling and monitoring are relatively low compared to the potential impact they can have on maintaining grain at a high quality. One of the most significant variable costs, and one that is often overlooked, is the opportunity cost of the stored grain, i.e. the cost of having grain in storage rather than having the money in the bank paying off an overdraft or a term loan.

# The result

While it's difficult to put an exact dollar value on each of the potential benefits and costs, a calculated estimate will determine if it's worth a more thorough investigation. If a grower compares the investment of on-farm grain storage to other investments and the result is similar, then they can revisit the numbers and work on increasing their accuracy. If the return is not even in the ball park, the grower has potentially avoided a costly mistake. On the contrary, if, after checking the numbers the return is favourable, they can proceed with the investment confidently.

#### Summary

Unlike a machinery purchase, grain storage is a long-term investment that cannot be easily changed or sold. Based on what the grain-storage extension team is seeing around Australia, those growers who take a planned approach to on-farm grain storage and do it well are being rewarded for it. Grain buyers are seeking out growers who have a well-designed storage system that can deliver insect-free, quality grain without delay.

Table 2 is a tool that can be used to figure out the likely economic result of on-farm grain storage for each individual business. Each column can be used to compare various storage options, including type of storage, length of time held or paying a bulk handler.  $^{17}$ 

# i MORE INFORMATION

Stored Grain Information Hub,

<u>Economics of on-farm grain storage</u>,

cost benefit analysis

Economics of on-farm grain storage: a grains industry guide











WATCH: On-farm storage in the SA Mallee with Corey Blacksell



WATCH: <u>On-farm storage in SA:</u> <u>Linden Price, SA</u>



WATCH: Over the Fence: On-farm storage delivers harvest flexibility and profit



WATCH: <u>GCTV: Stay safe around grain</u> <u>storage</u>



**Table 2:** Cost-benefit template for grain storage.

Figure 10 with from storage.					
Financial gains fro		Example \$/t			
Harvest logistics/ timeliness	Grain price x reduction in value after damage % x probability of damage %	\$16			
Marketing	Post harvest grain price - harvest grain price				
Freight	Peak rate \$/t - post harvest rate \$/t	\$20			
Cleaning to improve grade	Clean grain price - original grain price - cleaning costs - shrinkage				
Blending to lift average grade	Blended price - ((low grade price x %mix) + (high grade price x %mix))				
Total benefits	Sum of benefits	\$36.20			
Capital cost	Infrastructure cost / storage capacity	\$155			
Fixed costs					
Annualised depreciation cost	Capital cost \$/t / expected life storage e.g. 25 yrs	\$6.20			
Opportunity cost on capital	Capital cost $\frac{t}{x}$ opportunity or interest rate e.g. $\frac{8}{7}$	\$6.20			
Total fixed costs	Sum of fixed costs	\$12.40			
Variable costs					
Storage hygiene	(Labour rate \$/hr x time to clean hrs / storage capacity) + structural treatment	\$0.23			
Aeration cooling	Indicatively 23c for the first 8 days then 18c per month / $t$	\$0.91			
Repairs and maintenance	Estimate, e.g. capital cost \$/t x 1%	\$1.51			
Inload/outload time and fuel	Labour rate $\frac{hr}{60}$ minutes / auger rate $\frac{hr}{3}$	\$0.88			
Time to monitor and manage	Labour rate \$/hr x total time to manage hrs / storage capacity	\$0.24			
Opportunity cost of stored grain	Grain price x opportunity interest rate e.g. 8% / 12 x No. months stored	\$7.20			
Insect treatment cost	Treatment cost \$/t x No. of treatments	\$0.35			
Cost of bags or bunker trap	Price of bag / bag capacity (tonnes)				
Total variable costs	Sum of variable costs	\$11.32			
Total cost of storage	Total fixed costs + total variable costs	\$23.72			
Profit/Loss on storage	Total benefits - total costs of storage	\$12.48			
Return on investment	Profit or loss / capital cost x 100	8.1%			
Source: GRDC.					

# 13.2 Stored grain pests

# Key points:

 Effective grain hygiene and aeration cooling can overcome 85% of pest problems.



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- When fumigation is needed it must be carried out in pressure-tested, sealed silos.
- Monitor stored grain monthly for moisture, temperature and pests.

# 13.2.1 Prevention is better than cure

The combination of meticulous grain hygiene and well-managed aeration cooling generally overcomes 85% of storage pest problems. For grain storage, the key factors provide significant gains for both grain storage pest control and grain quality: hygiene, aeration cooling, and correct fumigation. <sup>18</sup>

# 13.2.2 Common species

The most common insect pests of stored cereal grains in Australia are (Figure 3): 19

- weevils (Sitophilus spp.)—rice weevil is the most in cereals in Australia
- lesser grain borer (Rhyzopertha dominica)
- rust-red flour beetle (Tribolium spp.)
- saw-toothed grain beetle (Oryzaephilus spp.)
- flat grain beetle (Cryptolestes spp.)
- Indian meal moth (Plodia interpunctella)
- angoumois grain moth (Sitotroga cerealella)

Another dozen or so beetles, psocids (booklice) and mites are sometimes present as pests in stored cereal grain.



<sup>18</sup> Stored Grain Information Hub (2016) Northern and southern regions grain storage pest control guide. GRDC, <a href="http://storedgrain.com.au/pest-control-quide-ns/">http://storedgrain.com.au/pest-control-quide-ns/</a>

<sup>19</sup> Stored Grain Information Hub (2013) Northern and southern regions stored grain pests: identification. GRDC, <a href="http://storedgrain.com.au/stored-grain-pests-id-ns/">http://storedgrain.com.au/stored-grain-pests-id-ns/</a>







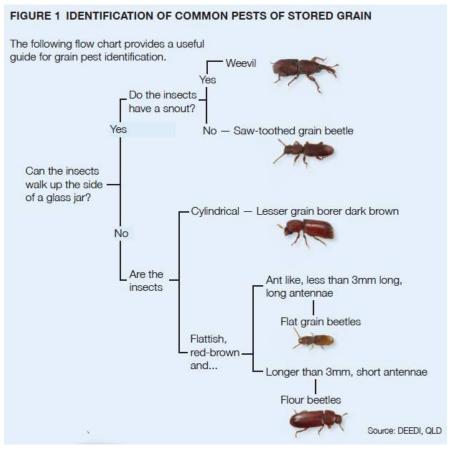


Figure 3: Identification of common pests of stored grain.

Source: Stored Grain Information Hub

# Why identify insect pests of stored grain pests?

Most insect-control methods for stored grain work against all species, so it is not necessary to identify the storage pests to make decisions about most control methods. But if you intend to spray grain with insecticides you may need to know which species are present if:

- A previous application has failed and you want to know whether resistance was the reason—if more than one species survived, resistance is unlikely to be the cause.
- You intend using a residual protectant to treat infested grain—pyrimiphos-methyl, fenitrothion and chlorpyrifos-methyl are ineffective against the lesser grain borer, and pyrimiphos-methyl and fenitrothion are generally ineffective against the sawtoothed grain beetle.
- You intend to use dichlorvos to treat infested grain—if the lesser grain borer is present you need to apply the higher dose rate, which increases the withholding period (WHP) before grain can be marketed from 7 days to 28 days.

# 13.2.3 Monitoring grain for pests

Damage by grain pests often goes unnoticed until the grain is removed from the storage. Regular monitoring will help to ensure that grain quality is maintained.

Sample each grain storage at least monthly. During warmer periods of the year fortnightly sampling is recommended.



Stored grain pests: identification



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# **MORE INFORMATION**

Stored grain pests: the back pocket guide

Monitoring stored grain on farm



# **VIDEOS**

WATCH: GCTV2: Grain storage insect ID



 Take samples from the top and bottom of grain stores and sieve using 2 mm mesh onto a white tray to separate any insects (Photo 5).

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- Hold the tray in the sunlight for 10–20 seconds to trigger movement in any insects, making them easier to see. Use a magnifying glass to identify pests.
- Also use grain probes or pitfall traps to check for insects. Traps are kept in the grain while it is being stored and are often able to detect the start of an infestation.
- Push the probe or trap into the grain surface and pull up for inspection fortnightly or monthly. Place 1–2 traps in the top of a silo or several traps in a grain shed.
- Be sure to check grain three weeks before sale to allow time for treatment if required. <sup>21</sup>



**Photo 5:** A 2 mm mesh sieve will separate insects from grain.

Source: Plant Health Australia

# 13.2.4 Hygiene

Key points

- Effective grain hygiene requires the complete removal of all waste grain from storages and equipment.
- Be meticulous with grain hygiene: pests only need a small amount of grain for survival.

A bag of infested grain can produce more than one million insects during a year, which can walk and fly to other grain storages where they will start new infestations. Meticulous grain hygiene involves removing any grain that can harbour pests and allow them to breed. It also includes regular inspection of seed and stockfeed grain so any pest infestations can be controlled before pests spread.

# Where to clean

Removing an environment for pests to live and breed in is the basis of grain hygiene, which includes all grain handling equipment and storages. Grain pests live in dark, sheltered areas and breed best in warm conditions. Common places to find them include:



<sup>20</sup> Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, <a href="http://www.planthealthaustralia.com.au/wp-content-uploads/2015/11/Monitoring-stored-grain-on-farm.pdf">http://www.planthealthaustralia.com.au/wp-content-uploads/2015/11/Monitoring-stored-grain-on-farm.pdf</a>

<sup>21</sup> Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, <a href="http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/Monitoring-stored-grain-on-farm.pdf">http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/Monitoring-stored-grain-on-farm.pdf</a>

**TABLE OF CONTENTS** 





- · Aeration ducts, augers and conveyers.
- Harvesters, field bins and chaser bins.
- Left-over bags or loose grain in grain trucks.
- · Spilt grain around grain storages.
- Equipment and rubbish around storages.
- Seed grain.
- Stockfeed grain.

Successful grain hygiene involves cleaning all areas where grain gets trapped in storages and equipment (Photo 6). <sup>22</sup> Grain pests can survive in a tiny amount of grain, so any parcel of fresh grain in a machine or storage can become infested.



**Photo 6:** Grain left in trucks is an ideal place for grain pests to breed. Keep trucks, field bins and chaser bins clean.

Source: Stored Grain Information Hub

#### When to clean

Straight after harvest is the best time to clean grain-handling equipment and storages, before they become infested with pests. One trial revealed more than 1,000 lesser grain borers in the first 40 L of grain through a harvester at the start of harvest; the harvester had been considered to be reasonably clean at the end of the previous season. Discarding the first few bags of grain at the start of the next harvest is a good idea to help keep grain pest-free. Other studies have showed that insects are least mobile during the colder months of the year, so cleaning around silos in July–August can reduce insect numbers before they become mobile.

#### How to clean

The better the cleaning job, the less chance of pests being harboured. The best tools to get rid of all grain residues are a combination of:

- brooms
- · vacuum cleaners
- compressed air
- blow/vacuum guns
- pressure washers
- fire-fighting hoses



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<sup>22</sup> Stored Grain Information Hub (2013) Hygiene and structural treatments for grain storage. Factsheet. GRDC, <a href="http://storedgrain.com.au/hygiene-structural-treatments/">http://storedgrain.com.au/hygiene-structural-treatments/</a>







Using a broom or compressed air gets rid of most grain residues, and a follow-up wash-down removes grain and dust left in crevices and hard-to-reach spots (Photo 7). <sup>23</sup> Choose a warm, dry day to wash storages and equipment so it dries out quickly and doesn't rust. When inspecting empty storages, look for ways to make the structures easier to keep clean. Seal or fill any cracks and crevices to prevent grain lodging and insects harbouring. Bags of leftover grain lying around storages and in sheds create a perfect harbour and breeding ground for storage pests. After collecting spilt grain and residues, dispose of them well away from any grain storage areas.

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**Photo 7:** Clean silos, including the silo wall, with air or water to provide a residue-free surface to apply structural treatments.

Source: Stored Grain Information Hub

The process of cleaning on-farm storages and handling equipment should start with the physical removal, blowing and/or hosing out of all residues. Once the structure is clean and dry, consider the application of diatomaceous earth (DE) as a structural treatment. See Section 1.2.4 Structural treatments for more information.

TIP: A concrete slab underneath silos makes cleaning much easier (Photo 8).



<sup>23</sup> Stored Grain Information Hub (2013) Hygiene and structural treatments for grain storage. Factsheet. GRDC, <a href="http://storedgrain.com.au/hygiene-structural-treatments/">http://storedgrain.com.au/hygiene-structural-treatments/</a>









**MORE INFORMATION** 

Aeration cooling for pest control



Source: Stored Grain Information Hub

# 13.2.5 Aeration cooling for pest control

While adult insects can still survive at low temperatures, most juveniles stop developing at temperatures below 18–20°C (Table 3). <sup>24</sup> At temperatures below 15°C the common rice weevil stops developing.

At low temperatures insect pest life cycles (egg, larvae, pupae and adult) are lengthened from the typical four weeks at warm temperatures (30–35°C) to 12–17 weeks at cooler temperatures (20-23°C).

**Table 3:** The effect of grain temperature on the development of insects and mould.

Grain temp (°C)	Insect and mould development	Grain moisture content (%)		
40–55	Seed damage occurs, reducing viability			
30–40	Mould and insects are prolific	>18		
25–30	Mould and insects are active	13–18		
20–25	Mould development is limited	10–13		
18–20	Young insects stop developing	9		
<15	Most insects stop reproducing, mould stops developing	<8		

Source: Kondinin Group

For more information, see Section  $\underline{13.4.2}$  Aeration cooling below .

#### 13.2.6 Structural treatments

Key points

- Structural treatments such as diatomaceous earth (DE) can be used on storages and equipment to protect against grain pests.
- Check delivery requirements before using chemical treatments.

Using chemicals as structural treatments risks exceeding the maximum residue limit (MRL) and so is not recommended. These chemicals do not list this use on their labels



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<sup>24</sup> Stored Grain Information Hub (2014) Aeration cooling for pest control. Revised. GRDC, http://storedgrain.com.au/aeration-cooling/









# **MORE INFORMATION**

<u>Hygiene and structural treatments for</u> grain storages

or their MRLs. If you are storing grains or intend to in the future, be aware that MRLs are either low or nil.

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JANUARY 2018

Diatomaceous earth (sometimes called inert dust) is an amorphous silica commercially known as Dryacide® and acts by absorbing and cutting the insect's cuticle (protective waxy exterior), causing death by desiccation. Using DE as a structural treatment is possible, but the storage and equipment must be washed and dried before using. This will ensure the DE doesn't discolour the grain surface. If applied correctly; i.e. with complete coverage in a dry environment, DE can provide up to 12 months of protection for storages and equipment.

If unsure, check with the grain buyer before using any product that will come in contact with the stored grain.  $^{25}$ 

# 13.2.7 Application

Inert dust requires a moving airstream to direct it onto the surface being treated; alternatively, it can be mixed into a slurry with water and sprayed onto surface. Read and follow label directions. Throwing dust into silos by hand will not achieve an even coverage, and so will not be effective. For very small grain silos and bins, a hand-operated duster, such as a bellows duster, is suitable. Larger silos and storages require a powered duster, e.g. a Venturi duster such as the Blovac BV-22 gun (Photo 9), operated by compressed air or a fan. If compressed air is available, it is the most economical and suitable option for use on the farm.



**Photo 9:** A blower and vacuum gun such as the Venturi gun is the best applicator for inert dusts. Aim for an event coat of diatomaceous earth across the roof, walls and base.

Photo: C. Warrick, Proadvice

The application rate is calculated at  $2 \text{ g/m}^2$  of surface area treated. Although DE is inert, breathing in excessive amounts of it is not ideal, so use a disposable dust mask and goggles during application. Apply DE at the recommended rates (Table 4).











# **MORE INFORMATION**

<u>Hygiene and structural treatment for grain storages</u>



WATCH: GCTV7: Applying diatomaceous earth dust



# Silo application

Apply inert dust in silos, starting at the top (if safe), by coating the inside of the roof then working your way down the silo walls, finishing by pointing the stream at the bottom of the silo. If silos are fitted with aeration systems, distribute the inert dust into the ducting, taking care not to get it into the motor, where it could cause damage. <sup>26</sup>

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Table 4: DE application guide.

