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GROWNOTES

DURUM

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GRAINS RESEARCH & DEVELOPMENT CORPORATION

What's New - October 2016

The GRDC GrowNotes are dynamic documents that are updated according to user feedback and newly available information.

This version of the GRDC Durum GrowNotes, updated in October 2016, contains the following updates on original content published in March 2014:

Section 1: Planning/Paddock preparation

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- C McMaster, N Graham, J Kirkegaard, J Hunt, I Menz, (2015) "Buying a spring" – the water and nitrogen cost of poor fallow weed control. http://www.agronomy2015.com.au/1238
- K Verburg, B Cocks, T Webster, J Whish, (2015) Methods and tools to characterise soils for plant available water capacity (Coonabarabran). https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Methods-and-tools-to-characterise-soils-for-plant-available-water-capacity-Coonabarabran
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- D Freebairn (2016) SoilWaterApp – a new tool to measure and monitor soil water. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/SoilWaterApp-a-new-tool-to-measure-and-monitor-soil-water
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SECTION A

Introduction

A.1 Crop overview

Durum wheat (*Triticum turgidum* L. *var. durum*) or pasta wheat (Figure 1) is known for its hardness, protein, intense yellow colour, nutty flavour and excellent cooking qualities. In 2005–06, production was ~500,000 tonnes (t), with New South Wales (NSW) accounting for around 56% and South Australia (SA) 41% of production. The balance is produced in Queensland and Victoria. [1]

Durum wheat should only be grown on highly fertile soils where high-protein grain can be produced, as protein levels >13% are required to meet premium market grades. Protein levels below 10% can be marketed only as feed. [2]

A.2 Keywords

Durum, northern grains region, winter cereals, crop rotation, fallow weed control, cereal diseases, root-lesion nematodes, water use efficiency, nitrogen use efficiency, soil testing, crown rot, Fusarium head blight, protein, pasta, crop nutrition and fertiliser.

Figure 1: Durum wheat.

[1] J Kneipp (2008) Durum wheat production. NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

[2] DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

SECTION 1

Planning and paddock preparation

For more information, see the *GRDC GrowNotes WHEAT (Northern region),* Section 1: Planning and paddock preparation.

1.1 Paddock selection

Select paddocks that are fertile, and store good levels of stored water or receive reliable in-crop rainfall or have access to supplementary irrigation. Durum wheat must only be grown where a reliable harvest of high protein (13%+), plump hard vitreous grain can be produced. The highest grade of durum (ADR1) must have a minimum protein level of 13% and ADR2 >11.5%. Careful management of soil nitrogen (N) is essential to achieve this. [1]

Durum wheats should not be sown into paddocks known to carry high levels of crown rot inoculum. A suitable rotation should be practised to reduce the crown rot inoculum levels. Paddocks that were planted to corn in the previous season should be avoided. Ground preparation is the same as that for bread wheat. Adequate weed control should eliminate all weeds and volunteer plants of bread wheat, barley or other crop species. [2]

1.2 Paddock rotation and history

Figure 1: Rotations with non-cereal species, including canola, are important for durum paddocks.

Crop rotations using pulses, canola, sorghum, sunflower and pasture legumes are essential to control disease, and also to provide opportunities for weed control. A robust crop rotation must be planned over a number of seasons if successful crops of durum wheat are to be produced. [3]

1 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

2 DAFF (2012) Durum wheat in Queensland, Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

3 J Kneipp (2008) Durum wheat production. NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

Rotations with non-cereals, including pulses, canola, pasture legumes (especially lucerne) and sunflowers, are essential in order to:

- control root disease, especially crown rot
- provide for the biological fixation of N_2 through legumes
- control weeds and contaminant crop species, and aid in herbicide group rotation.

Durum should be the first cereal crop after a non-cereal species. Avoid successive durum crops. [4]

1.3 Benefits of durum as a rotation crop

Generally, durums are relatively resistant to the root lesion nematode, *Pratylenchus thornei*, compared with other winter cereal crops. Durum crops in rotation reduce the nematode count in the soil.

More information

C McMaster, N Graham, J Kirkegaard, J Hunt, I Menz, (2015) "Buying a spring" – the water and nitrogen cost of poor fallow weed control.

1.4 Disadvantages of durum as a rotation crop

Durum will more rapidly build up crown rot inoculum that can negatively affect subsequent winter cereal crops.

1.5 Fallow weed control

Good weed control can be achieved effectively by controlling weeds in preceding crops and fallow, rotating crops, growing competitive durum crops, and the judicious use of herbicides. It is important to control weeds such as New Zealand spinach, climbing buckwheat (black bindweed) and Mexican poppy, as their small black seeds can be difficult to remove from the grain, affecting consumer acceptance. [5] Controlling these winter weeds in both preceding crops and winter fallows is important for subsequent durum crop quality.

More information

K Verburg, B Cocks, T Webster, J Whish, (2015) Methods and tools to characterise soils for plant available water capacity (Coonabarabran).

G Wockner, D Freebairn, (2016) Commonly asked questions about soil water and soil management.

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D Freebairn (2016) SoilWaterApp – a new tool to measure and monitor soil water.

K Verburg, J Which, (2016) Drivers of fallow efficiency: Effect of soil properties and rainfall patterns on evaporation and the effectiveness of stubble cover.

1.6 Seedbed requirements

Quality seed for planting is essential. Only use seed that has a high germination rate, is large and plump, is genetically pure, and is free of all contaminants such as weed seeds and impurities of other winter cereals, in particular bread wheat and barley. Seed must be treated with an appropriate fungicide to avoid head disease (smuts and bunts) and leaf diseases (stripe rust).

Plant seed into a cultivated or chemically prepared seedbed at around 4–6 cm depth and preferably use minimum disturbance equipment with a press wheel adjusted to soil and moisture conditions. Seeding rates and sowing times will vary from state to state, so consult local information. [6]

1.7 Soil moisture

While ~20% of rain is stored during fallows, small changes in soil management can improve this apparent low water efficiency and have large impacts on profit.