Dust quantity (kg)
0.12
0.25
0.42
0.60
1.00
1.70
2.60

# 13.2.8 Fumigation

Fumigation prior to storage in sealed silos effectively reduces the risk of insect damage when storing triticale.  $^{27}$ 

There are a number of chemical options for the control of grain pests in stored cereals (Table 5).  $^{28}$ 

**Table 5:** Resistance and efficacy guide for stored grain insects.

Treatment and example product	WHP	Lesser grain borer	Rust-red flour beetle	Rice weevil	Saw- toothed grain beetle	Flat grain beetle	Psocids (booklice)	Structural treatments
Grain disinfestants—used on infested grain to control full life cycle (adults, eggs, larvae, pupae)								
Phosphine (Fumitoxin*) <sup>1,3</sup> when used in gas-tight, sealable stores	2							
Sulfuryl fluoride (ProFume*)10	1							
Grain protectants—applied postharvest. Poor adult control if applied to infested grain								
Pirimiphos-methyl (Actellic 900°)	nil <sup>2</sup>							
Fenitrothion (Fenitrothion 1000*) <sup>4, 7</sup>	1–90							
Chlorpyrifos-methyl (Reldan Grain Protector®) <sup>5</sup>	Nil <sup>2</sup>							
'Combined products' (Reldan Plus IGR Grain Protector)	Nil <sup>2</sup>							
Deltamethrin (K-Obiol®)10	$Nil^2$							
Spinosad and Chlorpyrifos-methyl (eg Conserve On-Form $^{\!TM})^9$								
Diatomaceous earth, amorphous silica—effective internal structural treatment for storages and equipment.  Specific-use grain treatments								
Diatomaceous earth, amorphous silica (Dryacide*)8	Nil <sup>2</sup>							
			tered for this pest I resistance in flat	grain beetle has be	een identified, send insec	its for testing if fum	igation failures occur	



<sup>27</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

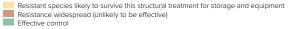


<sup>28</sup> Stored Grain Information Hub (2016) Northern and southern regions grain storage pest control guide. Factsheet. Revised. GRDC, <a href="http://storedgrain.com.au/pest-control-quide-ns/">http://storedgrain.com.au/pest-control-quide-ns/</a>



**TABLE OF CONTENTS** 





1 Unlikely to be effective in unsealed sites, causing resistance, see label for definitions

2 When used as directed on label 3 Total of (exposure + ventilation + withholding) = 10 to 27 days

4 Nufarm label only

5 Stored grains except malting barley and rice/ stored lupins registration for Victoria only/ not on stored maize destined for export 6 When applied as directed, do not move treated grain for 24 hours 7 Periods of 6–9 months storage including mixture in adulticide (e.g. Fenitrothion at label rate

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8 Do not use on stored maize destined for export, or on grain delivered to bulk-handling authorities 9 Dichlorvos 500 g/L registration only

10 Restricted to licensed fumigators or approved users

11 Restriced to use under permit 14075 only. Unlikely to be practical for use on farm

Source: Registration information courtesy of Pestgenie, APVMA and InfoPest (DEEDI) websites

Source: GRDC

Before applying, check with your grain buyers and bulk handlers and read labels carefully.

Fumigation with phosphine is a common component of many integrated pest-control strategies (Photo 10).

Taking fumigation shortcuts may kill enough adult insects in grain so it passes delivery standards, but the repercussions of such practices are detrimental to the grains industry. Poor fumigation techniques fail to kill pests at all stages of the life cycle, so while some adults may die, grain will soon be reinfested again as soon as larvae and eggs develop. What's worse, every time a poor fumigation is carried out, insects with some resistance survive, making the chemical less effective in the future.



**Photo 10:** Phosphine is widely accepted as having no residue concerns.

Photo: DAF Qld

While there is some resistance to phosphine, it is widely accepted as having no residue concerns for use in grains. The grain industry has adopted a voluntary strategy to manage the build-up of phosphine resistance in pests: its core recommendations are to limit the number of conventional phosphine fumigations on undisturbed grain to three per year, and to employ a break strategy. <sup>29</sup>



WATCH: GCTV Stored grain: Fumigation recirculation

















Managing MRLs factsheet



WATCH: <u>GCTV Stored grain:</u> <u>Phosphine dose rates</u>



#### Maximum residue limits

By observing several precautions, growers can ensure that grain coming off their farm is compliant with the maximum pesticide residue limits that apply to Australian exports. Violations of maximum residue limits (MRLs) affect the marketability of Australian grain exports, and consequences may include costs being imposed on exporters and/or growers.

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Measures growers need to take to avoid MRL violations are detailed in a new *Grain Marketing and Pesticide Residues* Fact Sheet, produced by the Grains Research and Development Corporation (GRDC). The Fact Sheet states it is essential that both pre-harvest and post-harvest chemical applications adhere to the Australian Grain Industry Code of Practice, only registered products are used and all label recommendations, including rates and withholding periods, must be observed. Other key points include:

- Trucks or augers that have been used to transport treated seed or fertiliser can be a source of contamination – pay particular attention to storage and transport hygiene;
- Silos that have held treated fertiliser or pickled grain will have dust remnants these silos either need to be cleaned or designated as non-food grade storage;
- Know the destination of your grain. When signing contracts, check the importing countries' MRLs to determine what pesticides are permitted on a particular crop. 30

#### Phosphine application

In order to kill grain pests at all stages of their life cycle (egg, larvae, pupae, adult), phosphine gas concentrations need to reach and remain at 300 parts per million (ppm) for seven days, or 200 ppm for 10 days. Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3 ppm close to the leaks. Gas levels were lower than necessary in the rest of the silo, too.

Achieve effective fumigation by placing phosphine at the correct rates (as directed on the label) onto a tray and hanging it in the top of a pressure-tested, sealed silo, or into a ground-level application system if the silo is fitted with recirculation.

After fumigation, ventilate grain for a minimum of one day with aeration fans running, or for five days if no fans are fitted.

After ventilation, a minimum withholding (WHP) period of two days is required before grain can be used for human consumption or stockfeed.

The total time needed for fumigating is 10–17 days.

As a general rule, only keep a silo sealed while carrying out the fumigation (e.g. one to two weeks).

After fumigation has been completed, return to aeration cooling to hold the stored grain at a suitable temperature level.

#### Handle with care

Phosphine is a highly toxic gas with potentially fatal consequences if handled incorrectly. As a minimum requirement, the label directs users to wear cotton overalls buttoned at the neck and wrist, eye protection, elbow-length PVC gloves, and a breathing respirator with a combined dust and gas cartridge.

#### Where to apply

Arrange the tablets where as much surface area as possible is exposed to air, so the gas can disperse freely throughout the grain stack. Spread phosphine tablets evenly across trays before hanging them in the head space or placing them level on the grain surface inside a gas-tight, sealed silo. Hang bag chains in the head space



<sup>30</sup> S Watt. (2014). Know your maximum residue limits. <a href="https://qrdc.com.au/Media-Centre/Media-News/South/2014/07/Know-your-maximum-residue-limits">https://qrdc.com.au/Media-Centre/Media-News/South/2014/07/Know-your-maximum-residue-limits</a>









# **MORE INFORMATION**

Grain fumigation guide

Fumigating with phosphine, other fumigants and controlled atmospheres

Stored Grain Information Hub, <u>K-Obiol</u> EC Combi

or roll out flat on the top of the grain so air can freely pass around them as the gas dissipates. Bottom-application facilities must have a passive or active air circulation system to carry the phosphine gas out of the confined space as it evolves. Without air movement, if left in a confined space, phosphine can reach explosive levels.

SOUTHERN

#### Time to kill

Insect activity is slower in cooler grain temperatures so require longer exposer to the gas to receive a lethal dose. <sup>31</sup> To control pests at all life stages and prevent insect resistance, phosphine gas concentration needs to reach 300 ppm for seven days (when grain is above 25°C), or 200 ppm for 10 days (grain between 15–25°C).

# Non-chemical treatment options

Two non-chemical treatment options are:

- Carbon dioxide—treatment involves displacing the oxygen inside a gas-tight silo with CO<sub>2</sub>, which creates an atmosphere toxic to grain pests. To achieve a complete kill of all the main grain pests at all life stages, CO<sub>2</sub> must be retained at a minimum concentration of 35% for 15 days.
- Nitrogen—grain stored under  $N_2$  provides insect control and quality preservation with the advantages of also being safe to use and environmentally acceptable. The main operating cost is the capital cost of equipment and electricity.  $N_2$  also produces no residues, so grains can be traded at any time (compared with chemical fumigants, which have withholding periods). Insect control with  $N_2$  entails using pressure-swinging adsorption (PSA) technology to modify the atmosphere inside the grain storage to remove everything except  $N_2$ , thereby starving pests of oxygen.  $N_2$

# 13.3 Grain protectants for storage

The widespread resistance of the lesser grain borer (*Rhyzopertha dominica*) to grain protectants is decreasing with the availability of products based on deltamethrin (e.g. K-Obiol® EC Combi) and spinosad (e.g. Conserve™ On-Farm).

#### K-Obiol® EC Combi

K-Obiol® EC Combi is a synergised grain protectant for use on cereal grains, malting barley and sorghum. <sup>33</sup> It can be used in any type of storage, sealed or unsealed. It is suitable for use by grain growers and grain accumulators. Like all protectants, it is a liquid and must be evenly applied as a dilution to the grain as it is fed into the storage. It is for use on un-infested grain and is not recommended for eradicating insect pests when they have infested grain.

The active constituent is deltamethrin. Piperonyl butoxide is added as a synergist, i.e. to increase the effectiveness of the deltamethrin. As K-Obiol® EC Combi is based on deltamethrin, there are none of the insect-resistance problems that growers have with other protectants.

Because protectants are residual, grain end users may be concerned that the grain does not contain excessive levels of chemicals. This would generally only come about with incorrect treatment or double treatment as the grain moves along the supply chain. To protect the end user, and ultimately Australian grain growers, a product stewardship program has been developed to help ensure correct use of the product, including minimising the development of insect resistance and increasing the usable life of the chemical. <sup>34</sup>



<sup>31</sup> Stored Grain Information Hub (2016) Grain fumigation: A guide. Factsheet. Revised. GRDC, http://storedgrain.com.au/fumigation-guide/

<sup>32</sup> C Warrick (2012) Fumigating with phosphine, other fumigants and controlled atmospheres. GRDC, <a href="http://storedgrain.com.au/fumigating-with-phosphine-and-ca/">http://storedgrain.com.au/fumigating-with-phosphine-and-ca/</a>

<sup>33</sup> Bayer (n.d.) K-Obiol. Bayer, http://www.k-obiol.com.au/

<sup>34</sup> GRDC Stored Grain Information Hub. K-Obiol Combi. GRDC, http://storedgrain.com.au/k-obiol-combi/



**TABLE OF CONTENTS** 





Stored Grain Information Hub, Conserve

# Conserve<sup>™</sup> On-farm

Conserve™ On-Farm is a Dow AgroSciences grain protectant that has three active ingredients that control most major insect pests of stored grain, including the resistant lesser grain borer (LGB). 35 It provides six to nine months of control and has no WHP. MRLs have been established with key trading partners, and there are no meat residue bioaccumulation problems.

SOUTHERN

Conserve™ On-Farm is a combination of two parts that are mixed together for application. Using Part A and Part B together is very important in order to successfully control the complete spectrum of insects. They comprise:

- Part A—1 x 5 L of chlorpyrifos-methyl and S-methoprene, which controls all stored grain insect pests other than the LGB
- Part B—2 x 1 L of spinosad, which is very effective on the LGB, including resistant strains, but has little to no effect on other key species. 36

# 13.4 Aeration during storage

# 13.4.1 Dealing with moist grain

Key points:

- Deal with high-moisture grain promptly.
- Monitoring grain moisture and temperature daily will enable early detection of mould and insects.
- Aeration drying requires airflow rates in excess of 15 litres per second per tonne (L/s/t).
- Dedicated-batch or continuous-flow dryers are a more reliable way to dry grain than aeration drying in less-than-ideal ambient conditions.

Aeration is recommended when storing triticale. It is also particularly recommended that a protectant be used, given the softness of the grain. 37

A Queensland Department of Employment, Economic Development and Innovation (DEEDI) trial demonstrated that high-moisture grain generates heat when put into a confined storage, such as a silo. Wheat at 16.5% MC and a temperature of 28°C was put into a silo with no aeration. Within hours, the grain temperature reached 39°C, and within two days reached 46°C, providing ideal conditions for mould growth and grain damage (Figure 4).  $^{38}$  Grain that is over the standard safe storage moisture content of 12.5% can be dealt with by:

- Blending—mixing high-moisture grain with low-moisture grain, then aerating.
- Aeration cooling—for a short time holding grain of moderate moisture, up to 15% MC, under aeration cooling until drying equipment is available.
- Aeration drying—forcing large volumes of air to push a drying front through the grain in storage to slowly remove moisture. Supplementary heating can be added.
- Continuous-flow drying—transferring grain through a dryer, which uses a high volume of heated air to pass through the continual flow of grain.
- Batch drying—using a transportable trailer to dry 10-20 tonnes of grain at a time with a high volume of heated air, which passes through the grain and out perforated walls.



<sup>35</sup> Dow AgroSciences (n.d.) Conserve, Dow AgroSciences, http://www.conserveonfarm.com.au/en

<sup>36</sup> GRDC Stored Grain Information Hub. Conserve. GRDC, http://storedgrain.com.au/conserve-farm/

Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, http://www.porkci Final\_Fact\_Sheets.pdf

Stored Grain Information Hub (2013) Dealing with high-moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-high-moisture grain. moisture-grain/







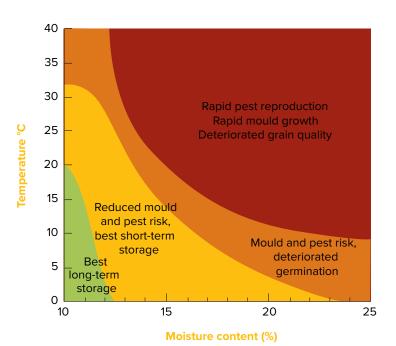


Figure 4: Effects of temperature and moisture on stored grain.

Source: GRDC

# 13.4.2 Aeration cooling

Key points:

- Grain temperatures below 20°C significantly reduce mould and insect development.
- Reducing grain temperature with aeration cooling protects seed viability.
- Controlling aeration cooling is a three-stage process: continual, rapid, and maintenance.
- Stop aeration if ambient, relative humidity exceeds 85%.
- Automatic grain aeration controllers that select optimum fan running times give the most reliable results.

Aeration cooling can be used to reduce the risk of mould and insect development for a month or two until drying equipment is available to dry grain down to a safe level for long-term storage or delivery. In most circumstances, grain can be stored at up to 14–15% MC safely with aeration cooling fans running continuously and delivering at least 2–3 L/s/t. It is important to keep fans running for the entire period, stopping them only if the ambient relative humidity is above 85% for more than about 12 hours, to avoid wetting the grain further.

Even keeping the grain at 12% MC, you may still need to treat the grain to protect it from insect pests, mould and fungal growth.  $^{39}$ 

#### **Blending**

Blending is the practice of mixing slightly over-moist grain with lower-moisture grain to achieve an average moisture content below the ideal 12.5% MC. It is successful with grain with MC up to 13.5%, and can be an inexpensive way of dealing with wet grain, providing the infrastructure is available. Aeration cooling does allow blending in



SOUTHERN
JANUARY 2018

<sup>39</sup> Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, <a href="http://www.porkcrc.com.au/IA-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf">http://www.porkcrc.com.au/IA-102\_Triticale\_Guide\_Final\_Fact\_Sheets.pdf</a>







layers but if aeration cooling is not available, blending must be evenly distributed (see Figure 5).  $^{40}$ 

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JANUARY 2018



**GRDC** Aerating Stored Grain



WATCH: GCTV2: Grain storage cooling aeration



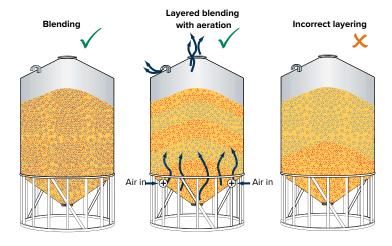


Figure 5: Diagram demonstrating the correct practices for blending.

Source: GRDC

#### Seed viability

Research trials have revealed that cereal grain stored at 12% MC for six months at  $30-35^{\circ}$ C (unaerated grain temperature) will have reduced seedling vigour and a lower rate of germination.

# 13.4.3 Aeration drying

Aeration drying relies on a high air volume and is usually done in a purpose-built drying silo or a partly filled silo with high-capacity aeration fans. Aeration drying is a slow process and relies on four factors:

- High airflow rates.
- Well-designed ducting for even airflow through the grain.
- Exhaust vents in the silo roof.
- Warm, dry weather.

It is important to seek reliable advice on equipment requirements and correct management of fan running times, otherwise there is a high risk of damaging the grain and reducing its quality.