Water stored can be improved through longer fallow, weed control, soil cover and reduced compaction. This can be achieved through reduced tillage, controlled traffic and planting crops before the soil fills.

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4 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

5 DAFF (2102) Durum wheat in Queensland, Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

6 J Kneipp (2008) Durum wheat production. NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

Stubble retention combined with reduced or zero tillage almost universally results in better water storage.

Better water storage results in better yields, especially in dry years.[7]

1.7.1 Dryland

In NSW, the major production area is in the north, and in Queensland it is the Darling Downs and central Queensland. Northern NSW and southern Queensland share similar, summer-dominant rainfall conditions The Vertosol soils of both the Darling Downs and the Liverpool Plains are typically deep, friable black clays capable of storing plant-available water to the depth of 1 m+. Most fallows are no-tilled to maximise storage of moisture from summer rainfall. [8]

1.7.2 Irrigation

Durum wheat is grown successfully under irrigated conditions in most of the production areas, using both surface and overhead irrigation systems. Both water and N management are crucial if high-yielding crops of high-quality grain are to be achieved. In northern NSW, irrigated crops have yielded 8–10 t/ha with ~3.5 megalitres (ML) water/ha. [9]

1.8 Yield and targets

Eight commercial durum crops were monitored in 1999 in the Liverpool Plains (northern NSW) to identify the factors limiting durum wheat yields and the levels for target yields. WHEATMAN-generated values for critical plant and soil parameters for durum production were used as benchmarks. Low plant population (42–91 plants/m^2) resulting from poor seed quality (60–95% germination), combined with insufficient nitrate supply (3–27 kg N/ha at harvest at four of five sites) appeared to be major factors limiting durum yields in the monitored crops (range 4.3–5.3 t/ha). Disease management was also likely to be a contributing factor, as crown rot levels in the wheat paddocks were <5% following sorghum and 15–30% following wheat. [10]

1.8.1 Water-use efficiency

Plant breeders in the Durum Breeding Australia project (NSW DPI and The University of Adelaide) and researchers at CSIRO Plant Industry (Canberra) are breeding water-use-efficient and salt-tolerant durum wheats to increase durum yields in current production areas as well as new environments.

Researchers are improving water-use efficiency by trying to combine several traits: high transpiration efficiency, long coleoptiles and early vigour. They have found, using 50 years of climate data and computer simulation, that combining high transpiration efficiency and early vigour is likely to make durum wheat much more suitable for growing in both southern and northern cropping areas.

Elite durum varieties have low transpiration efficiency, but the research team has found a highly transpiration-efficient durum to cross with them. This will give the plants a water-use efficiency trait similar to that of the HRZ wheats Drysdale⦻ and Rees⦻.

The team is also introducing alternative dwarfing genes from European durum wheats into commercial varieties. These genes restrict plant height, but allow the expression of long coleoptiles (about 15 cm compared with 9cm for Tamaroi⦻).

7 D Freebairn (2016) Improving fallow efficiency. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Improving-fallow-efficiency

8 J Kneipp (2008) Durum wheat production. NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

9 J Kneipp (2008) Durum wheat production. NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

10 GJ Butler, PT Hayman, DF Herridge, T Christian. (2001) Working with farmers to benchmark high-yielding durum wheat on the Liverpool Plains. 10th Australian Agronomy Conference. Australian Society of Agronomy/The Regional Institute Ltd, http://www.regional.org.au/au/asa/2001/4/b/butler.htm

Longer coleoptiles provide insurance that the shoot will reach the soil surface, even when deep sowing is required because of receding topsoil moisture, or when there is uneven sowing depth due to stubble or direct drilling. Durum lines combining the high transpiration efficiency and long coleoptiles may be available within 4–5 years.

CSIRO and NSW DPI are developing salt-tolerant durum wheats, to allow durum to be grown in areas affected by subsoil salinity. This follows a search of the Australian Winter Cereal Collection in Tamworth that revealed ancient Persian durum wheats have the ability to exclude salt from their roots. Elite lines derived from crosses between Tamaroi ⏀ and the sodium-excluding ancestors were grown in saline and non-saline soils for the first time in the 2004 season.

The team has identified two major genes that confer the salt tolerance, and a molecular marker has been found for one. There is ongoing research to find a marker for the other. The research is being conducted through the AUSGRAINZ joint venture between CSIRO and NZ Crop and Food Research (GRDC Research Codes: CSP344, CSP298, CSP00058).[11]

1.8.2 Nitrogen-use efficiency

Nitrogen-use efficiency is a term that is rarely understood. It aims to quantify the amount of N fertiliser applied that is available to the crop. In GRDC-funded benchmarking trials carried out by NSW Department of Primary Industries (DPI) in 2009, this value ranged from 25 to 95% in the benchmarked crops, which varies dramatically from the figure of 50% commonly used for N-budgeting purposes.

The major reason for the variation is the level of N that is tied up by trash, and the amount released by mineralisation. In the crops benchmarked, crops following cotton tended to have lower N-use efficiency, as the cotton trash that is incorporated into the soil requires large amounts of N to feed the bugs that break the trash down. In addition, there is minimal short-term, in-crop mineralisation. Crops following maize or fallow, however, had very little N tied up, and released much more N through mineralisation, and hence had higher N-use efficiency.

The amount of N removed was calculated by N in grain (kg/ha) = yield (t/ha) x 1.75 x protein (%), and crop N requirement = N in grain (kg/ha) x N uptake efficiency factor. So, if we know the starting soil N, the yield and the protein percentage, we can then estimate the N uptake efficiency factor. [12]

For more information, download 'Growing wheat after cotton—Durum benchmarking 2009': http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/08/Growing-wheat-after-cotton-Durum-benchmarking-2009

1.9 Disease status of paddock

The crown rot fungus enters the plant through the roots, disrupting plant water supply and hence grain yield. Moisture stress will exacerbate these conditions, resulting in the appearance of 'whiteheads' in the crop, which produce small shrivelled grain. It is therefore recommended that durum crops not be grown following a previous wheat crop or maize, which is also a carrier of the Fusarium head blight (FHB) fungus (*F. graminearum*).[13]

1.9.1 Crown rot

The ground should contain very little crown rot inoculum. The most conspicuous broadacre symptom of crown rot is the appearance of 'whiteheads' in the crop.

11 GRDC (2005) Tracking water-use efficiency. GRDC Groundcover Issue 54, Feb. 2005, http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-54/Tracking-wateruse-efficiency

12 B Haskins, M Sissons (2011) Growing wheat after cotton—Durum benchmarking 2009, GRDC Update Papers 10 August 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/08/Growing-wheat-after-cotton-Durum-benchmarking-2009

13 J Kneipp (2008) Durum wheat production, NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

However, not all whiteheads are due to crown rot infection. Insect attack on stem tissues, frost and moisture stress damage can lead to whiteheads.

Stems that exhibit a brown (honey) discoloration on the lower internodes are a good indicator of crown rot infection, and a more reliable indicator of inoculum than whiteheads, which may not always be expressed in the crop. On severely affected plants, pink fungal growth is often present on the lower part of the stem and crown. Paddocks that have previously grown natural pasture should not be used, as the native grass species harbour the crown rot fungus.

These precautions are the same as those observed in bread wheat cultivation. Ground known to carry high levels of crown rot inoculum should be sown to an alternative crop such as sorghum or the broadleaf crops (e.g. chickpea, faba bean, mungbean, canola, sunflower) over a period of 2 years before replanting durum. The sowing of a durum crop following bread wheat is not recommended, as inoculum will be increased by both susceptible species. [14]

1.9.2 Fusarium head blight

Fusarium head blight (FHB) is not a major disease in Australian durum due to dry cropping conditions. This is a major advantage for Australian durum growers because FHB in North America and EU countries could lead to formation of a toxin known as deoxynivalenol (DON) in the grain rendering it unsuitable for human consumption if higher than certain levels. However, it is not advisable to plant maize in the rotation prior to durum, as maize is a susceptible host of the FHB fungus, *Fusarium graminearum*. Inoculum carried by the maize trash may pass the disease to the following durum crop if suitable weather conditions for infection, such as an extended wet period, prevail during and following flowering. [15]

1.9.3 Testing for disease

Soil sampling for future risk

PreDicta B™ is a DNA-based soil test that detects levels of a range of cereal pathogens, including the main Fusarium species that causes crown rot:

- It is commercially available to growers from accredited agronomists through the South Australian Research and Development Institute (SARDI).
- The test identifies the level of risk for crown rot (and other soil-borne pathogens) prior to sowing. However, this requires a dedicated sampling strategy and is not a simple add on to a soil nutrition test.
- Soil cores should be targeted from the previous winter cereal rows, if possible, and any stubble fragments should be retained.
- Short pieces of stubble (1–2 from each PreDicta B™ soil sampling location) from previous winter cereal crops and/or grass weed residues should be added to the soil sample to enhance detection of the inoculum that causes crown rot.
- Accredited agronomists can consult SARDI for the latest recommended sampling strategy for your region.

More information

PreDicta B™

Stubble assessment

- A commercial stubble assessment service is available through Crown Analytical Services for crown rot and common root rot pathogens.[16]

[14] R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

[15] R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

[16] GRDC (2016) Crown rot in winter cereals. https://grdc.com.au/Resources/Factsheets/2016/02/Crown-rot-in-winter-cereals

SECTION 2

Pre-planting

For more information, see the *GRDC GrowNotes WHEAT (Northern region),* Section 2: Preplanting.

More information

NSW DPI. Winter crop variety sowing guide 2016.

T Napier, L Gaynor, D Slinger, N Graham, C Podmore (2015). Drivers of high-yielding irrigated wheat production.

Z Hochman, D Gobbett, H Horan, JN Garcia (2015).Visualizing yield gaps in Australia's wheat cropping zone.

M Robertson, G Rebetzke, J Kirkegaard, R Llewellyn, Tim Wark (2015). Are future yield gains in wheat of 1.5% per year achievable?

2.1 Varietal performance and yield ratings

Figure 1: Durum in the paddock.

Caparoi⊕ ADR quality. A mid season maturity durum, with a maturity between EGA_Bellaroi and Jandaroi. It is a semi-dwarf durum variety with good yield potential in all regions. The grain quality is better than Wollaroi, and similar to Jandaroi and EGA_Bellaroi. Caparoi has improved dough strength compared with EGA_Bellaroi, but is inferior to Jandaroi for this trait. Caparoi is superior to Jandaroi for semolina yellowness. Moderately susceptible to root lesion nematode (Pratylenchus thornei) and very susceptible to crown rot. Adequate resistance to common root rot. Good shedding resistance. (Marketed by Seednet).

DBA_Aurora⊕ ADR quality. A mid season maturity durum variety with high yield potential, released for the southern grains region. High yield potential, with yield levels similar to Hyperno in most NSW regions, so nitrogen management is important to obtain acceptable grain protein levels for delivery into durum quality grades, especially DR1. Higher levels of screenings can occur in some circumstances when compared with varieties such as Jandaroi and Caparoi. Avoid sowing DBA_Aurora later than the suggested sowing window for your region as grain quality and yield potential can be affected. It can lodge under irrigation or high yielding conditions. It is rated resistant–moderately resistant to root lesion nematodes (P. thornei) and susceptible–very susceptible to crown rot. Bred by the Southern Program of Durum Breeding Australia (University of Adelaide). (Marketed by SA Durum Growers Association).