#### High airflow for drying

Unlike aeration cooling, aeration drying requires high airflow, in excess of 15 L/s/t, to move drying fronts quickly through the whole grain profile and depth, and carry moisture out of the grain bulk. As air passes through the grain, it collects moisture from the grain, and forms a drying front. If airflow is too low, the drying front will take too long to reach the top of the grain stack, an occurrence that is often referred to as a 'stalled drying front'. Providing the storage has sufficient aeration ducting, a drying front can pass through a shallow stack of grain much faster than a deep stack of grain. As air will take the path of least resistance, make sure the grain is spread to an even depth to ensure even and adequate drying.



Stored Grain Information Hub (2013) Dealing with high moisture grain. Factsheet. GRDC, <a href="http://storedgrain.com.au/dealing-with-high-moisture-grain/">http://storedgrain.com.au/dealing-with-high-moisture-grain/</a>







# **Ducting for drying**

The way to avoid hot spots is with adequate ducting to deliver an evenly distributed flow of air through the entire grain stack (as can be seen on the silo sides in Photo 11). <sup>41</sup> A flat-bottomed silo with a full floor aeration plenum is ideal providing it can deliver air at at least 15 L/s/t. The silo may only be able to be part filled, which in many cases is better than trying to dry grain in a cone-bottomed silo with insufficient ducting.



Photo 11: Aeration drying requires careful management, high airflow rates, well designed ducting, exhaust vents and warm, dry weather.

Source: GRDC

# Venting for drying

Adequate ventilation maximises airflow and allows moisture to escape rather than forming condensation on the underside of the roof and wetting the grain at the top of the stack. The amount of moisture that has to escape with the exhaust air is 10 L for every 1% MC removed per tonne of grain.

# Weather conditions for drying

For moisture transfer to occur and drying to succeed, the external air, which is harnessed for pushing through the grain, must have a lower relative humidity than the grain's equilibrium moisture content. For example, grain at 25°C and 14% MC has an equilibrium point of the air around it at 70% relative humidity: in order to make this grain drier, the aeration drying fans would need to be turned on when the ambient air was below 70% relative humidity (Table 6). 42



Stored Grain Information Hub (2013) Dealing with high moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-highmoisture-grain/

Stored Grain Information Hub (2013) Dealing with high moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-highmoisture-grain/









Dealing with high moisture grain



WATCH: GCTV5: Aeration drying getting it right





Aeration drying fans can be turned on as soon as the aeration ducting is covered with grain, and left running continuously until the air coming out of the top of the storage has a clean, fresh smell. The only time drying fans are to be turned off during this phase is if ambient air exceeds 85% relative humidity for more than a few hours.

SOUTHERN

#### Phase two of drying

By monitoring the temperature and moisture content of the grain in storage and referring to an equilibrium moisture table, such as Table 6, a suitable relative humidity trigger point can be set. As the grain dries, the equilibrium point will fall, so the relative humidity trigger point will need to be reduced to dry down the grain further. Reducing the relative humidity trigger point slowly during phase two of the drying process will help keep the difference in grain moisture from the bottom to the top of the stack to a minimum, by ensuring the fans get adequate run time to push each drying front right through the grain stack.

Table 6: Equilibrium moisture content for wheat.

Relative		Temperature		
humidity (%)	15	25	35	
30	9.8	9.0	8.5	G
40	11.0	10.3	9.7	Grain con
50	12.1	11.4	10.7	mo Iten
60	13.4	12.8	12.0	rain moisture content %)
70	15.0	14.0	13.5	Ō,

Note: values may be different for triticale grain. Source: GRDC

#### Supplementary heating

Heat can be added to aeration drying in proportion to the airflow rate. Higher airflow rates allow more heat to be added as it will push each drying front through the storage quick enough to avoid overheating the grain close to the aeration ducting. As a general guide, inlet air shouldn't exceed 35°C.

# Cooling after drying

Regardless of whether supplementary heat is added to the aeration drying process, the grain should be cooled immediately after it has been dried. Cool to the desired level. 43

### 13.4.4 Aeration controllers

Aeration controllers can manage both aeration drying and cooling, as well as maintenance functions, in up to 10 separate storages (Photo 12). 44 The unit takes into account the moisture content and temperature of grain at loading and the desired grain condition after time in storage, and sets aeration factors accordingly to achieve safe storage.

A single controller has had the ability to control the diverse functions of aeration: cooling, drying and maintenance. The controller can not only combine the ability to control all three functions, but automatically selects the correct type of aeration strategy to obtain the desired grain moisture and temperature. 45



<sup>43</sup> Stored Grain Information Hub (2013) Dealing with high moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-high-

GRDC (2007) New generation in aeration controller. Ground Cover. No. 57. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-57-Grain-Storage-Supplement/New-generation-aeration-controller



**TABLE OF CONTENTS** 



Research has shown that, with the support of an aeration controller, aeration can rapidly reduce stored grain temperatures to a level that helps maintain grain quality and inhibits insect development.

SOUTHERN

JANUARY 2018

During trials, where grain was harvested at 30°C and 15.5% MC, grain temperatures rose to 40°C within hours of being put into storage. An aeration controller was used to rapidly cool grain to 20°C and then hold the grain between 17°C and 24°C from November to March.

Before replicating similar results on farm, growers need to:

- Know the capacity of their existing aeration system.
- Determine whether grain requires drying before cooling can be carried out.
- Understand the effects of relative humidity and temperature when aerating stored grain.
- Determine the target conditions for the stored grain.



Photo 12: Automatic aeration controllers are the most effective way to cool grain and are designed to manage many storages from one central control unit.

Source: GRDC







**TABLE OF CONTENTS** 





# Key messages

 Triticale appears to be more sensitive to frost than other cereals. Dry sowing for a portion of the crop is one option that has proven very successful and can be considered for triticale as well as other cereals.

SOUTHERN

- Of all the cereals available to farmers, triticale has the best adaptation to waterlogged soils and those with high pH (alkaline soils).
- Triticale is also tolerant of low pH (acid) soils, grows well on sodic soils, and tolerates soils high in boron.
- Farmers appreciate the ability of triticale to tolerate periods of drought through the growing season, and at the other extreme, its tolerance of waterlogging.<sup>2</sup>
- The crop is highly tolerant to soil with high concentrations of aluminium and to saline soils.<sup>3</sup>

Due to the effects of climate change, both heat stress and frost are likely to play an increasing role in farming in the future, and growers will need to take steps to manage the risks and decrease their impact on crops. <sup>4</sup> A survey conducted in 2015 revealed that south-eastern Australian grain growers and advisers rate grain-filling heat (heat shock) as a greater risk than frost. <sup>5</sup>

Climate variability is an increasing concern for grain growers. This was evident in trials in 2007: where an experiment exploring triticale's capacity to compete with weeds, was inundated with poor weather. A concerning peripheral issue highlighted by the experimental findings in the study was the risk of widespread crop failure that could be attributed to climatic variability, and the devastating impact this could have on global food security. The experiment had begun based on the premise that optimal crop densities are a given, and aimed to demonstrate that crop competitiveness against weeds is achieved through sound agronomic management, which starts with competitive cultivar selection. The highly variable climatic conditions resulted in poor crop establishment, and the question could not be tested properly. However, the trials did provide outcomes that are useful to farmers: the implication is that no matter how superior the crop genetic potential is for competitive ability, or how favourable the agronomic management is before crop establishment, an unexpectedly adverse variation in the local climate can result in poor crop emergence and establishment, and dramatically increase the risk of yield loss, or even crop failure, due to ineffective crop-weed suppression. 6

Despite these results, triticale, being a derivative of rye, is still assumed to be relatively resistant to abiotic stress. Its high productivity is most likely derived from high rates of carbon assimilation linked to stomatal physiology and, probably, low respiration rate. Triticale retains good to excellent adaptation to conditions of limited water supply and problem soils which involve salinity, low pH, defined mineral toxicities and deficiencies and waterlogging. <sup>7</sup>



The abiotic stress response and adaptation of triticale

Agronomist's guide to information for managing weather and climate

Tools to reduce impact of climate variability—southern region



<sup>1</sup> Agriculture Victoria (2012) Growing Triticale. Note AG0497. Revised. Agriculture Victoria, <a href="http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale">http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale</a>

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<sup>3</sup> CO Qualset and HG Pinto (1996) Triticale: Milestones, Millstones, and World Food. In H. G. Pinto, N. Darvey and V. P. Carnide (Eds.), Triticale: Today and Tomorrow (pp. 5-9). Netherlands: Kluwer Academic Publishers. Sourced in S Tshewang (2011) Frost tolerance in Triticale and other winter cereals at flowering. Master's thesis. University of New England, <a href="https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821jsessionid=C91FFA8964B3A49AD3A44FC3BPD3EA2Fesact=sm.contributor%3A822Birchall+C%22</a>

<sup>4</sup> Barr R. (2016). Diversity the key to balancing frost-heat risks. <a href="https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks">https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks</a>

<sup>5</sup> D Grey, J Nuttal, K Barlow (2015) South east Australian grain growers and advisors rate grain filling heat as a greater risk than frost. 17th Australian Agronomy Conference, 20–24 September, <a href="http://www.agronomy2015.com.au/1031">http://www.agronomy2015.com.au/1031</a>

B Sindel (2008) UHS127: The effect of cultivation and row spacing on the competitive ability of triticale against weeds. GRDC Final Reports. GRDC, <a href="https://finalreports.grdc.com.au/UHS127">https://finalreports.grdc.com.au/UHS127</a>

A Blum (2014) The abiotic stress response and adaptation of triticale: a review. Cereal Research Communications, 42 (3), 359–375.







# 14.1 Frost issues for triticale

#### Key points:

- Frost is estimated to cost south-east Australia at least \$100 million a year in unfulfilled or lost yield potential.
- Frost events can have major and sudden impacts on cereal yields.
- Frost is a relatively rare occurrence but some areas are more prone to it.
- There has been an increase in frost frequency in many areas in the last 20 years.

SOUTHERN

- Minor agronomic tweaks might be necessary in some frost prone areas but most growers should be steady as she goes.
- In the event of severe frost, monitoring needs to occur up to two weeks after the event to detect the full extent of the damage.
- Triticale has been reported as one of the most susceptible cereals to frost. Crop susceptibility to frost from most to least susceptible is triticale, wheat, barley, cereal rye, and oats. 9

Spring radiation frost is of significant importance in Australia, as it causes large yield and revenue losses to the national economy: frost is estimated to cost south-east Australia alone at least \$100 million a year in unfulfilled or lost yield potential. <sup>10</sup> Winter cereals are most susceptible to low temperatures during the reproductive stage as reproductive parts are not protected by the leaf sheaths and ice can nucleate directly on them. As a result of these circumstances, complete or serious yield losses are felt when frost occurs between the booting and grain ripening stages (Photo 1). <sup>11</sup> Identification of winter cereals with reproductive frost tolerance is a priority for frost research in Australia.



<sup>8</sup> D Grey (2014) Frost damage in crops: where to from here? GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-nevelopment/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here">https://grdc.com.au/Research-and-nevelopment/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</a>

<sup>9</sup> GRDC (2009) Managing the risk of frost. Factsheet. GRDC, <a href="https://grdc.com.au/uploads/documents/GRDC\_FS\_Frost.pdf">https://grdc.com.au/uploads/documents/GRDC\_FS\_Frost.pdf</a>

R Barr (2016) Diversity the key to balancing frost heat risks. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks">https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks</a>

<sup>11</sup> N Lee (2014) Frost publication addresses hot research topic. GRDC, <a href="https://qrdc.com.au/Media-Centre/Media-News/West/2014/03/Frost-publication-addresses-hot-research-topic">https://qrdc.com.au/Media-Centre/Media-News/West/2014/03/Frost-publication-addresses-hot-research-topic</a>



TABLE OF CONTENTS

FEEDBACK



Photo 1: Frosted cereal grain head.

Source: GRDC

Once heads and grain have been frosted, small discoloured grain may be produced (Photo 2).  $^{12}$  In addition to direct yield loss, frost also causes economic losses by causing downgraded crop quality through lower organic matter digestibility and lower metabolisable energy. Frost can cause reductions in grain size, decrease flour extraction, decrease dough strength and baking quality, and increases in flour ash and  $\alpha$ -amylase activity. It is estimated that frost causes a monetary loss of A\$1.9 million from quality downgrading (e.g. to feed quality) in Victoria and SA.  $^{13}$ 



**SOUTHERN** 

S Tshewang (2011) Frost tolerance in Triticale and other winter cereals at flowering. Master's thesis. University of New England, <a href="https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821:jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22">https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821:jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22</a>

S Tshewang (2011) Frost tolerance in Triticale and other winter cereals at flowering, Master's thesis. University of New England, <a href="https://epublications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22">https://epublications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22</a>



TABLE OF CONTENTS

FEEDBACK



H20 (CONTROL)

H20 (FROSTED)

**SOUTHERN** 

Source: S Tshewang 2011

# 14.1.1 Triticale and frost

Triticale has been variously rated as susceptible to frost damage (Photo 3). One study has ranked frost resistance in the order of increasing resistance: rye, bread wheat, triticale, barley, oats, and durum wheat, while another study has reported that triticale is the most susceptible crop, followed by wheat, barley, rye and oats. While species difference in frost tolerance do exist, frost damage is also determined by other factors such as crop growth stage and other environmental conditions.

**Photo 2:** Comparison of healthy (left) and frost damaged (right) H20 triticale grain.

One of the anecdotal reasons why a greater area is not devoted to triticale on most farms is the poor tolerance to frost at flowering: in one study, growers said that frost susceptibility was one of the main constraints on triticale production and expansion. <sup>14</sup> While most cereals can suffer some yield loss to frost at flowering, triticale is regarded as one of the most likely of the cereals to suffer serious yield loss in the event of frost from flowering through to soft dough stage. <sup>15</sup>



J Roake, R Trethowan, R Jessop, M Fittler (2009) Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/1A-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/1A-102\_Final\_Research\_Report\_pdf</a>

<sup>15</sup> J Lawes, R Jessop, C Bluett, M Jenkinson (1998) Frost tolerance of triticale varieties 1998. Online Farm Trials, <a href="http://www.farmtrials.com.au/trial/15345">http://www.farmtrials.com.au/trial/15345</a>



**TABLE OF CONTENTS** 

FEEDBACK



**Photo 3:** Frost-damaged grain head of H20 triticale plant (left); and cold damage to triticale leaf (right),

Sources: left, S Tshewang 2011; right, Florida Downunder

# **IN FOCUS**

# Frost tolerance in triticale and other winter cereals at flowering

A series of experiments was conducted to evaluate the relative reproductive frost tolerance in different commercial triticale genotypes, and how they compared with two other winter cereals, wheat and barley. Eight triticales (cv. Bogong(b, Tahara, H2O, H151, H418, H426, JRCT 74 and JRCT 400), four bread wheats (cv. Kite, Ventura, Young and Wyalkatchem), one durum wheat (cv. Bellaroi) and one barley (cv. Kaputar) were tested over two years (2009 and 2010). In addition, the roles of cold hardening and potassium fertilisation in frost tolerance were also investigated using the triticale variety H426. The plants were grown in a glasshouse and treated to a single overnight natural frost at flowering (±5 days). The damage was assessed by counting the number of fertile grains at maturity.

The collated results of two years showed a difference in frost tolerance between the different triticale varieties. However, the difference was not huge and varietal responses were mainly determined by frost temperature. Temperatures particularly below  $-3.90^{\circ}$ C were found to be destructive (Figure 1). At  $-4.2^{\circ}$ C, there was little effect on barley floret survival, while triticale and wheat were severely affected (Figure 2). <sup>16</sup>



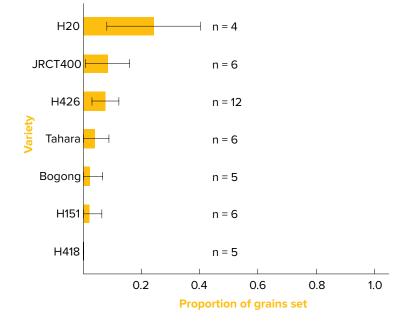
S Tshewang (2011) Frost tolerance in triticale and other winter cereals at flowering. Master's thesis. University of New England, <a href="https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22">https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm\_contributor%3A%22Birchall+C%22</a>







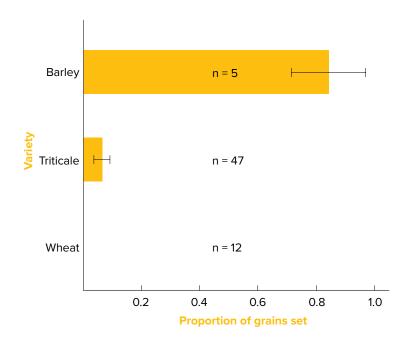




**SOUTHERN** 

**Figure 1:** Proportion of grains set in different triticale varieties at  $-4.2^{\circ}$ C (2009). Bars are the lower and upper 95% confidence interval. N = the number of heads frosted.