DBA_Lillaroi⦶ ADR quality. An early–medium maturity variety, three days later flowering than Jandaroi, with a higher grain yield. Excellent durum quality with the large grain size of the commercial varieties, low screenings, high test milling yield, and the highest semolina colour compared with current varieties. Adapted to the rain-fed durum production regions of NSW and is also suited to sowing later in the season. DBA_Lillaroi is not recommended for high-input irrigated systems without the appropriate agronomic management. Rated moderately resistant to root lesion nematode (*P.thornei*) and susceptible–very susceptible to crown rot. Bred by the Northern Program of Durum Breeding Australia (NSW Department of Primary Industries). (Marketed by Seednet).

EGA_Bellaroi⦶ ADR quality. A mid season maturity durum variety. The grain yield is typically better than Yallaroi or Wollaroi, but inferior to the newer-released varieties, Caparoi, DBA_Lillaroi and Jandaroi. The grain protein is consistently higher than other current commercial varieties. EGA_Bellaroi makes good quality pasta, but has poor dough strength. Moderately resistant to common root rot and very susceptible to crown rot. It can lodge under high yielding conditions, but is still the best variety for reduced crop lodging in irrigated durum production systems in southern NSW. (Marketed by Seednet/Heritage Seeds.)

Hyperno⦶ ADR quality for northern NSW. A mid season maturity durum with excellent yield potential. Maturity is earlier than EGA_Bellaroi. It is resistant to stem rust and resistant–moderately resistant to leaf rust; susceptible–very susceptible to crown rot. It has a good level of sprouting and black point tolerance. It can produce higher screenings than other durum varieties in some circumstances. It can lodge under irrigation or high yielding conditions. (Marketed by AGT).

Jandaroi⦶ ADR quality for northern NSW. A quick maturity variety adapted to most durum producing regions and is suited to sowing later in the season. It has been shown to have improved weather tolerance at harvest compared with other varieties. Grain quality is superior to Caparoi, EGA_Bellaroi and Wollaroi, with much stronger dough properties but lower yellow pigment. An erect, semi-dwarf plant type. It is very prone to lodging under high yield conditions in southern NSW. It is moderately susceptible–susceptible to root lesion nematode, moderately resistant to black point and very susceptible to crown rot. (Marketed by Seednet.)

More information

Graincorp (2015), Durum standards 2015-2016

See Table 1 for resistance ratings of some durum cultivars. Information about varieties is also available at National Variety Trials on http://www.nvtonline.com.au/nvt-results-reports/

Table 1: Levels of resistance to diseases and other conditions (Source: www.acasnvt.com.au)

Variety	Rust Resistance: Stem rust	Leaf rust	Stripe rust	RLN (*P. thorneii*) Resistance/ Tolerance	RLN (*P. neglectus*) Resistance/ Tolerance	Yellow Leaf Spot	Septoria tritici	Crown Rot	Common Root Rot	Black-point
DBA Lillaroi	MR	MR	R-MR	MR/MI-I	MR-MS/-	MR-MS	MR-MS	S-VS	MR-MS	MR
Jandaroi	R-MR	MR	MR	MR-MS / MI	MS / MI	MS	R-MR	VS	MR	R-MR
Caparoi	MR	MR-MS	MR	MR / T-MT	MS-S / MI	MR-MS	MR	VS	MS	MR
EGA Bellaroi	MR	MR-MS	MR	MR / MT	MS / MI-I	MR-MS	MR-MS	VS	MR	R-MR

2.1.1 Quality traits

Grain quality is very important for obtaining premium prices with durum wheat. Downgrading may occur if grain contains mottling, black point or weather damage (Table 2).

Table 2: Major durum wheat quality classes[1]

	Protein	Vitreous kernels	Falling number	Screenings	Stained grains[A]
ADR1	13.0%	>80%	>300	<5%	<3%
ADR2	11.5–12.9%	>70%	>300	<5%	<5%
ADR3	10.0–11.4%		>250	<10%	<20%
Feed	< 10.0%				

[A]Includes black point.

2.1.2 Maturity

There is currently a relatively small range in maturity length in durum varieties compared with bread wheat varieties. Durums are generally similar in maturity to the faster growing bread wheat varieties. This is an important consideration when managing frost risk and can limit opportunities to exploit early-planting opportunities.

Extended flowering could reduce the risk of pollination failure caused by frost or extended moist weather. The time difference in reaching full maturity between the early-flowering and late-flowering tillers is normally fairly small; therefore, the early heads are not likely to be ripe for many days ahead of the later heads. Harvesting should not be delayed significantly.

Durum wheats will perform well if sown later, but grain yields will depend on seasonal conditions, especially during the flowering and grain-filling stages. [2] However, best yields are achieved with planting in the mid-May to mid-June window and crops sown in early parts of the sowing window establish well, escape terminal drought to some extent and yield the best.

2.2 Planting-seed quality

2.2.1 Seed size

Durum seed is, on average, 20% larger than bread wheat seed. The planting rate should be adjusted based on 1000 grain weight data to sow 100 seeds/m^2. However, a higher planting rate may be beneficial in some situations (e.g. seed with a low germination, irrigated crops or early/late sowings). Conventional sowing equipment can be used but the larger seed size may necessitate adjustments.

2.2.2 Seed germination and vigour

Use germination tested viable seed that is true to type (varietal purity)—free of diseased seed and weed seeds, cracked and small grain, and barley and bread wheat grain. Ensure that the initial seed of a purchased variety is of high quality, preferably from certified seed stocks, with a germination percentage >80%. Before harvesting seed stocks for the following season, remove all off-types and contaminant crop and weed plants. [3]

1 DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

2 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

3 R Hare, (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

Seed grain kept for sowing in subsequent seasons must be stored in clean silos capable of aeration, sealing for insect control and keeping grain dry and as cool as possible. Such storage conditions will assist the maintenance of high-viability seed for the following season.