Source: S Tshewang 2011



**Figure 2:** Proportion of grains set in different species at  $-4.2^{\circ}$ C (2009). Bars are the lower and upper 95% confidence interval. N = number of heads frosted.

Source: S Tshewang 2011



Frost and plant physiology: Q&A with Glenn McDonald



WATCH: <u>Plant frost mechanisms—</u> explained.





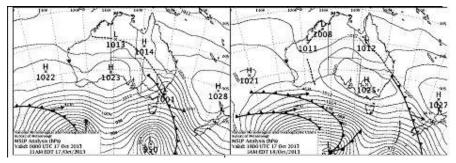




# 14.1.2 Conditions that lead to frost

Clear, calm and dry nights following cold days are the precursor conditions for a radiation frost (or hoar frost). These conditions are most often met during winter and spring where high pressures follow a cold front, bringing cold air from the Southern Ocean and calm, settled, cloudless weather (Figure 3). <sup>17</sup> When the loss of heat from the earth during the night decreases the temperature at ground level to zero, a frost occurs. Wind and cloud reduce the likelihood of frost by decreasing the loss of heat to the atmosphere. The extent of frost damage is determined by how quickly the temperature gets to zero, the length of time its stays below zero, and the how far below zero it gets.

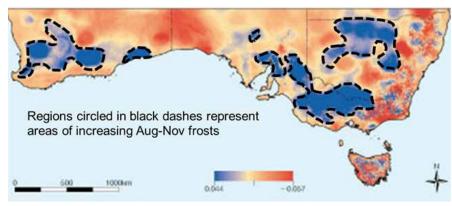
SOUTHERN



**Figure 3:** A cold front passes through, injecting cold air in from the Southern Ocean the day before a frost (left). Overnight, the high-pressure system stabilises over south-east Australia, meaning clear skies and no wind leading to a frost event (right).

Source: GRDC

Though temperatures (particularly in winter and spring) are getting warmer, frost is still a major issue, and likely to remain so. CSIRO researchers have found that in some areas of Australia the number of frost events is increasing (with the greatest increase in August), and that central western NSW, the Eyre Peninsula, Esperance and the northern Victorian Mallee were the only major crop growing areas to be less affected by frost from 1961–2010 (Figure 4). <sup>18</sup> This increase is thought to be caused by the latitude of the subtropical ridge of high pressure drifting south (causing more stable pressure systems) and the existence of more El Niño conditions during this period. <sup>19</sup>



**Figure 4:** Region of increasing August–November frost events.

Source: GRDC



**VIDEOS** 



<sup>17</sup> D Grey (2014) Frost damage in crops: where to from here? GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-bevelopment/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here">https://grdc.com.au/Research-and-bevelopment/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</a>

D Grey (2014) Frost damage in crops: where to from here? GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here">https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</a>

D Grey (2014) Frost damage in crops: where to from here? GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here">https://grdc.com.au/Research-and-development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</a>





# **14.1.3** Diagnosing stem and head frost damage in cereals

Table 1 shows how to diagnose frost damage to stems and heads. Although the information given is for wheat, it applies equally to triticale.  $^{20}$ 

**SOUTHERN** 

**Table 1:** Symptoms of frost during early growth stages.

		<b>Table 1:</b> Symptoms of frost of	3 , 5 5
Crop growth stage	Inspection details	Frost symptoms in wheat	Example
Vegetative (before stem extension)	Examine leaves	Leaves are limp and appear brown and scorched	
Elongation (before and after head emergence)	Pull back leaf sheath or split stem to inspect damage	Stem has a pale green to white ring that usually appears sunken, rough to touch, and soft to squeeze Stem or nodes can also be cracked or blistered	Frost damaged stems
		Stems can be damaged on the peduncle (stem below head) or lower in the plant	Healthy stem
		If the head has emerged it is likely that the flowering parts or developing grain has sustained damage	
		If the head is in the boot then ongoing monitoring is required to assess the level of damage	Frost damaged floret

<sup>20</sup> R Barr (2014) Frost-damage concern for south-eastern Australia. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2014/09/Frost-damage-concern-for-southeastern-Australia">https://grdc.com.au/Media-Centre/Media-News/South/2014/09/Frost-damage-concern-for-southeastern-Australia</a>





# **TABLE OF CONTENTS**

# **FEEDBACK**

#### Crop growth stage

Flowering and postflowering

(Flowering is the most vulnerable stage, because exposed florets cannot tolerate low temperatures and are sterilised)

#### **Inspection details**

Peel back the lemma (husk), inspect the condition of the florets (floral organs) in the head

#### Frost symptoms in wheat

Grain will not form in frosted

Some surviving florets may not be affected

Pollen sacs (or anthers, normally bright yellow) but become dry, banana-shaped and turn pale yellow or white

#### Example



SOUTHERN

Source: GRDC

# What to look for in the paddock

- Symptoms may not be obvious until 5–7 days after the frost.
- Heads on affected areas have a dull appearance that becomes paler as frosted tissue dies (Photo 4). 21
- At crop maturity severely frosted areas remain green longer.
- Severely frosted crops have a dirty appearance at harvest, due to blackened heads and stems and discoloured leaves.



Photo 4: Frost damage in wheat at Black Rock in the South Australian upper north.

Photo: Jim Kuerschner



 $R \ Barr \ (2014) \ Frost-damage \ concern \ for \ south-eastern \ Australia. \ GRDC, \ \underline{https://grdc.com.au/Media-Centre/Media-News/South/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/2014/09/$ Frost-damage-concern-for-southeastern-Australia

**TABLE OF CONTENTS** 



# What to look for in the plant

- Before flowering:
- Freezing of the emerging head by cold air or water is caught next to the flag
  leaf or travels down the awns into the boot. Individual florets or the whole head
  can be bleached and shrivelled, stopping grain formation. Surviving florets will
  form normally.
- Stem frost by a small amount of water that has settled in the boot and frozen around the peduncle. Symptoms include paleness or discolouration, roughness at the affected point on the peduncle, and blistering or cracking of nodes and leaf sheath. Stems may be distorted.
- Flowering head:
- The ovary in frosted flowers feels spongy when squeezed and turns dark in colour. In normal flowers the ovary is bright white and feels crisp when squeezed. As the grain develops it turns green.
- Anthers are dull-coloured and are often banana-shaped. Normal anthers are green to yellow before flowering, or yellow turning white after flowering.
- Grain:
- Frosted grain at the milk stage is white, turning brown, with a crimped appearance. It is usually spongy when squeezed and doesn't exude milk or dough. Healthy grain is light to dark green and plump, and exudes white milk or dough when squeezed (Photo 5).
- Frosted grain at the dough stage is shrivelled and creased along the long axis, rather like a pair of pliers has crimped the grain (Photo 6).



**Photo 5:** A normal cereal head (left) compared to frost-damaged cereal showing discoloured and deformed glumes and awns.

Source: DAFWA



<sup>22</sup> DAFWA (2015) Diagnosing stem and head frost damage in cereals. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-stem-and-head-frost-damage-cereals">https://www.agric.wa.gov.au/mycrop/diagnosing-stem-and-head-frost-damage-cereals</a>









WATCH: GCTV15: Frost ratings



WATCH: GCTV15: The frost ranking challenge



WATCH: GCTV12: Frost susceptibility ranked





SOUTHERN

**Photo 6:** Frosted hollow grain dries back to the typical shrivelled frosted grain.

Source: GRDC

# 14.1.4 Managing frost risk

Key points:

- In some areas the risk of frost has increased due to widening of the frost-event window and changes in grower practices.
- The risk, incidence and severity of frost varies between and within years, as well as across landscapes, so growers need to assess their individual situation regularly.
- The occurrence of frost and subsequent frost damage to grain crops is determined by a combination of factors including: temperature; humidity; wind; topography; soil type, texture and colour; crop species and variety; and how the crop is managed.
- The greatest losses in grain yield and quality are observed when frosts occur between the booting and grain-ripening stages of growth.
- Frost damage is not always obvious and crops should be inspected 5–7 days after a suspected frost.
- Methods to deal with the financial and personal impact of frost also need to be considered in the farm management plan.
- Careful planning and zoning, and choosing the right crops, are the best options to reduce frost risk.  $^{23}$

Significant frost damage has occurred several times in triticale crops in recent years in the eastern cropping regions of north-east Victoria and southern New South Wales. Because triticale suffers more from frost damage than wheat, it should generally be sown later. Although the risk of frosting, particularly in low-lying paddocks, can be reduced by not planting too early, heat stress during grainfill will, potentially, become more of a factor the longer the sowing date is delayed.

It is recommended that main season varieties of triticale not be sown before the end of the first week in May in the south. Newer varieties, which may have more tolerance to the cold, combined with the ability to cope with drier seasons, give growers a significant improvement in variety choice. In regions other than those listed above, and where spring frosts are a likely problem, a delay 7–10 days in sowing compared with main-season wheat varieties should reduce exposure to frosts. The avoidance



<sup>23</sup> GRDC (2016) Managing frost risk: northern, southern and western regions. Tips and Tactics. GRDC, <u>www.grdc.com.au/ManagingFrostRisk</u>







of frost-prone areas (e.g. low lying paddocks and creek areas) will also reduce possible frosting.  $^{\rm 24}$ 

The variability in the incidence and severity of frost means that growers need to adopt a number of strategies as part of their farm management plan. These include pre-season, in-season, and post-frost strategies.

SOUTHERN

There are two types of pre-season management tactics available for growers:

- 1. at the level of farm management planning; and
- 2. within identified frost zones of a farm.

### Farm management planning tactics

#### Step 1: Assess personal approach to risk

Consider your personal approach to risk in your business; every individual will have a different approach. As part of this process, identify and measure the extent of the risk, evaluate risk-management alternatives and tailor the risk advice according to your attitude to and level of comfort with risk. The risk of frost can promote conservative farming practices, which should be carefully and regularly reviewed in light of the latest research.

#### Step 2: Assess frost risk of property

Carefully consider the risk of your property incurring frosts due to the location. Use historical seasonal records and forecasts. Because cold air will flow into lower areas, spatial variability (topography and soil type) across the landscape should also be considered. Temperature-monitoring equipment, such as Tinytags, iButtons and weather stations, can determine temperature variability across the landscape.

#### Step 3: Diversify the business

A range of enterprise options should be considered as part of a farm-management plan to spread financial risk in the event of frost damage. This is subject to the location of the business and skill set of the manager, but the largest financial losses with frost have occurred where growers have a limited range of enterprises or crop types. Intensive-cropping systems, especially those focused on canola and spring wheat, are more at the mercy of frost than a diversified business, as both crops are highly susceptible to frost.

#### Step 4: Zone property and paddock

Paddocks or areas in paddocks that are prone to frost can be identified through past experience, and the use of precision tools such as topographic, electromagnetic and yield maps, and temperature monitors to locate susceptible zones. This can help determine the appropriate management practice to use to mitigate the incidence of frost. Be aware that frost-prone paddocks can be high-yielding areas on a farm when frosts do not occur.

# Frost zone management tactics

#### Step 1: Consider enterprise within a zone

The use of identified frost zones should be carefully considered, for example using them for grazing, hay or oat production, and avoiding large-scale exposure to frost of highly susceptible crops like peas or expensive crops like canola. It may be prudent to sow annual or perennial pastures on areas that frost regularly, in order to avoid the high costs of crop production.



<sup>24</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/iA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/iA-102\_Final\_Research\_Report\_pdf</a>



TABLE OF CONTENTS

FEEDBACK



WATCH: Frost Initiative: Do micronutrients reduce frost risk?



WATCH: MPCN: <u>Copper and frost</u> relationship investigated



#### Step 2: Review nutrient management

Targeting fertiliser (nitrogen, phosphorus, potassium) on high-risk paddocks, and seed rates to achieve realistic yield targets should minimise financial exposure, reduce frost damage and increase whole-paddock profitability over time. These nutrients could be reallocated to lower-risk areas of the farm.

SOUTHERN

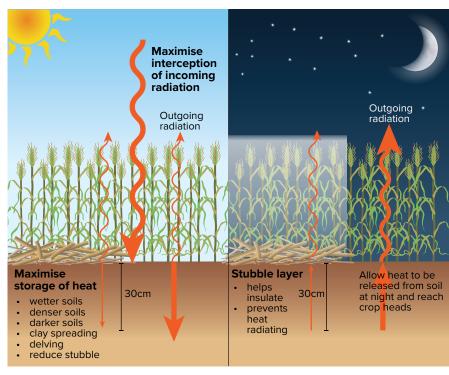
While high levels of nitrogen (N) increase yield potential, N also promotes vegetative biomass production and increases the susceptibility of the crop to frost. Using conservative N rates at seeding and avoiding late top-ups results in less crop damage.

It is best if crops are not deficient in potassium or copper, as this may increase susceptibility to frost events. The levels of these nutrients can be assessed from initial soil tests and with plant-tissue testing. Copper deficiency can be ameliorated with a foliar spray pre-flowering and as late as the booting stage to optimise yield, even in the absence of frost. Potassium plays a role in maintaining cell-water content in plants, and it has been shown that plants deficient in potassium are more susceptible to frost. Soils that are deficient in potassium could benefit from increasing potassium levels at the start of the growing season. However, it is unlikely that there will be a benefit of extra potassium applied to plants that are not potassium-deficient.

There is no evidence that applying other micronutrients has any impact to reduce frost damage.

#### Step 3: Modify soil heat-bank

The soil heat-bank is important for reducing the risk of frost (Figure 5). <sup>25</sup> Farmers can manipulate the way heat-banks operate, to store heat absorbed during the day and release it during the night into the crop canopy, to reduce the impact of a frost event.



**Figure 5:** The soil heat bank has an important role. It captures heat during the day and radiates heat into the crop canopy overnight to warm flowering heads and minimise frost damage. A range of farming practices can be utilised to increase the capacity of the soil heat bank.

Source: GRDC

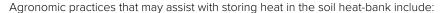


<sup>25</sup> GRDC (2016) Managing frost risk: northern, southern and western regions. Tips and Tactics. GRDC, <a href="https://grdc.com.au/ManagingFrostRisk">https://grdc.com.au/ManagingFrostRisk</a>



**TABLE OF CONTENTS** 





SOUTHERN

- Practices that alleviate non-wetting sands, such as clay delving, mouldboard
  ploughing or spading, have multiple effects, and include increasing heat storage,
  nutrient availability and infiltration rate.
- Rolling sandy soil and loamy clay soil after seeding can reduce frost damage. It
  also prepares the surface for hay cutting should that be necessary.
- Reducing the amount of stubble—stubble loads above 1.5 t/ha in low-production environments (2–3 t/ha) and 3 t/ha in high-production environments (3–5 t/ha) generally increase the severity and duration of frost events, and have had a detrimental effect on yield under frost.
- Halving the normal seeding rates can reduce frost severity and damage by creating a thinner canopy and more tillers, which result in a spread of flowering time. However, weed competitiveness can be an issue.
- Cross-sowing—crops sown twice, with half the seed sown in one direction
  and half in the other, have a more even plant density. This means that heat is
  released from the soil heat-bank more slowly, to warm the crop canopy at head
  height in the early morning when frosts are more severe. This practice, however,
  increases sowing costs.

#### Step 4: Select appropriate crops

Crop selection is an important factor to consider for frost-prone paddocks. Crops grown for hay are harvested for biomass, so the problem of grain loss from frost does not arise. Pasture rotations are a lower-risk enterprise, and oats are the most frost-tolerant crop during the reproductive stage. Barley is more tolerant than wheat at flowering, but it is not known if barley and wheat have different frost tolerance during grainfill. Canola is an expensive crop to risk on frost-prone paddocks, due to high input costs.

Yield Prophet and Flower Power are useful tools to match the flowering time of varieties to your own farm conditions.

#### Step 5: Manipulate flowering times

When cereals are sown in frost-risk areas, a good tactic is to ensure the flowering window of the cropping program is spread widely. This can be done by using more than one variety and manipulating sowing date and planting varieties with different phenology drivers so that crops flower over a wide period during the season. It should be noted that flowering later than the frost may result in lower yields in seasons with hot, dry finishes, as plants will be subjected to heat and moisture stress.

Staging sowing dates over a 3–6-week period is recommended. If sowing just one variety, this would provide a wide flowering window. If sowing more than one variety: sow winter wheat first; then a long-season spring wheat or a day-length-sensitive wheat; then an early-maturing wheat last. A whole-wheat program like this is planned so that flowering occurs over a two-week period, potentially exposing it to more frost risk but maximising the yield potential in the absence of frost. Even with this strategy in place, it is possible to have more than one frost event that causes damage. Flowering over a wide window will probably mean that some crop will be frosted, but the aim is to reduce extensive loss rather than prevent it altogether.

Sowing at the start of a variety's preferred window will achieve higher yields at the same cost as sowing late. Sowing time remains a major driver of yield in all crops, so the primary objective with this tactic is to achieve a balance between crops flowering after the risk of frost has passed and before the onset of heat stress. The loss of yield from sowing late to avoid frost risk is often outweighed by the gains from sowing on time to reduce heat and moisture stress in spring.

Trials have shown that blending a short-season variety with a long-season variety is an effective strategy. However, the same effect can be achieved by sowing one paddock with one variety and the other with another variety to spread risks.



Yield Prophet

Flower Power





**TABLE OF CONTENTS** 



To minimise frost risk there needs to be a mix of sowing dates, crop types and maturity types to be able to incorporate frost avoidance strategies into the cropping system. In years of severe frost, regardless of which strategy is adopted it may be difficult to prevent damage.

SOUTHERN

## **IN FOCUS**

#### Diversity the key to balancing frost and heat risks

Sowing a range of cultivars in their ideal sowing windows will give wheat growers the best chance of balancing the increasing risks of heat and frost damage that are part of climate change. It is more important than ever to optimise the sowing window so that, as much as possible, all wheat flowers in its ideal window to minimise the risk of frost or heat damage.

Growers who plant most of their wheat using a single, high-performing cultivar are likely to struggle to plant their whole wheat program in a time close to the ideal sowing window. This can result in flowering occurring earlier or later than desired; this, in turn, can lead to a higher risk of heat stress if sowing is delayed, or a higher risk of frost if planting too early. For example, if the ideal sowing window is considered to be about five days either side of the target date, growers who sow a single cultivar over three weeks will have sown at least half of their crop (11 days out of 21) outside this window. By comparison, if the wheat program is split between two cultivars, almost 100% of the crop can be sown in its ideal window.

It would be impossible to choose a combination of sowing time and cultivars that would prevent exposure to heat and frost risk. However, trials in South Australia and Victoria on the time of sowing have shown that certain strategies will give crops the best chance, with farmers making different choices depending on the local climate and the duration of the wheat sowing program.

In many regions of Victoria, growers can start with a winter wheat after a rain in April, then move onto slow-spring wheats and then mid-fast cultivars in May. The different maturity drivers of the cultivars mean that they still flower in the ideal window despite being sown at different times, so that overall yield is optimised and risk is minimised.

A time-of-sowing trial at Berriwillock in Victoria showed that where there is soil moisture, sowing early can provide higher yields than traditional sowing dates. In this trial, early rains were simulated with 8 mm of irrigation. (Winter wheats should not be sown dry.)

Currently, winter wheats do not perform particularly well in South Australia. However, three years of trials in different environments have shown that incorporating different cultivars into the program improves overall results. These trials showed that yields decline at a rate of 28 kg/ha per day once sowing extends past the end of the first week in May. In order to maximise average yields, growers should therefore aim to finish seeding by mid-May.

The best strategy to manage heat and frost risk is diversity. By choosing a range of crops, and cultivars with different maturity drivers and optimum sowing dates, growers will have the highest percentage of their program flowering in its ideal window. The opportunities to take advantage of early sowing have never been better, with previous barriers overcome through the use of no-till technologies, summer fallow management, and cheaper chemical control of early pests and diseases.

Researchers are working on developing new cultivars that are better suited for sowing early. But there is no reason most growers can't spread out their sowing by incorporating a few different cultivars with different maturity drivers.





**TABLE OF CONTENTS** 





SOUTHERN

Spreading flowering dates out has turned out to be a bad way to manage frost and heat risk, because the really extreme frost and heat events will affect crops at a very broad range of growth stages. Modelling shows that yields are maximised and variability minimised by getting as much crop to flower during the optimal window as possible.

Growers are better off managing risk by including a variety of crops into their program, including frost tolerant crops like rye, barley or oats, and considering further diversification such as the inclusion of hay or livestock into the business. <sup>26</sup>

#### Step 6: Fine-tune cultivar selection

As no wheat or barley varieties are tolerant of frost, consider using varieties that have lower susceptibility to frost during flowering as a means of managing frost risk to the cropping program while maximising yield potential. There is no point selecting less-susceptible varieties for the whole cropping program if there is an opportunity cost of lower yield without frost.

Preliminary ranking information on current wheat and barley varieties for susceptibility to reproductive frost is available from the <u>National Variety Trial website</u>. A new variety should be managed based on how known varieties of similar ranking are currently managed.

## 14.1.5 New insight into frost events and management

Key points:

- Growers need to consider carefully whether earlier sowing is justified in seasons where warmer temperatures are predicted.
- Warmer temperatures may reduce the frequency of frosts, but also increase the rate of crop development so that crops arrive at the susceptible, post-heading stages earlier.
- Situation analysis of national impact of frost indicates substantial losses in all regions, averaging approximately 10% using current best practice.
- There can be even greater losses in yield potential due to late sowing.
- Continued research into reducing frost risk remains a high priority, despite temperatures increasing overall.
- Variety guides and decision-support software are useful for matching cultivars to sowing opportunities.
- Current variety ratings based on floret damage may not provide a useful guide to frost damage of heads and stems.
- Crops become most susceptible to frost once awns emerge.
- If crop temperature at canopy height drops below -3.5C after awn emergence, crops should be assessed for damage.
- Consider multiple sowing dates and or crops of different phenology to spread risk.



<sup>26</sup> R Barr (2016) Diversity the key to balancing frost heat risks. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2016/01/">https://grdc.com.au/Media-Centre/Media-News/South/2016/01/</a>
Diversity-the-key-to-balancing-frost-heat-risks

**TABLE OF CONTENTS** 

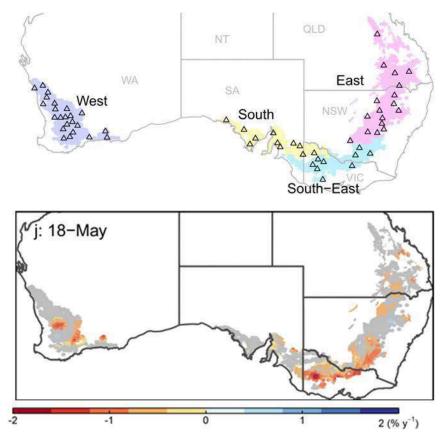


The first nationwide assessment of the comparative impact of frost in different Australian cropping regions provides important insights into how to manage frost risk in our cropping environments.

SOUTHERN

Climate data from 1957–2013 was used to assess the frequency and severity of frost for each region of the Australian cropping belt. <sup>27</sup> Night-time minimum temperatures have been observed to increase over much of the Australian cropping region during that period. However, when researchers analysed the climate data they learned that frost risk and frost impact did not reduce over the whole cropping area during that time. The effect has been that warmer temperatures have accelerated plant development, causing crops to reach the frost-susceptible, heading stages more rapidly. So, counterintuitively, planting earlier or even at the conventional date during warmer seasons may sometimes increase frost risk.

The researchers used historical climate data from a grid database and for 60 locations that represent each of the four major cropping regions of Australia to determine the frequency and severity of frost (Figure 6 top). They used the cropsimulation model Agricultural Production Systems slMulator program (APSIM) to estimate crop yields. Expert knowledge combined with data from frost trials was used to estimate crop losses. The computer simulation allowed them to predict crop losses for all Australian cropping regions, using damage information from a limited number of frost trial sites. It also allowed them to simulate potential yields using sowing dates optimised for yield in the hypothetical absence of frost risk, something that had not been achieved in experiments before.



**Figure 6:** Maps showing sites and regions for which climate data were analysed for the frequency and severity of frosts (top panel) and annual percentage change in yield loss due to frost from 1957 to 2013 (bottom panel). In the lower map, negative values (yellow to red) represent areas where yield loss became worse over recent



<sup>27</sup> J Christopher, B Zheng, S Chapman, A Borrell, T Frederiks, K Chenu (2016) An analysis of frost impact guidelines to reduce frost risk and assess frost damage. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/An-analysis-of-frost-impact-plus-guidelines-to-reduce-frost-risk-and-assess-frost-damage">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/An-analysis-of-frost-impact-plus-guidelines-to-reduce-frost-risk-and-assess-frost-damage</a>



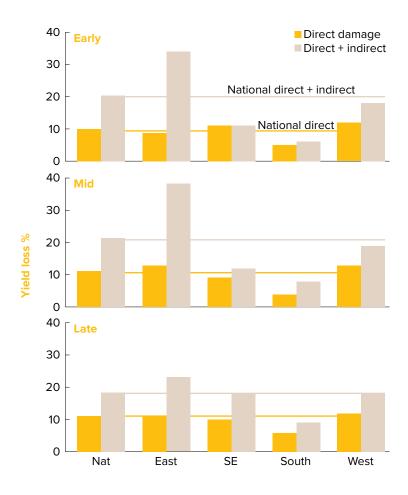


decades. Estimations in the lower panel were for the cultivar Janz, sown 18 May and are based on a  $^{\sim}5$  km  $\times$  5 km grid of climatic data. (Gridded climate data may not reflect local climatic conditions of particular paddocks within each grid, as frost events are highly spatially variable.)

SOUTHERN

Source: GRDC

The study revealed that estimated yield losses due to direct frost damage averaged close to 10% nationally for all crop maturity types, following current sowing guidelines (Figure 7). To estimate the loss of yield potential due to late sowing, which is necessary in many areas to manage frost risk, a theoretical optimal sowing date (as early as the 1 May) was used. When lost yield potential from delayed sowing (indirect cost of frost) was added to direct damage, estimated yield losses approximately doubled to 20% nationally (see Figure 7 'direct + indirect' impact). In the eastern grains region (Queensland to central NSW), losses were even greater, with estimated yield losses due to direct damage and delayed sowing (indirect losses) of 34%, 38% and 23% for early-, mid- and late-flowering cultivars, respectively (Figure 7).



**Figure 7:** Estimated wheat yield losses (%) due to frost damage for crops sown at the current best sowing date ('direct' frost damage), and crop losses due to both direct damage and delayed sowing currently necessitated to manage frost risks (direct + indirect) for early-, mid- and late-flowering crops.

Source: GRDC

In some areas in each region, simulated frost impact has significantly increased between 1957 and 2013 (Figure 6, bottom panel, yellow, orange and tan areas). The estimated date of last frost has come later in some areas, but earlier in others. However, even in areas where it has come significantly earlier, higher temperatures





**TABLE OF CONTENTS** 



have also increased the rate of development to frost-susceptible heading stages. The modelling suggests that crop heading dates have been brought forward more rapidly than the date of last frost, leading to an overall modelled increase in frost impact in many areas.

SOUTHERN

Over time, these trends may have implications for growers making planting decisions. They indicate that sowing early to increase yield potential may not always be the best course of action in warmer seasons, even when a lower frequency of frost events is anticipated. By increasing the rate of crop development, warmer temperatures cause the crop to develop more rapidly to the frost-susceptible, heading stages, which may actually increase frost risk.

These results indicate that continued research to reduce frost risk remains a high priority, despite increasing temperatures due to climate change.

# **14.1.6** Guidelines to reduce frost risk and assess frost damage

### Matching variety to planting opportunity

The current best strategy to maximise long-term crop yields is to aim to time crop heading, flowering and grainfilling in the short window of opportunity after the main frost risk period has passed and before day-time maximum temperatures become too high.

It is essential that varieties are sown within the correct window for the district, as outlined in variety guides.

Planting in the optimum window does not guarantee that crop loss due to frost will be averted, nor does it always prevent drastic yield reduction due to late-season heat and drought stress. However, planting a variety too early gives a much higher probability of crop loss.

With seasonal temperature variation, the days to flowering for each variety will change from season to season, as discussed above.

Current variety ratings based on floret damage may not provide a useful guide. Floret damage ratings are yet to be correlated with more significant head and stem damaging frosts.

#### Measuring crop temperature

In-crop temperature measurements are useful to determine whether a crop may have been exposed to damaging temperatures. A historic comparison of on-farm and district minimum temperatures also allows growers to fine-tune district management recommendations to better suit their property and individual paddocks. District recommendations are based on one, or at best, a few sites, for each district, and may not correlate well with the experience of individual growers. Thus, in many instances, the recommendations likely err on the side of caution.

Stevenson screen temperatures measured at Bureau of Meteorology stations do not fully explain frost risk, either. In crops, the temperature can vary several degrees from the temperature measured in the screen. On nights of still, cold air, clear skies, and low humidity, temperatures can drop rapidly, resulting in radiant frost (Figure 8). Temperatures in a crop can vary widely, due to differences in topography, microenvironments and recording methods.



**TABLE OF CONTENTS** 

FEEDBACK

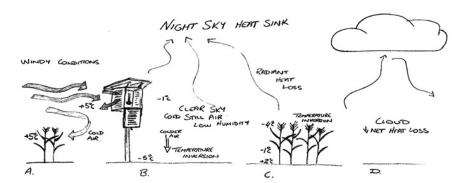


Figure 8: If clear skies and still, cold, low-humidity air coincide, heat can be lost rapidly to the night sky, resulting in a radiant frost. Minimum air temperatures measured at head height can be several degrees colder than reported 'screen' temperatures. Some indicative temperatures are illustrated for (A) windy conditions, (B) clear, still conditions in an open area, (C) clear, still conditions in a crop, and (D) cloudy conditions.

Source: GRDC

Measurements taken using exposed thermometers at canopy height (Photo 7) give a much more accurate indication of the likelihood of crop damage. <sup>28</sup>



**Photo 7:** Canopy temperature measured using a calibrated minimum—maximum thermometer. For best results, a minimum of two or three field thermometers are required to give representative temperatures for a crop. In undulating country, more thermometers should be used to record temperatures at various heights in the landscape.

Source: GRDC

### 14.1.7 What to do with a frosted crop

Once a frost event has occurred, especially at or after flowering, the first step is to inspect the affected crop and collect a random sample of heads to estimate the yield loss incurred.



J Christopher, B Zheng, S Chapman, A Borrell, T Frederiks, K Chenu (2016) An analysis of frost impact guidelines to reduce frost risk and assess frost damage. GRDC Update Paper. GRDC, <a href="https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/An-analysis-of-frost-impact-plus-guidelines-to-reduce-frost-risk-and-assess-frost-damage">https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/An-analysis-of-frost-impact-plus-guidelines-to-reduce-frost-risk-and-assess-frost-damage</a>



**TABLE OF CONTENTS** 



In the event of severe frost (Photo 8),  $^{29}$  monitoring needs to occur for up to two weeks after the event to ensure all the damage is detected. After the level of frost damage is estimated, the next step is to consider options for the crop (Table 2).  $^{30}$ 

SOUTHERN



**Photo 8:** Severely frosted areas such as these mature later and are often stained or discoloured.

Source: DAFWA

### Option 1: Take through to harvest

If the frost is prior to or around growth stage GS 31 to GS 32, most cereals can produce new tillers to compensate for damage, provided spring rainfall is adequate, so it may be worth keeping the crop and harvesting it. Tillers already formed but lower in the canopy may become important. Naturally, tiller response, depends on the location and severity of the damage. Compensatory tillers will have delayed maturity, but where soil-moisture reserves are high, or it is early in the season, they may contribute to grain yield.

A later frost is more concerning as there is less time for compensatory growth. The grain yield needed to recover the costs of harvesting should be determined using gross margins.

#### Option 2: Cut and bale

Cutting and baling is an option when late frosts occur during flowering and through grainfill. Assess crops for hay quality within a few days of a frost and be prepared to cut a larger area than you had intended to before the start of the season. Producing hay can also be a good management strategy to reduce stubble, weed seedbank



<sup>29</sup> DAFWA (2015) Diagnosing head and stem frost damage in cereals. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-stem-and-head-frost-damage-cereals">https://www.agric.wa.gov.au/mycrop/diagnosing-stem-and-head-frost-damage-cereals</a>

<sup>30</sup> R Barr (2014) Frost damage concern for south-eastern Australia. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2014/09/Frost-damage-concern-for-southeastern-Australia">https://grdc.com.au/Media-Centre/Media-News/South/2014/09/Frost-damage-concern-for-southeastern-Australia</a>

**TABLE OF CONTENTS** 



and disease loads for the coming season. This may allow more rotational options in the following season to recover financially from frost, for example to go back to cereal on cereal in paddocks cut early for hay. However, as hay making can be an expensive exercise, growers should have a clear path to market or a use for the hay on the farm before committing to this option.