Treat seed with an appropriately registered product just prior to sowing to control smut and bunt. Some chemical constituents can reduce viability and seedling vigour if they remain in contact with the seed for any length of time.

Seed treatment will offer protection to the establishing seedlings from damping-off diseases and insect attack such as armyworms, cutworms, false wireworms and wireworms. Ground preparation is the same as for bread wheat. Adequate cultivation and/or spraying should eliminate all volunteer plants of bread wheat, barley and other crop/weed species. [4]

4 R Hare, (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

SECTION 3

Planting

For more information, see the *GRDC GrowNotes WHEAT (Northern region),* Section 3: Planting.

3.1 Seed treatments

Research is under way to establish whether it is of economic benefit to use seed treatments (such as imidacloprid) to prevent aphids in durum. The cost of around AU$33/ha was considered worthwhile during times of high grain prices. Northern Grower Alliance (NGA) research over two seasons found yield increases averaged ~11% in barley and durum, and 5% in wheat. One of the challenges of electing to use a prophylactic treatment such as a seed dressing is that aphids are a sporadic pest and will not reach damaging levels every year. [1]

For more information, download: http://www.grdc.com.au/uploads/documents/GRDC_FS_CerealAphids1.pdf

For details of registered seed treatments, visit: www.apvma.gov.au

More information

R Graham, N Graham, S Simpfendorfer (2015), Yield impact of crown rot and sowing time on winter cereal crop and variety selection Tulloona 2015

J Hunt, B Trevaskis, A Fletcher, A Peake, A Zwart, N Fettell (2015), Novel wheat genotypes for early sowing across Australian wheat production environments.

3.2 Time of sowing

The optimum sowing date will depend on the maturity ranking of the variety, latitude of the sowing site, and topographic aspect (e.g. north/south facing slope, elevation). Durum wheats will perform well if sown later, but grain yields will depend on seasonal conditions, especially during the flowering and grain-filling stages.

The sowing time of a variety is a critical factor in crop risk management. Growers should aim for a balanced minimisation of the combined risks of frost damage around flowering/grain-filling, moisture stress at this time, and rain or storm damage just prior to harvest.

Crops sown earlier than optimal will be exposed to an elevated frost risk, whereas those sown later than the optimal period could encounter high moisture stress and harvest spoilage. None of these risks can be eliminated, but minimisation is possible.

The normal sowing window for durum in the northern regions is from mid/late May to mid-June. EGA Bellaroi and Caparoi are suitable for sowing in mid/late May. Jandaroi is early maturing and it should be sown late May onwards and it is also suitable for sowing late after a cotton crop. The suggested sowing time for DBA Lillaroi in the northern region is late May to end of June. It is also suitable for late sowing (e.g. after a cotton crop).

The sowing of several varieties of different maturity ranking over several weeks should spread the risks associated with flowering, grain-filling and harvest. Given differing rates of growth development, each variety should not be exposed to the same degree of risk at any specific critical stage (e.g. at flowering). [2]

More information

Winter Cereal Planting Guides: http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

NVT Queensland Wheat Variety Guide 2015.

https://grdc.com.au/Research-and-Development/National-Variety-Trials/Crop-Variety-Guides

1 GRDC (2010) Cereal aphids—aphid control in cereals can pay. GRDC Fact Sheet Northern Region July 2010, http://www.grdc.com.au/uploads/documents/GRDC_FS_CerealAphids1.pdf

2 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

More information

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Yield-impact-of-crown-rot-and-sowing-time-on-winter-cereal-crop-and-variety-selection-Tulloona-2015

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Durum-agronomy-a-northern-perspective

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/High-crown-rot-risk-barley-vs-wheat

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Variety-specific-agronomy-2014-agronomy-trials-in-the-northern-grain-region-of-NSW

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

3.3 Targeted plant population

Commonly used seeding rates are 45–50 kg/ha (northern NSW) and the standard planting times are May–June. Planting should be adjusted to suit the local seasonal conditions to avoid frost damage to the heads and stems at head emergence and during flowering. [3]

Durum wheat remains the most susceptible of the winter cereal crops to crown rot infection and yield loss. Management strategies such as rotation, fallow/stubble management, inter-row sowing and planting time have been investigated, with demonstrated benefits. However, little work has focused on the effect of varying plant population and the carryover effect on soil water available for the critical crop development stages of flowering and grain-fill, which dictates the extent of yield loss to crown rot.

In 2009, five replicated trials were conducted across northern NSW, using the four main durum varieties in the region, to assess whether the impact of crown rot could be minimised by varying plant populations and using different varieties.

Varying plant populations at sowing did not reduce the impact of crown rot in the four durum varieties examined. In fact, at lower plant populations there appeared to be a higher risk of lodging associated with crown rot infection, which usually results in lower yields. High loads of crown rot reduced plant establishment, as well as reducing tiller and head production. However, there were significant varietal differences in yield and tiller production (Figure 1).

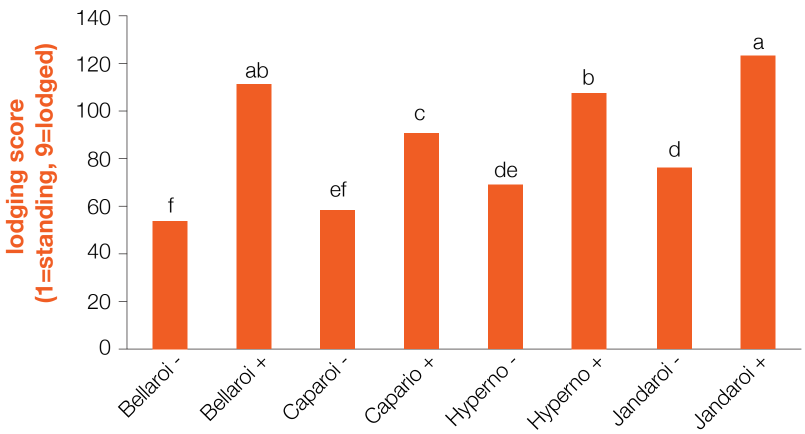

Figure 1: Yield loss due to crown rot in northern NSW.