SOUTHERN

#### Option 3: Grazing, manuring and crop-topping

Grazing is an option after a late frost, when there is little or no chance of plants recovering, or when hay is not an option. Spraytopping for weed seed control may also be incorporated into this option, especially if the paddock will be sown to crop the next year. Ploughing in the green crop is an option to return organic matter and nutrients to the soil, manage crop residues and weeds, and improve soil fertility and structure. The economics need to be considered carefully. 31

Depending on the degree of damage, the grain may still make valuable stockfeed. Severely frosted grain can have metabolisable energy (ME) of approximately 1 MJ/kg lower than unfrosted grain. Provided allowance is made for this, the grain is useful in a feed ration. 32

Table 2: Management options for frost-damaged crops, with advantages and disadvantages.

Options	Potential advantages	Potential disadvantages
Harvest	Salvage remaining grain	Cost may be greater than return
	More time for stubble to break down before sowing Machinery available	Need to control weeds
		Threshing problems
		Removal of organic matter
Hay, silage	Stubble removed	Costs \$35–50/t to make hay
	Additional weed control	Quality may be poor
		Nutrient removal
Chain, rake	Retains some stubble (which	Raking costs \$5/ha
	reduces erosion risk)	Time taken
	Allows better stubble handling	
Graze	Feed value	Inadequate stock to use feed
		Remaining grain may cause acidosis
		Stubble may be difficult to sow into
Spray	Stops weeds seeding Preserves feed quality for grazing Gives time for final decisions Retains feed Retains organic matter	With a thick crop, difficulty getting chemicals onto all of the weeds
		May not be as effective as burning
		Boom height limitation
		Costs \$5/ha plus cost of herbicide
		Some grain still in crop
Plough	Recycles nutrients and retains organic matter  Stops weed seedset  Green manure effect	Requires offset disc to cut straw
		Soil moisture needed for breakdown and incorporation of stubble

GRDC (2016) Managing frost risk: northern, southern and western regions. Tips and Tactics. GRDC, www.grdc.com.au/ ManagingFrostRisk



Jessop RS, Fittler M. (2009). Triticale production manual—an aid to improved triticale production and utilisation. http://www.apri.com. au/1A-102\_Final\_Research\_Report\_.pdf



TABLE OF CONTENTS

**FEEDBACK** 



## **MORE INFORMATION**

Managing frost risk: A guide for southern Australian growers

Ranking cereals for frost susceptibility using frost values—southern region

Managing frost risk



WATCH: GCTV3: Frost R&D



WATCH: GCTV16: National Frost Initiative



Options	Potential advantages	Potential disadvantages
Swathe	Stops weed seedset	Relocation of nutrients to windrow
	Windrow can be baled	Low market value for straw
	Regrowth can be grazed	Poor weed control under swathe
	Weed regrowth can be sprayed	Costs \$20/ha to swathe
		Costs \$5/ha per herbicide to spray
Burn	Recycles some nutrients	Potential soil and nutrient losses
	Controls surface weed seeds	Fire hazard
	Permits re-cropping with disease control	Organic matter loss
	Can be done after rain	

SOUTHERN

JANUARY 2018

Source: GRDC

#### Useful tools

- Yield Prophet
- AgExcellence Alliance has an annotated list of several weather and farming apps.
- Plant-development apps, e.g. MyCrop, DAFWA Flower Power
- Temperature monitors

#### 14.1.8 National Frost Initiative

The objective of the GRDC's National Frost initiative is to provide the Australian grains industry with targeted research, development and extension solutions to manage the impact of frost and maximise seasonal profit. It funds multidisciplinary projects in these areas:

- Genetics—developing more frost-tolerant wheat and barley germplasm, and ranking current wheat and barley varieties for susceptibility to frost.
- Management—developing best-practice crop canopy, stubble, nutrition and agronomic management strategies to minimise the effects of frost, and searching for innovative products that may minimise the impact of frost.
- Environment—predicting the occurrence, severity and impact of frost events on crop yields and at the farm scale to enable better risk management. 33

## 14.2 Waterlogging and flooding issues for triticale

Key points:

- Waterlogging occurs when roots cannot respire due to excess water in the soil profile.
- Though cereals can be more prone to waterlogging than other crops, triticale has been found to be more tolerant of waterlogged conditions than wheat. 34
- Water does not have to appear on the surface for waterlogging to be a problem.
- Improving drainage from the inundated paddock can decrease the period at which the crop roots are subjected to anaerobic conditions.
- While raised beds are the most intensive management strategy, they are also the most effective at improving drainage.
- Waterlogged soils release greater amounts of nitrous oxide (N2O), a particularly damaging greenhouse gas.



GRDC (2016) Managing frost risk: northern, southern and western regions. Tips and Tactics. GRDC, www.grdc.com.au/ ManagingFrostRisk

CJ Thomson, TD Colmer, ELJ Watkin, H Greenway (1992) Tolerance of wheat (*Triticum aestivum* cvs Gamenya and Kite) and triticale (*Triticosecale* cv. Muir) to waterlogging. New Phytologist, 120(3), 335–344.



**TABLE OF CONTENTS** 



Waterlogging occurs whenever the soil is so wet that there is insufficient oxygen in the pore spaces for plant roots to be able to adequately respire (Photo 9). <sup>35</sup> Other gases detrimental to root growth, such as carbon dioxide and ethylene, also accumulate in the root zone and affect the plants.

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Plants differ in their demand for oxygen, so there is no universal level of soil oxygen that can be used to identify what constitutes waterlogged conditions for all plants. In addition, a plant's demand for oxygen in the root zone will vary with its stage of growth. <sup>36</sup>



**Photo 9:** The 2016 July wet had a big impact on producers in Murrumburrah.

Photo: Harden Murrumburrah Express

Many wetland plants are specially adapted to cope with life in waterlogged soils: they have a combination of a high volume of aerenchyma (soft plant tissue containing air spaces) and a barrier to prevent radial oxygen loss (ROL) from roots. The lack of a barrier to ROL in dryland cereals presumably contributes to their sensitivity to soil waterlogging. <sup>37</sup>

Among the cereals, triticale has been reported to be more tolerant of waterlogged conditions than wheat.  $^{38}$  Some farmers have noted that triticale also outperforms barley in areas prone to waterlogging.  $^{39}$  At one farm, Rufus was completely under water for 4–5 days and still yielded 1.34 t/ha. It also carried no rust, and the straw was baled for sale to dairy producers.  $^{40}$ 

Researchers in WA explored the responses of two genotypes of wheat (*Triticum aestivum* cvs Gamenya and Kite) and one genotype of triticale (*Triticosecale* cv. Muir) to waterlogging. They put 23 to 36-day-old plants in a stagnant solution culture and waterlogged soil. The stagnant nutrient solutions decreased shoot fresh weight of Gamenya by 21% compared with aerated plants, while shoot fresh weight of Muir was



<sup>35</sup> Harden Murrumburrah Express (2016) Farmers feel the wet with crops under water. 19 August. Harden Murrumburrah Express, <a href="http://www.hardenexpress.com.au/story/4106306/crops-still-water-logged/">http://www.hardenexpress.com.au/story/4106306/crops-still-water-logged/</a>

 $<sup>{\</sup>tt 36} \quad {\tt D} \; {\tt Bakker}. \; {\tt Waterlogging}. \; {\tt Factsheet}. \; {\tt Soilquality.org.}, \\ {\tt \underline{http://soilquality.org.au/factsheets/waterlogging}. }$ 

<sup>37</sup> Al Malik., AKMR Islam, TD Colmer. Physiology of waterlogging tolerance in wheat, hordeum marinum and their amphiploid

<sup>38</sup> CJ Thomson, TD Colmer, ELJ Watkin, H Greenway (1992) Tolerance of wheat (Triticum aestivum cvs Gamenya and Kite) and triticale (Triticosecale cv. Muir) to waterlogging. New Phytologist, 120(3), 335–344.

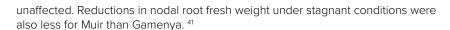
<sup>39</sup> GRDC (2006) Triticale. Ground Cover. No. 59. GRDC. https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-59/Triticale

<sup>40</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/iA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/iA-102\_Final\_Research\_Report\_pdf</a>









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Australian researchers have found that seed size is related to waterlogging tolerance. On average, larger seeds resulted in greater plant growth for triticale cultivars, and seed mass produced greater amounts of biomass and adventitious nodal root mass under waterlogged conditions. 42

## 14.2.1 Where waterlogging occurs

Waterlogging has a greater impact:

- Where water accumulates or drains poorly in areas such as valleys, at the change of slope, or below rocks.
- In duplex soils, particularly sandy duplexes with less than 30 cm sand over clay.
- With deeper-sown crops.
- In crops with low nitrogen.
- In very warm conditions when oxygen is more rapidly depleted in the soil. 43

Waterlogging greatly increases crop damage from salinity. Germination and early growth can be much worse on marginally saline areas after they have been waterlogged.

## **IN FOCUS**

## Constraints and opportunities for crop production in the high-rainfall zone of southern Australia

Annual cropping has been expanding in the high-rainfall zone of southern Australia. The higher rainfall and longer growing season compared with the traditional wheatbelt contribute to a much higher yield potential for major crops. Potential yields range from 5–8 t/ha for wheat and 3–5 t/ha for canola, although at the time of the study, 2006, crop yields were only about half those rates. The researchers wanted to pinpoint ways to close the large gap between potential yield and actual results. They believed that genetic constraints and subsoil characteristics such as waterlogging, soil acidity, sodicity, and high soil strength contributed to the low yields.

They saw waterlogging as a widespread constraint to higher-yielding crop production in the region, and argued that controlling waterlogging using a combination of raised beds and surface or subsurface drains was the first step to raising productivity in the area. Increasing root growth into the subsoil remained a key to plants accessing more water and nutrients for higher yield through early planting, deep ripping, liming and the use of primer crops to improve the subsoil.

They also argued that it was essential to achieve higher optimum dry matter at anthesis and high ear number through agronomic management, including early sowing with appropriate cultivars, a high seeding rate, and applying adequate nitrogen along with other nutrients.

The cultivars of spring wheat then available may not have been fully utilising the growing season and may have genetic limitations in drainage capacity that prevented yields meeting their potential. There was a need to breed or identify cultivars of long-season milling wheat that could fully



CJ Thomson, TD Colmer, ELJ Watkin, H Greenway (1992) Tolerance of wheat (*Triticum aestivum* cvs Gamenya and Kite) and triticale (Triticosecale cv. Muir) to waterlogging. New Phytologist, 120 (3), 335–344.

<sup>42</sup> Singh, D. K., & Singh, V. (2003). Seed size and adventitious (nodal) roots as factors influencing the tolerance of wheat to waterlogging. Crop and Pasture Science, 54(10), 969-977.

DAFWA (2015) Diagnosing waterlogging in cereals. DAFWA, <a href="https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-cereals">https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-cereals</a>







utilise the longer growing season and tolerate waterlogging and subsoil acidity, while being resistant to disease.

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They concluded that improving crop production in the high rainfall zone of southern Australia requires attention to overcoming soil constraints, particularly waterlogging, and the development of longer-season cultivars.  $^{44}$ 

#### Identifying problem areas

The best way to identify problem areas is to dig holes about 40 cm deep in winter and see if water flows into them (Photo 10). If it does, the soil is waterlogged. Some farmers put slotted PVC pipe into augured holes. They can then monitor the water levels in their paddocks. Digging holes for fence posts often reveals waterlogging.

Symptoms in the crop of waterlogging include:

- Yellowing of crops and pastures.
- Presence of weeds such as toad rush, cotula, dock and Yorkshire fog grass.



**Photo 10:** In areas prone to waterlogging, water will fill a hole dug in the soil.
Source: Soilquality.org

## 14.2.2 Symptoms and causes

Waterlogging occurs when the soil profile or the root zone of a plant becomes so saturated with water that there is no longer enough oxygen in the soil (which becomes anaerobic). In rain-fed situations, this happens when more rain falls than the soil can absorb or the atmosphere can evaporate. The lack of oxygen causes plants' root tissues to decompose. Usually this occurs from the tips of roots, and causes the roots to appear as if they have been pruned. The consequence is that the plant's



<sup>44</sup> H Zhang, NC Turner, ML Poole, N Simpson (2006) Crop production in the high rainfall zones of southern Australia: potential, constraints and opportunities. Animal Production Science, 46 (8), 1035–1049.

<sup>45</sup> D Bakker. Waterlogging. Factsheet\_Soilquality.org, http://soilquality.org.au/factsheets/waterlogging





growth and development is stalled. If the anaerobic circumstances continue for a long time the plant will eventually die.

SOUTHERN

JANUARY 2018

Most often, however, waterlogging does not last this long. Once a waterlogging event has passed, plants recommence respiring. If soil conditions are moist, the older roots close to the surface allow the plant to survive. However, further waterlogging-induced root pruning and/or dry conditions may weaken the plant to the extent that it may not recover, and may eventually die.

Many farmers do not realise that a site is waterlogged until water appears on the soil surface. However, by this stage, plant roots may already be damaged and yield potential severely affected.

#### What to look for in the paddock

- Poor germination or pale plants in areas where water collects, particularly on shallow duplex soils (Photo 11). 46
- Wet soil and/or water-loving weeds are present.
- Early plant senescence.



Photo 11: Pale plants in waterlogged areas.

Source: DAFWA

#### What to look for in the plant

- Plants are particularly vulnerable from seeding to tillering, with seminal roots being more affected than the nodal roots, which form later.
- Waterlogged seed will be swollen and may have burst.
- Seedlings may die before emergence, or be pale and weak if they do emerge.
- Waterlogged plants appear to be nitrogen-deficient, with pale plants, poor tillering, and older leaf death.



 $DAFWA~(2015)~Diagnosing~waterlogging~in~cereals.~DAFWA,~\underline{https://www.aqric.wa.qov.au/mycrop/diagnosing-waterlogging-cereals.}$ 





- If waterlogging persists, roots (particularly root tips) cease growing, become brown and then die (Photo 12).
- Seminal roots are important for accessing deep subsoil moisture. If damaged by waterlogging, the plants may be more sensitive to spring drought (Photo 12).

SOUTHERN
JANUARY 2018



**Photo 12:** Waterlogged roots, particularly seminal roots and tips, become brown and then die.

Source: DAFWA

#### How waterlogging can be monitored

Waterlogging can be monitored by:

- Monitoring water levels using bores or observation pits, but keep in mind that water tables can vary greatly over short distances.
- Digging a hole in the paddock and watching for the appearance of water in it—plants can become waterlogged if there is a water table within 30 cm of the surface. There may be no indication on the surface that the soil is waterlogged. Also observe plant symptoms and paddock clues. 47

#### Other impacts of waterlogging and flood events

#### Heat from stagnant water

Stagnant water, particularly if it is shallow, can heat up in hot, sunny weather and kill plants in a few hours. Remove excess water as soon as possible after flooding to give plants the best chance of survival.

#### Chemical and biological contaminants

Floodwater may carry contaminants, particularly from off-farm run-off. You should discard all produce exposed to off-farm run-off, particularly leafy crops.

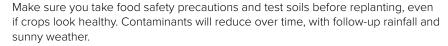


<sup>47</sup> DAFWA (2015) Diagnosing waterlogging in cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-cereals









SOUTHERN

#### Iron chlorosis or nitrogen deficiency

Floods and high rainfall can leach essential nutrients from the soil, which can affect plant health. Nutrients such as iron and nitrogen can be replaced through the use of fertiliser.

#### Soils with high clay content

Soils with a high clay content can become compacted and form a surface crust after heavy rainfall or flooding. Floodwater may also deposit a fine clay layer on top of the soil. The clay layer dries into a crust, which prevents oxygen penetration into the soil (aeration). This layer should be broken up and incorporated into the soil profile as soon as possible.

#### Pests and diseases

Many diseases are more active in wet, humid conditions, and pests can also cause problems then, too. Remove dying or dead plants that may become an entry point for disease organisms or insect pests. Apply suitable disease control measures as soon as possible and monitor for pests. <sup>48</sup>

## 14.2.3 Managing waterlogging

Key points:

- Sow waterlogging-tolerant crops such as oats and faba beans.
- Sow as early as possible with a higher cereal seeding rate.
- Drainage may be appropriate on sandy duplex soils on sloping sites.
- Raised beds are more effective on relatively flat areas and on heavier-textured soils, but areas need to be large enough to justify the machinery costs.

#### Draining

Drainage is usually the best way of reducing waterlogging. Good drainage is essential for maintaining crop health. Wet weather provides a good opportunity to improve the drainage of your crop land, as it allows you to identify and address any problem areas. Drain waterlogged soils as quickly as possible, and cultivate between rows to aerate the soil.

Other management options to reduce the impact of waterlogging include: choice of crop, seeding, fertiliser and weed control.

#### Ways to improve drainage

In the longer term, look for ways to improve the drainage of the affected areas. Options include:

- re-shaping the layout of the field
- improving surface drainage
- · installing subsurface drainage

If the drainage can't be improved, consider using the area for some other purpose (e.g. as a silt trap).  $^{50}$ 



Cropping on raised beds in southern NSW



WATCH: <u>GCTV3: Big Wet—Managing</u> <u>strategies after flooding</u>



WATCH: Over the Fence: Raised beds boost yields at Winchelsea





<sup>48</sup> Queensland Government (2016) Managing risks to waterlogged crops. Queensland Government, <a href="https://www.business.qld.qov.au/">https://www.business.qld.qov.au/</a> industry/agriculture/crop-growing/disaster-recovery-for-crop-farming/saving-crops-floods/managing-risks-waterlogged-crops

 $<sup>49 \</sup>quad \text{DAFWA (2015) Diagnosing waterlogging in cereals. DAFWA, } \underline{\text{https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-cereals.}}$ 

<sup>50</sup> Queensland Government (2016) Improving drainage of crop land. Queensland Government, <a href="https://www.business.qid.qov.au/industry/agriculture/crop-growing/disaster-recovery-for-crop-farming/saving-crops-floods/improving-drainage-crop-land">https://www.business.qid.qov.au/industry/agriculture/crop-growing/disaster-recovery-for-crop-farming/saving-crops-floods/improving-drainage-crop-land</a>









After significant rain or flooding, inspect the crops as soon as it is safe to do so and mark areas (e.g. with coloured pegs) that are affected by poor drainage. If possible, take immediate steps to improve the drainage of these areas so that the water can get away (e.g. by digging drains).

SOUTHERN

#### Irrigation after waterlogging

To avoid the recurrence of waterlogging, time irrigation by applying small amounts often until the crop's root system has recovered.

#### Choice of crop species

Some species of grains crop are more tolerant of waterlogging than others. Grain legumes and canola are generally more susceptible to waterlogging than cereals and faba beans.

Seeding crops early and using long-season varieties help to avoid crop damage from waterlogging. Crop damage is particularly severe if plants are waterlogged between germination and emergence. Plant first those paddocks that are susceptible to waterlogging. However, if waterlogging delays emergence and reduces cereal plant density to fewer than 50 plants/m², re-sow the crop.

#### Seeding rates

Increase sowing rates in areas susceptible to waterlogging to give some insurance against uneven germination, and to reduce the dependence of cereal crops on tillering to produce grain. Waterlogging depresses tillering. High sowing rates will also increase the competitiveness of the crop against weeds, which will take advantage of stressed crops.

#### Nitrogen fertiliser

Crops tolerate waterlogging better if the soil has a good nitrogen status before waterlogging occurs. Applying nitrogen at the end of a waterlogging period can be an advantage if nitrogen was applied at or shortly after seeding because it avoids loss by leaching or denitrification. However, nitrogen cannot usually be applied from vehicles when soils are wet, so consider aerial applications.

If waterlogging is moderate (7–30 days), then nitrogen application after waterlogging events when the crop is actively growing is recommended where basal nitrogen applications were 0–50 kg N/ha. However, if waterlogging is severe (greater than 30 days), then the benefits of nitrogen application after waterlogging are questionable. But this recommendation requires verification in the field at a range of basal nitrogen applications using a selection of varieties.

#### Weeds

Weed density affects a crop's ability to recover from waterlogging. After the water has drained, they will compete with the crop for water and the small amount of remaining nitrogen. The waterlogged parts of a paddock are often weedy, and require special attention if the yield potential is to be achieved. <sup>51</sup>

#### 14.3 Other environmental issues

Triticale will grow on similar soils to wheat and barley, but is also adapted to soils that are too acid for the other cereals. It is relatively tolerant to boron, and is tolerant to high aluminium levels. On alkaline soils where other cereals are affected by manganese, zinc or copper deficiency, triticale is less affected. <sup>52</sup>



Should waterlogged crop be topdresses with N fertiliser?



WATCH: <u>The 2012 N story and planning for 2013</u>





<sup>51</sup> DAFWA (2015) Management to reduce the impact of waterlogging in crops. DAFWA, <a href="https://www.agric.wa.gov.au/waterlogging/management-reduce-impact-waterlogging-crops">https://www.agric.wa.gov.au/waterlogging/management-reduce-impact-waterlogging-crops</a>

Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, http://www.farmtrials.com.au/trial/13801

**TABLE OF CONTENTS** 





SOUTHERN

## 14.3.1 Drought and heat stress

Drought is one of the major environmental factors that reduces grain production in the rain-fed and semi-arid regions of Australia (Photo 13). The direct effects of heat stress are estimated to cost grain growers in south-east Australia almost \$600 million per year and about \$1.1 billion nation-wide. Due to the effects of climate change, both heat stress and frost are likely to play an increasing role in the future and will require growers to take steps to manage the risks. <sup>53</sup>



**Photo 13:** Drought conditions in the Wimmera in 2015 left a dry landscape prone to dust storms.

Photo: Brad Collis, Source: GRDC.

Triticale has been variably rated for its resilience in drought, with one study ranking cereal in terms of highest-yielding under drought conditions in descending order as: barley, complete triticale, durum wheat, bread wheat, substituted triticale, and oats. <sup>54</sup> Triticale is well adapted to conditions where water supply is limited.

Overseas data indicate that under dry conditions triticale's biomass production falls, but that the biomass of wheat normally falls much further, so triticale's relative advantage is likely to become more pronounced during droughts.

These data are backed up by a study in a Mediterranean climate, in which researchers found that yields of wheat dropped significantly (by 25%, 54% and 87%) under drought stress, while those for triticale showed only a slight decrease (8%) in comparison to the irrigated control. It is suggested that the greater drought resistance of triticale can be attributed to the earliness of its heading and to the greater capacity of its roots to extract water from the soil. <sup>55</sup>

In another study, in 1988–89 in Mexico, 24 early triticale lines were tested in under drought stress (mean yield of 1,720 kg/ha–1) and normal conditions (mean yield of 7,180 kg/ha–1) and compared with the best standard wheat cultivar available. Under drought conditions, triticale had a significant yield advantage over wheat.  $^{56}$ 

In 2009, laboratory experiments indicated that common South Australian varieties (Tickit and Credit) were able to accumulate more carbohydrates (sugars) in their



<sup>53</sup> R Barr (2016) Diversity the key to balancing frost heat risks. GRDC, <a href="https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks">https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks</a>

<sup>54</sup> C López-Castañeda, RA Richards (1994) Variation in temperate cereals in rainfed environments II. Phasic development and growth. Field Crops Research, 37 (1), 63–75.

F Giunta, R Motzo, M Deidda (1993) Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranean environment. Field Crops Research, 33 (4), 399–409.

A Blum (2014) The abiotic stress response and adaptation of triticale: a review. Cereal Research Communications, 42 (3), 359–375.



**TABLE OF CONTENTS** 



stems and to translocate them to the grain compared with New South Wales varieties such as Everest and Kosciusko. The better translocation capacity may be related to improved drought tolerance. More detailed field assessment of water relations in triticale compared with wheat is needed, especially with the likelihood of drier conditions associated the current projections on climate change. 57

OUTHERN

Heat stress is a key yield-limiting factor in crop production. Heat-stress affects crop and cereal production in all regions of the Australian wheatbelt. It can have significant effects on grain yield and productivity, with potential losses equal to, and potentially greater than, other abiotic stress such as drought and frost. Controlled-environment studies have established that a 3–5% reduction in the grain yield of wheat can occur for every 1°C increase in average temperature above 15°C. Additionally, field data suggests that yield losses can be in the order of 190 kg/ha for every 1°C rise in average temperature, in some situations having a more severe effect on yield loss than water availability.

Plants are more sensitivity to elevated temperatures during the reproductive stages of growth, with physiological responses including premature leaf senescence, reduced photosynthetic rate, reduced seedset, reduced duration of grainfill, and reduced grain size, all of which lead, ultimately, to reduced grain yield. High temperatures are common and largely unavoidable during the reproductive phase of Australian crops in September and October. 58

In some cereals, heat stress can be identified by the withering and splitting of leaf tips (Photo 14). The tips can also turn brown to grey in colour. In this situation, some or all grains fail to develop in a panicle. 59



Photo 14: Withered and split tips in heat stressed cereal.

Source: DAFWA

## Managing drought stress

Because drought events can be unpredictable and can last extended periods of unknown lengths, it is difficult to prepare for drought conditions.

In drought, it is important to not ignore the signs and to have a plan, act early, review and then plan again, and revise the plan with each action as you play out your strategy.



RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, au/1A-102\_Final\_Research\_Report\_.pdf

P Telfer, J Edwards, H Kuchel, J Reinheimer, D Bennett (2013) Heat stress tolerance of wheat. GRDC Update Paper. 7 February 2013. GRDC. http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Heat-stress-tolerance-of-wheat

DAFWA (2016) Diagnosing heat stress in oats. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-heat-stress-oats









## **MORE INFORMATION**

#### Drought planning

Make sure to consider the impacts of herbicide residues following drought

Winter cropping following drought

Soil management following drought

**Drought Planning** 

Managing Drought

#### Step One: Check the most limiting farm resources:

- mental and physical energy to do the continuous tasks required;
- funds available;
- stock and domestic water available;
- surface/subsoil moisture for crop leaf and root growth;
- need to service machinery breakdowns cost time, money and frustration.

Audit sheets are provided on the following pages to assist in guiding you through the resource audit.

SOUTHERN

#### Step Two: Set action strategies, considering:

- breakeven position of each strategy chosen;
- windows of opportunity to adopt management practices that will be profitable during drought;
- available resources and the implications for ground cover, chemical residues, etc., of carrying out each strategy;
- when situations are changing, conditional and timely fall-back options.

#### Step Three: Monitor and review performance, position and outlook by:

- using your established network to stay informed about key factors that affect your drought strategies;
- being proactive about the decisions made;
- · being prepared for change;
- remembering that the impact falls very heavily not only on the decision makers but on the whole farm family.  $^{60}$

#### Soil management following drought

The principal aim after rain should be to establish either pasture or crop as a groundcover on your bare paddocks as quickly as possible. This is especially important on the red soils, but is also important for the clays. After drought, many soils will be in a different condition to what is considered to be their 'normal' condition. Some will be bare and powdery on the surface, some will be further eroded by wind or water, and some will have higher levels of nitrogen (N) and phosphorus (P) than expected. Loss of effective ground cover (due to grazing or cultivation) leaves the soil highly prone to erosion by wind and water. Research by the former Department of Land and Water Conservation's Soil Services showed that erosion due to drought-breaking rain can make up 90% of the total soil loss in a 20–30 year cycle. Following a drought, available N and P levels in the soil are generally higher than in a normal season. However, most of the N and P is in the topsoil, so if erosion strips the topsoil much of this benefit is lost. <sup>61</sup>

#### Managing heat stress

#### Key points:

- Heat stress has been shown to adversely affect yield as early as growth stage 45.
- Post-flowering heat stress is most common in southern Australia.
- Delayed sowing increases the chance of the crop being exposed to heat stress, particularly at the vulnerable pre-flowering growth stages.

Research in SA suggests that variety selection and early sowing are still the most effective means to reduce the risk of a crop being damaged by excessive heat. A later sown crop will have an increased likelihood of being exposed to the heat stress



<sup>60</sup> Meaker G, McCormick L, Blackwood I. (2007). Primefacts: Drought planning. NSW DPI. <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf\_file/0008/96236/drought-planning.pdf

<sup>51</sup> Jenkins A. (2007). Primefacts: Soil management following drought. NSW DPI. <a href="http://www.dpi.nsw.gov.au/">http://www.dpi.nsw.gov.au/</a> data/assets/pdf
file/0012/104007/soil-management-following-drought.pdf









Managing heat stress in wheat

at more sensitive growth stages, particularly pre-flowering, and will have greater consequences to the potential grain yield.  $^{62}$ 

SOUTHERN

## 14.3.2 Aluminium toxicity

At soil pH levels of below 5, aluminium (AI) and manganese (Mn) become available in soil solution, and can damage root growth and reduce yields. Screening work in flow-culture systems and field observations has indicated that triticale has a range of tolerances to aluminium. For example, Tahara is highly AI-tolerant whilst Empat (an older grazing—grain type) had much poorer AI tolerance. <sup>63</sup>

Triticale grows productively on acidic soils where the high availability of aluminium ions reduces the economic yield of many other crops. <sup>64</sup>

Many triticale cultivars are able to grow better than wheat in high aluminium toxicity soils.  $^{65}$ 

Many of the new varieties have now been screened in flow culture for Al tolerance (Table 3). In the screening system small plants are given an aluminium stress in solution and afterwards examined for root regrowth. The presence of regrowth and its length indicate relative tolerance, with greater length of regrowth being a measure of greater Al tolerance. As expected, the wheat variety (Janz) had poor tolerance, rye was tolerant, and there was a range of tolerances within the triticales, with Canobolas(b) being the most Al-tolerant variety. <sup>66</sup>

**Table 3:** Aluminium tolerance of newer triticales.

Variety	Regrowth length (mm)
Wheat	2.4
Rye	40.6
Tobruk(D	21.0
JCRT 74	29.5
JCRT 75	30.8
Breakwell	36.5
Tahara	35.1
AT528	27.6
H20	27.6
H55	39.6
H116	29.5
Bogong(b	29.5
H128	35.4
H157	29.5
H249	32.8
Canobolas(1)	46.1
H426	48.7

Source: Jessop and Fittler 2009



<sup>62</sup> P Telfer, J Edwards, D Bennett, H Kuchel (2013) Managing heat stress in wheat. Mallee Sustainable Farming, <a href="http://www.msfp.org.au/wp-content/uploads/Managing-heat-stress-in-wheat.pdf">http://www.msfp.org.au/wp-content/uploads/Managing-heat-stress-in-wheat.pdf</a>

<sup>63</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com">http://www.apri.com</a>, au/IA-102\_Final, Research. Report\_bdf

<sup>64</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/05553e00.pdf">http://www.fao.org/3/a-y5553e/05553e00.pdf</a>

<sup>65</sup> M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, <a href="http://www.fao.org/3/a-y5553e/y5553e00.pdf">http://www.fao.org/3/a-y5553e/y5553e00.pdf</a>

<sup>66</sup> RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Trethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, <a href="http://www.apri.com.au/lA-102\_Final\_Research\_Report\_pdf">http://www.apri.com.au/lA-102\_Final\_Research\_Report\_pdf</a>





## Marketing

The final step in generating farm income is converting the tonnes produced into dollars at the farm gate. This section provides best in class marketing guidelines for managing price variability to protect income and cash flow.

## 15.1 Southern feed grains: market dynamics and execution

## **15.1.1** Price determinants for feed grains in southern markets

Stockfeed markets are the biggest consumers of grain domestically. While South Australian markets are export oriented, strong livestock industries in Victoria draw grain into the domestic market. The consumption of grain for domestic stockfeed in southern Australia is equivalent to approximately 40% of the total winter crop produced in SA and Victoria.

Victoria traditionally draws grain in from NSW to support domestic stockfeed markets, as well to meet its bulk and container export programs. Southern Australia accounts for approximately 35% of national stockfeed use. The biggest stockfeed market in southern Australia is the dairy industry, which comprises 40% of the demand for stockfeed in these markets. About 90% of this demand is from Victoria.

In SA, the greatest demand is from the poultry industry, at 50% of South Australia's feed-grain demand (v. 25% in Victoria). Poultry accounts for ~30% of feed demand across southern Australia.

The poultry industry (for eggs and for chicken meat) has seen continued growth, with strong growth expected to continue, especially in South Australia. It is driven by the availability of land and feed grains, and a more favourable regulatory environment.

Similar factors are also driving growth in the production of pig meat in South Australia. The pig industry is the third largest consumer of feed grains across southern Australia, representing 13% of demand. It is the second largest consumer in South Australia, at nearly 25%.

The other major source of demand for stockfeed in southern markets is Tasmania, with grain being exported from Victoria for the dairy and aquaculture industries.

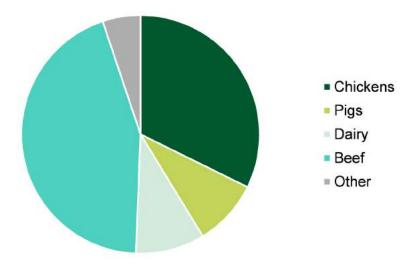


Figure 1: Sources of demand for stock feed in southern Australia.