The greatest impact on durum yield remains the crown rot inoculum level, with the disease having a greater impact on yield in the more western environments, which tend to have hotter/drier conditions during grain-fill. Analysis of the soil water and plant pathology data should provide additional insight into the impact of crown rot on soil water use. However, under high crown rot pressure, yield losses in durum cannot be managed by manipulating the plant population at sowing. Given the extreme susceptibility of durum wheat to crown rot, it remains critical to target durum production only in paddocks known to have low levels of inoculum. [4]

For more information, download the GRDC Update paper '*Impact of plant population on crown rot in durum wheat*': http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/IMPACT-OF-PLANT-POPULATION-ON-CROWN-ROT-IN-DURUM-WHEAT.

3 J Kneipp, (2008) Durum wheat production, NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

4 GRDC (2010) Impact of plant population on crown rot in durum wheat. GRDC Update Papers 24 Sept. 2010, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/IMPACT-OF-PLANT-POPULATION-ON-CROWN-ROT-IN-DURUM-WHEAT.

3.4 Calculating seed requirements

A sowing rate of 45 kg/ha is given as a general guide. However, growers may consider a variation, higher or lower, to benefit their situation. A reduced germination percentage or a late sowing will make it necessary to increase this rate. [5]

3.5 Sowing depth

In a well-prepared seedbed, the sowing depth should be about 3–6 cm and not exceed 8 cm. As the current durum cultivars are semi-dwarf cultivars, the length of the coleoptile is reduced and so it cannot penetrate greater soil depths. Sowing rate can be considered a risk-management tool. Dense stands of plants tend to produce few tillers per plant (i.e. the primary and a few secondary), whereas stands at a reduced density have plants that produce a larger number of tillers per plant. Such reduced-density stands have greater flexibility in response to changing growing conditions. For example, if moisture is limiting, fewer tillers are initiated; however, if seasonal conditions improve, additional tillers may develop. [6]

3.6 Sowing equipment

Use conventional sowing equipment, the larger grain size may need appropriate adjustments. A sowing rate of 45 kg/ha is given as a general guide. However, growers may consider a variation, higher or lower, to benefit their situation. A reduced germination percentage or a late sowing will make it necessary to increase this rate. [7]

5 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

6 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

7 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

SECTION 4

Plant growth and physiology

For more information, see the *GRDC GrowNotes WHEAT (Northern region),* Section 4: Plant growth and physiology.

4.1 Germination and emergence

Durum crops grow to about 80 cm at maturity (15–20 cm shorter than bread wheat) depending on seasonal conditions and variety.

Low-density crops tend to have heads flowering over a longer interval. Such a prolonged flowering period may reduce the impact of a frost around flowering. Protracted moist weather at flowering can have an adverse effect on pollination by inhibiting the release of pollen from the anthers. If the female part of the flower (the stigma and ovule) is not fertilised while in its receptive phase, a grain will not develop.

Low-density crops are likely to use available soil moisture reserves at a slower rate than the higher density crops.

Avoidance of moisture stress before and at flowering is critical for satisfactory grain set, as pollen will abort during periods of stress as part of a natural survival mechanism of the plant. Extended flowering could reduce the risk of pollination failure caused by frost or extended moist weather.

The time difference in reaching full maturity between early-flowering and late-flowering tillers is usually small; therefore, the early heads are not likely to be ripe for many days ahead of the later heads. Harvesting should not be delayed significantly. [1 2]

Figure 1: Early durum heads are not likely to ripen well ahead of later heads.

More information

J Whish (2016), Accessing and using day degrees in field crops as a tool to assist crop management.

[1] R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

[2] J Whish (2016), Accessing and using day degrees in field crops as a tool to assist crop management. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Accessing-and-using-day-degrees-in-field-crops-as-a-tool-to-assist-crop-management

SECTION 5

Nutrition and fertiliser

For more information, see the *GRDC GrowNotes WHEAT (Northern region),* Section 5: Nutrition and fertiliser.

5.1 Current general pre-plant nutritional levels for nitrogen

Paddocks with deep soil and high natural N fertility would be suitable for growing dryland durum wheat. Soil sampling to the full depth of root exploration prior to sowing should be a good guide to the available soil N supply. For the production of a 3.0 t/ha crop with 13% protein, access to 140 kg N/ha is necessary. [1]

Crop nutrition is critical to the durum crop to achieve a high-quality product. To obtain high protein levels (13%+) soil N management requires careful planning. Ideally durum should be planted into a rotation following a grain or pasture legume phase. Alternatively, use cropping history in conjunction with soil tests to calculate an N budget. It is important to test soil for N to the effective rooting depth of the crop. Nitrogen fertiliser is now an expensive input in our farming systems, and so it pays dividends to get the critical levels correct. Depending on the location, other nutrients such as phosphorus (P), sulfur (S) and, on highly alkaline soils, zinc (Zn) requirements may need to be managed. [2]

Fertiliser rates should be aimed at producing a finished protein level at ADR1 (≥13%). This may necessitate soil tests to establish base N levels. As a rule of thumb, for every tonne per hectare of high-protein grain harvested, about 50 kg of N is removed in the grain. This amount of N must be replaced, together with other N losses such as from leaching and de-nitrification. The amount of N fertiliser required can be calculated when the percentage of elemental N is known for the fertiliser product (e.g. urea N 46%, anhydrous NH3 82%). [3]

For general information on N crop nutrition and application see: http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/nitrogen

More information

M Bell, G Schwenke, D Lester (2016), Understanding and managing N loss pathways.

B O'Mara, C Walker (2015), Lessons learnt about nitrogen and phosphorus from a 30 year study in a sub-tropical continuous cropping system on a vertosol.