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The key drivers of prices for feed grains in southern markets include:

- The rate of exports, and the remaining supply of feed grains for domestic markets.
- Commodity prices in the consuming industry (i.e. meat prices).
- Trends in the dairy industry (i.e. milk price).
- Consumption trends in domestic livestock markets.
- Livestock health
- Seasonality and the supply of pasture and fodder v. grain.
- Imports of alternate feed sources (i.e. soybean meal).
- Prices of competing feed grains.

Demand for grain from stockfeed markets tends to be steady throughout the year. However, knowing there is strong competition from the export market, some buyers will seek to secure their requirements shortly after harvest, when the supply of grain is more certain.

Demand for grain from stockfeed markets tends to be steady throughout the year. However, some buyers, knowing there is strong competition from the export market, will seek to secure their requirements shortly after harvest, when the supply of grain is more certain.

## 15.1.2 Converting tonnes into cash

When it comes to accessing domestic stockfeed markets, there are three ways this can be approached:

- Sale to a feed miller or manufacturer.
- Sale directly to a farm or other end-user.
- Sale to a trader or merchant who on-sells the grain to the stockfeed market.

Principle: Always keep written records.

Thorough record keeping is everyone's responsibility, not just the buyer's.

Each organisation will differ in:

- its professionalism;
- · how it manages grain requirements and purchases; and
- · its documentation and record keeping.

Hence it is prudent when making sales into any market to be vigilant in maintaining your own records of contracts, even when they are executed by phone. It is strongly advised that the seller keeps a written record of the particulars of the contract, including price, quantity, quality, and delivery and payment terms, to protect themselves in the event of a dispute with the counterparty over the details of the sale agreement.

It is even better practice to send a confirmation of contract to the buyer in the event that they don't provide one to you, and even if they do. Grain Trade Australia provides standard contract documents which can be completed by either party and returned to the buyer by email as confirmation of a verbal contract (Figure 2). This way, any misunderstandings that may have taken place on the phone can be quickly identified and rectified while the conversation is still fresh in the minds of both parties.

#### How to sell for cash

Like any market transaction, a cash—grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components, with each component requiring risk to be managed:

 Price—future price is largely unpredictable, so devising a selling plan to put current prices into the context of the farm business is critical to managing price risk.



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 Quantity and quality—when entering a cash contract you are committing to deliver the nominated amount of grain at the quality specified, so production and quality risk must be managed.

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JANUARY 2018

- Delivery terms—the timing of the title transfer from the grower to the buyer is agreed at the time of contracting. If the contract requires delivery directly to end-users, the seller must manage operations to ensure delivery within the contracted period.
- Payment terms—in Australia, the traditional method of contracting requires title on the grain to be transferred ahead of payment, so counterparty risk must be managed.





**TABLE OF CONTENTS** 

Grain Trade Australia is the industry body ensuring the efficient facilitation of commercial activities across the

contract trade and dispute resolution

rules. All wheat contracts in Australia

Quantity (tonnage) and quality (bin grade) determine the actuals of your

Price basis or price point is important as it determines where in the supply

chain the transaction will occur and

so what costs will come out of the price before the growers net return.

Timing of delivery (title transfer) is

agreed upon at time of contracting.

Hence growers negotiate execution and storage risk they may have to

Whilst the majority of transactions

are on the premise that title of grain

is transferred ahead of payment this

is negotiable. M anaging counterparty

commitment. Production and execution risk must be managed.

Price is negotiable at time of

contracting.

manage.

risk is critical.

grain supply chain. This includes

should refer to GTA trade and

dispute resolution rules.

FEEDBACK

#### GTA Contract No.3 CONTRACT CONFIRMATION GTA Trade Rules and Dispute Resolution Rules apply to this contract GRAIN TRADE AUSTRALIA SELLER Contract No: Contract No: Name: Name: Company: Company: Address: Address: Buyer ABN: Seller ABN NGR No: NGR No: The Buyer and Seller agree to transact this Contract subject to the following Terms and Conditions: Commodity: GTA Commodity Reference: Grade: Inspection: (Origin - Destination) Packaging Weights: (Origin - Destination) Price: Excl/Inc/Free GST Delivery/Shipment Period: Delivered, Shipped, Free In Store, Free On Board, Ex-Farm, etc. Delivery Point and Conveyance: Payment Terms: The buyer agrees to pay the seller within of week of delivery. In the absence of a declaration, payment will be 30 days end Levies and Statutory Charges: Any industry, statutory or government levies which are not included in the price shall be deducted as required by law. Disclosures: Is any of the crop referred to in this contract subject to a mortgage. Encumbrance or lien and/or Plant Breeders Rights and/or EPR liabilities and/or registered or unregistered Security Interest? ONO OYES (Please appropriate box) If "yes" please provide details: Other Special Terms and Conditions: All Contract Terms and Conditions as set out above and on the reverse of this page form part of this Contract. Terms and Conditions written on the face of this Contract Confirmation shall overrule all printed Terms and Conditions on the reverse with which they conflict to the extent of the inconsistency. This Contract comprises the entire agreement between Buyer and Seller with respect to the subject matter of this Contract. Recipient Created Tax Invoice (RCTI). Incorporation of GTA Trade & Dispute Resolution Rules: To assist with the processing of the Goods and Services Tax This contract expressly incorporates the GTA Trade Rules in force at

Figure 2: Typical cash contract of Grain Trade Australia.

This Contract has been executed and this form serves as confirmation and should be signed and a copy returned to the buyer/seller immediately,

compliance, the buyer may prepare, for the seller, a Recipient Created Tax Invoice (RCTI). If the seller requires this service they are required

PRINT NAME

to sign this authorisation.

Buyer's Name:

Buyer's Signature:

Please issue a RCTI (Please )

GGTA. For GTA member use only



2014 Edition

the time of this contract and Dispute Resolution Rules in force at the

controversy or claim arising out of, relating to or in connection with this contract, including any question regarding its existence, validity

PRINT NAME

commencement of the arbitration, under which any dispute,

or termination, shall be resolved by arbitration.

Seller's Name:

Seller's Signature:

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Most sales involve transferring the title of the grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

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Principle: Seller beware.

Know your counterparty.

Counterparty risk management includes:

- Dealing only with known and trusted counterparties.
- Conducting a credit check (banks will do this) before dealing with a buyer they
  are unsure of.
- Selling only a small amount of grain to unknown counterparties.
- Considering credit insurance or a letter of credit from the buyer.
- Never delivering a second load of grain if payment has not been received for the first.
- Not parting with the title before payment, or requesting and receiving a cash deposit of part of the value ahead of delivery. Payment terms are negotiated at time of contracting.

Above all, act commercially to ensure that the time invested in implementing a selling strategy is not wasted by the poor management of counterparty risk. Achieving \$5/t more on paper and not getting paid is a disastrous outcome.

#### Read market signals

The appetite of buyers for a particular commodity will differ over time, depending on market circumstances. Ideally, growers should aim to sell their commodity when buyer appetite is strong, and stand aside from the market when buyers are not very interested.

Principle: Sell when there is buyer appetite.

When buyers are chasing grain, growers have more market power to demand the price they want.

Buyer appetite can be monitored by:

- The number of buyers at or near the best bid in a public bid line-up. If there are
  many buyers, it could indicate that buyer appetite is strong. However, if one
  buyer is offering \$5/t above the next best bid, it may mean that cash prices are
  susceptible to falling \$5/t as soon as that buyer satisfies their appetite.
- Monitoring actual trades against public indicative bids. When trades are
  occurring above indicative public bids it may indicate strong appetite from
  merchants and the ability for growers to offer their grain at price premiums to
  public bids.

#### Know the specifications of your grain

A grower who knows the specifications of their grain can set more realistic sales goals and source appropriate markets more quickly.

Principle: Know your specs.

Grades don't always convey quality.

Feed grades of grain, as defined by bulk-handler receival standards, can have very broad quality specifications. For the lowest grades, there is often no minimum tolerance on screenings or protein; hence, no two parcels are the same.

The important factor for the stockfeed market is not what grade the grain is, but what proportion of energy and protein the grain contains, as these ultimately determine conversion into meat or other animal products. Hence, growers who have their grain









tested and know its specifications will know exactly what the value of the grain will be in the production system.

Without this information, the buyer may base their pricing on the minimum specification or likely worst-case scenario, to protect themselves in the event that they receive grain of the lowest quality allowable in the grade specification. However, if a buyer knows why the grain was downgraded and the specifications of that load of grain, they may pay a premium, because they will know the exact quality the seller is offering.

## 15.1.3 Ensuring access to markets

Planning on where to store the commodity after harvest is important in ensuring access to the market that is likely to yield the highest return.

In South Australia, the predominant animal industries of pigs and poultry are highly intensive and tend to be geographically concentrated. Hence, proximity to these markets can be an important determinant of market access. In a practical sense, some growers may not have access to markets, because large distances between production and demand make the cost of transport so high that it cancels out potential profits.

In Victoria, the dominant dairy market is concentrated in Gippsland, the Western Districts and the Goulburn Valley. Here, too, proximity to the market must be considered as part of any marketing plan to access demand from the stockfeed industry.

The market for feed grains into Tasmania is often serviced by feed manufacturers and traders who export the grain by truck and ferry from Melbourne.

#### Storage and logistics

The return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access, so as to maximise returns as well as harvest logistics.

Storage alternatives include variations of bulk handling, private off-farm storage, and on-farm storage. Delivery and quality management are key considerations in deciding where to store the commodity (Figure 3).

Commodities destined for the domestic end-user market (e.g. feedlot, processor, or container packer), may be more suited to on-farm or private storage, to increase delivery flexibility.

Storing commodities on the farm requires prudent quality management to ensure that the grain is delivered to the agreed specifications. If not well planned and carried out, it can expose the business to high risk. Penalties for out-of-specification grain arriving at a buyer's weighbridge can be expensive, as the buyer has no obligation to accept it. This means the grower may have to incur the cost of taking the load elsewhere, and may also have to find a new buyer.

On-farm storage also requires prudent delivery management to ensure that they buyer receives the commodities on time and with appropriate weighbridge and sampling tickets.

**Principle:** Storage is all about market access.

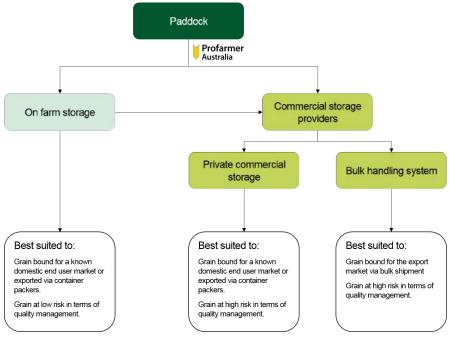
Storage decisions depend on quality management and expected markets.



**TABLE OF CONTENTS** 







**Figure 3:** Grain storage decision making: the storage chosen depends on the market growers want to access.

#### Separate delivery and pricing

Principle: Separate the delivery decision from the pricing decision.

Organised stockfeed buyers who have a clear outlook as to what their grain requirements will be across the season may seek to purchase their grain in advance of delivery; i.e. they may purchase grain in March for delivery between May and July. This provides the seller with the opportunity to obtain price certainty immediately, even though delivery may not take place for months.

The benefit of this is that a seller can capture strong value when it presents, even though it may not be a convenient time to arrange delivery. Or the seller can create cash-flow certainty for a known future commitment at today's price.

#### Cost of carrying grain

Storing grain to access sales opportunities post-harvest invokes a cost to 'carry', or hold, the grain. Price targets for carried grain need to account for the cost of carrying it. Carrying costs for canola are typically \$4–5/t per month and consist of:

- 1. Monthly storage fee charged by a commercial provider, typically  $^{\sim}$ \$1.50–2.00/t
- 2. Monthly interest associated with having wealth tied up in grain rather than available as cash or to pay off debt, ~\$2.50-\$3.00/t, depending on the price of the commodity and interest rates.

The price of carried grain therefore needs to be \$4–5/t per month higher than the price offered at harvest.

The cost of carrying also applies to grain stored on the farm, as there is the cost of the capital invested in the farm storage plus the interest component to cover. A reasonable assumption is a cost of \$4–5/t per month for on-farm storage.

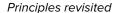
Principle: Carrying grain is not free.

The cost of carrying grain needs to be accounted for if holding if for sale after harvest is part of the selling strategy.









- . Always keep written records: thorough record keeping is everyone's responsibility, not just the buyer's.
- 2. Seller beware: know your counterparty.
- 3. Sell when there is buyer appetite: when buyers are chasing grain, growers have more market power to demand the price they want.

SOUTHERN

- 4. Know your specs: grades don't always convey quality.
- 5. Storage is all about market access: storage decisions depend on quality management and expected markets.
- 6. Separate the delivery decision from the pricing decision.
- 7. Carrying grain is not free: the cost of carrying grain needs to be accounted for if holding for sale after harvest is part of the selling strategy.

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GRDC, Stored Grain Information Hub

Stockfeed Manufacturers Council of Australia

Australian Fodder Industry Association

Grain Trade Australia membership

Grain Trade Australia, A guide to taking out grain contracts

Grain Trade Australia, <u>Trade rules</u>, <u>contracts and vendor declarations</u>

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Grain Trade Australia, Managing counterparty risk

GrainGrowers, Managing risk in grain contracts

Leo Delahunty, Counterparty risk: A producer's perspective









SOUTHERN

# Project Summaries www.grdc.com.au/ProjectSummaries

As part of a continuous investment cycle each year the Grains Research and Development Corporation (GRDC) invests in several hundred research, development and extension and capacity building projects. To raise awareness of these investments the GRDC has made available summaries of these projects.

These project summaries have been compiled by GRDC's research partners with the aim of raising awareness of the research activities each project investment.

The GRDC's project summaries portfolio is dynamic: presenting information on current projects, projects that have concluded and new projects which have commenced. It is updated on a regular basis.

The search function allows project summaries to be searched by keywords, project title, project number, theme or by GRDC region (i.e. Northern, Southern or Western Region).

Where a project has been completed and a final report has been submitted and approved a link to a summary of the project's final report appears at the top of the page.

The link to Project Summaries is <a href="www.grdc.com.au/ProjectSummaries">www.grdc.com.au/ProjectSummaries</a>

## Final Report Summaries http://finalreports.grdc.com.au/final\_reports

In the interests of raising awareness of GRDC's investments among growers, advisers and other stakeholders, the GRDC has available final reports summaries of projects.

These reports are written by GRDC research partners and are intended to communicate a useful summary as well as present findings of the research activities from each project investment.

The GRDC's project portfolio is dynamic with projects concluding on a regular basis.

In the final report summaries there is a search function that allows the summaries to be searched by keywords, project title, project number, theme or GRDC Regions. The advanced options also enables a report to be searched by recently added, most popular, map or just browse by agro-ecological zones.

The link to the Final Report Summaries is <a href="http://finalreports.grdc.com.au/final\_reports">http://finalreports.grdc.com.au/final\_reports</a>

# Online Farm Trials http://www.farmtrials.com.au/

The Online Farm Trials project brings national grains research data and information directly to the grower, agronomist, researcher and grain industry community through innovative online technology. Online Farm Trials is designed to provide growers with the information they need to improve the productivity and sustainability of their farming enterprises.

Using specifically developed research applications, users are able to search the Online Farm Trials database to find a wide range of individual trial reports, project summary reports and other relevant trial research documents produced and supplied by Online Farm Trials contributors.

The Online Farm Trials website collaborates closely with grower groups, regional farming networks, research organisations and industry to bring a wide range of









crop research datasets and literature into a fully accessible and open online digital repository.

Individual trial reports can also be accessed in the trial project information via the Trial Explorer.

The link to the Online Farm Trials is <a href="http://www.farmtrials.com.au/">http://www.farmtrials.com.au/</a>







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SOUTHERN

**TABLE OF CONTENTS** 





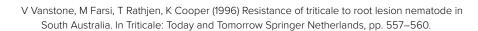
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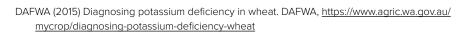


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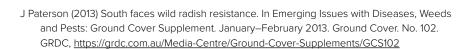
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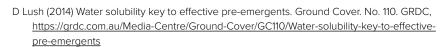
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**TABLE OF CONTENTS** 





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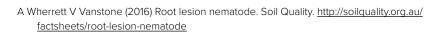
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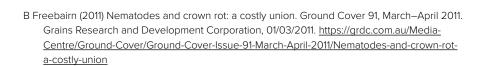


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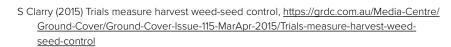
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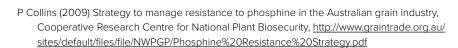
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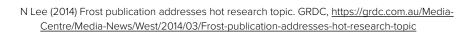
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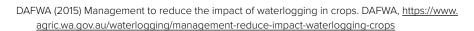
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**TABLE OF CONTENTS** 





SOUTHERN

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