R Graham, G McMullen, G Kadkol (2015), Durum wheat variety response to nitrogen management – Tamarang 2014. p159.

1 DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

2 J Kneipp (2008) Durum wheat production, NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

3 R ,Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

5.2 Current general pre-plant nutritional levels for phosphorus

Phosphorus is important in growing tissue where cells are actively dividing, i.e. seedling root development, flowering and seed formation. Use a soil test to determine phosphorus status. Long fallows due to crop rotation or drought may accentuate P deficiency through absence of mycorrhizae; P fertiliser should be used in this situation. Where needed, apply P with the seed at planting. [4]

Current research on the deep placement (10-30 cm) of phosphorus in Queensland and NSW trials is demonstrating mixed outcomes, from consistently good responses in some districts (e.g. Central Queensland), to more mixed results in southern Queensland and northern New South Wales.

Where evaluated, responses to starter fertiliser are demonstrable in most of our research sites where Colwell P in the top 10 cm is low. Growers are encouraged to continue using starter P fertilisers at rates appropriate for the crop row spacing and soil moisture conditions at sowing. Applying small amounts of P in the seed row at sowing is offering excellent utilisation of the nutrient by the emerging crop.

Yield increases with deep P application are predicated on a crops' ability to access and utilise the nutrient in the band.[5]

More information

DW Lester, M Bell, R Graham, D Sands, G Brooke (2016), Phosphorus and potassium nutrition.

K Andersson, M Tighe, C Guppy, P Milham, T McLaren (2016), The mobility of P in alkaline clays of the Northern Grains Region.

M Bell, D Sands, D Lester, R Norton (2015), Response to deep placed P, K and S in central Queensland.

G Blair, W Matamwa, I Yunusa, M Faint (2015), Adding sulfur to finished fertilisers: inside or outside?

5.3 Current general pre-plant nutritional levels for micronutrients

Compared with bread wheats, durums can be sensitive to low Zn levels. Elongated necrotic lesions (dead patches) on the lower leaves may indicate the onset of Zn deficiency. If the soil is known to be low in Zn, a 1% aqueous solution of zinc sulfate heptahydrate should be applied as a foliar spray 2–4 weeks after emergence, at about 1 kg/ha. Zinc sulfate monohydrate applications can provide 4–5 years supply of this essential micronutrient. Apply at 15 kg/ha on sandy and sandy-loam soils, or 30 kg/ha for clay and clay-loam soils and incorporate some months before sowing. Where P fertilisers are required, products that are coated with Zn provide a very efficient method of increasing crop recovery of applied Zn. Several Zn-fortified fertilisers are now available. [6]

Most northern durum varieties including EGA Bellaroi⚖ are usually not sensitive to low Zn levels when grown on very heavy, self-mulching black earth (pH 8–8.5). When a crop is growing in a very wet, high-phosphate soil for several weeks, Zn deficiency symptoms may be evident. Note that zinc oxide (5 kg Zn/ha) applications can be spread with N fertilisers but not with phosphate fertilisers, as the phosphate can bind with the Zn and could render it unavailable.[7]

4 DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

5 DW Lester, M Bell, R Graham, D Sands, G Brooke (2016), Phosphorus and potassium nutrition. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Phosphorus-and-potassium-nutrition

6 DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

7 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

Figure 1: As durum wheat is a high-quality product, appropriate nutrient management will help to reduce the risk of producing grain that does not meet the strict quality receival standards.

SECTION 6

Weed control

More information

C Preston, S Kleemann, G Gill (2016). Coupling pre emergent herbicides and crop competition for big reductions in weed escapes.

R Daniel (2016). Pre emergent herbicides: part of the package for FTR management?

M Street, B O'Brien (2016). Report on the 2014 GOA herbicide resistance survey.

R Llewellyn, J Ouzman, A Mayfield, S Walker, D Ronning, M Clark (2015). Weed management as a key driver of crop agronomy.

S Goss, R Wheeler (2015). Using crop competition for weed control in barley and wheat.

More information

www.apvma.gov.au

For more information, see the *GRDC GrowNotes WHEAT (Northern region),* Section 6: Weed control.

6.1 Pre-emergent herbicides

Durum wheats can compete well with weeds, but strong weed competition reduces yield. Good weed control is essential to make full use of stored summer rainfall, minimise yield losses, and prevent weed seed contamination at harvest. This can be achieved effectively by controlling weeds well in preceding crops and fallow, rotating crops, growing competitive durum crops, and the judicious use of herbicides. It is important to control weeds such as New Zealand spinach, climbing buckwheat (black bindweed) and Mexican poppy, as their small black seeds can be difficult to remove from the grain, affecting consumer acceptance.[1]

6.2 Post-plant pre-emergent herbicides

When selecting a herbicide it is important to know the weeds present, the crop growth stage, the recommended growth stage for herbicide application, and the herbicide history of the paddock. Weeds should be sprayed while they are small and actively growing. It is important to rotate between herbicide groups to prevent weeds developing herbicide resistance. Herbicide labels should be read carefully before use. Research has found that durum cultivars differ in their tolerance to herbicides registered for use in durum wheats. [2]

6.3 Herbicide tolerance ratings, National Variety Trials (NVT)

Durum wheats can be more sensitive to some herbicides commonly used safely in bread wheat. Refer to the latest information on varietal tolerances and the product label.

Varietal tolerance information is included in NSW Department of Primary Industries (NSW DPI) publication Weed Control in Winter Crops.

[1] DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

[2] DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

6.4 Potential herbicide damage effect

Timely and correct application of herbicides is essential. Seek local advice from advisers/agronomists and follow label directions. Good weed control is essential, as strong weed growth will compete with the crop for available moisture and nutrients causing yield reduction.[3]

A range of broadleaf and grass herbicides is available for weed control in durum wheat crops, as are listed in the recent publication from NSW DPI 'Weed control in winter crops'. This publication, together with advice from your agronomist/adviser, will assist with the choice of the most appropriate and safe products and their respective application procedures. The law requires that all chemical labels be read carefully before the product is used. New products and product formulations may have changed safety margins. Manufacturers or their representatives should be consulted for the latest usage information, especially if mixing chemicals or other products (e.g. zinc sulfate heptahydrate). The effectiveness of certain chemicals can be adversely affected when mixed with other compounds. Zinc sulfate heptahydrate can coagulate certain chemicals, with the coagulant causing major blockages in spray equipment, which can be difficult to clear. [4]

Where herbicide residue may remain in the soil, avoid the use of herbicides from the same mode of action group in following crops. Where a herbicide is applied on top of another existing herbicide a potentially damaging residual situation may arise or be made worse.

Good agronomic practice that promotes early crop health and vigour can assist in overcoming some low-level marginal damage. While any level of herbicide damage or setback to a young crop may potentially lead to a yield loss or change in phenology, and therefore should be avoided), it is not uncommon for crops suffering from low-level herbicide damage in the early vegetative phases of growth to compensate and yield well despite their early setback. Growers relying on the crop's ability to compensate and grow out of early damage are, however, taking a significant risk. For more information on herbicide injury, download GRDC app from your favourite app store or visit www.uteguides.net.au. [5]

More information

G Brooke, C McMaster (2016), Weed control in winter crops 2016.

J Cameron, M Congreve (2016), Recropping issues with pre emergent herbicides.

L Van Zwieten, M Rose, P Zhang, D Nguyen, C Scanlan, T Rose, G McGrath, T Vancov, T Cavagnaro, N Seymour, S Kimber, A Jenkins, A Claassens, I Kennedy (2016), Herbicide residues in soils – are they an issue? (Northern).

[3] J Kneipp (2008) Durum wheat production. NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

[4] R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

[5] J Cameron, M Congreve (2016), Recropping issues with pre emergent herbicides. https://grdc.com.au/RecroppingIssuesWithPreEmergentHerbicides

SECTION 7

Insect control

More information

GRDC Insect Id App: https://www.grdc.com.au/Resources/Apps

QDAFF Publications: http://ipmworkshops.com.au/wp-content/uploads/Wintercereals_north-manual-July13.pdf

http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/natural-enemies-who-eats-who

QDAFF Integrated Pest Management For Australia's Northern Region Blog: http://thebeatsheet.com.au/about/

NSW DPI Publications: http://www.dpi.nsw.gov.au/agriculture/broadacre/pests-diseases

Insects are not usually a major problem in wheat but sometimes they build up to an extent that control may be warranted. For current chemical control options refer to the Pest Genie (http://www.pestgenie.com.au) or Australian Pesticides and Veterinary Medical Authority (APVMA) (www.apvma.gov.au) websites. [1]

7.1 Cutworm

Several species of cutworms (*Agrotis* spp.) (Figure 1) attack establishing cereal crops in Queensland and New South Wales. As their name suggests, cutworm larvae sever the stems of young seedlings at or near ground level, causing the collapse of the plant (Table 1). Damage usually shows up as general patchiness or as distinct bare areas in a very short time. Controlling weeds in the fallow prior to planting will assist in reducing cutworm populations and reduce crop damage. This should be done at least 3-4 weeks prior to sowing. Chemical control may be warranted if larval numbers exceed 1 larva/m^2 in emerging crops. The best time to monitor is late afternoon–evenings when larvae feed. During the day, scratch away soil around damaged plants to find larvae sheltering in the soil. For more information read how to recognise and monitor for soil insects in 'Insect pest management in winter cereals'. [2]

Figure 1: Cutworm. (Source: QDAFF)

1 DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

2 DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

Table 1: Cutworm description and management summary [3]

Scientific name	*Agrotis* spp.
Description	Larvae are up to 50 mm long, hairless with dark heads and usually darkish coloured bodies, often with longitudinal lines and/or dark spots. Larvae curl up and remain still if picked up. Moths are a dull brown-black colour
Similar species	May be confused with armyworms and Helicoverpa larvae
Crops attacked	All field crops. Crops are at most risk during seedling and early vegetative stages
Damage	Young caterpillars climb plants and skeletonise the leaves or eat small holes. Older larvae may also climb to browse or cut off leaves, but commonly cut through stems at ground level and feed on the top growth of felled plants. Caterpillars that are almost fully grown often remain underground and chew into plants at or below ground level. They usually feed in the late afternoon or at night. By day they hide under debris or in the soil
Monitoring and action level	Inspect crop twice weekly in seedling and early vegetative stage. Larvae feed late afternoons and evenings. Chemical control is warranted when there is a rapidly increasing area or proportion of crop damage
Life cycle	Usually a single generation during early vegetative stages. Moths prefer to lay their eggs in soil in lightly vegetated (e.g. a weedy fallow) or bare areas. Early autumn egg-laying results in most damage to young cereals. Larvae hatch and feed on host plants right through to maturity. Mature larvae pupate in the soil. Under favourable conditions, the duration from egg-lay to adult emergence is 8–11 weeks, depending on the species
Control	Chemical control: Insecticide application is cost-effective. The whole crop may not need to be sprayed if distribution is patchy; spot spraying may suffice. See Pest Genie or APVMA for current control options. Cultural control: Control weeds 3–4 weeks prior to sowing. Natural enemies: Cutworms are attacked by a number of predators, parasites and diseases
Pest status	Minor, widespread, irregular

7.2 Aphids

Aphids are usually regarded as a minor pest of winter cereals, but in some seasons, they can build up to very high densities. Four different species of aphid can infest winter cereals, including oat aphid, corn aphid, rose-grain aphid, and the fourth species, rice root aphid, which exists in the northern grain region, but does not cause as much damage to cereals. For more information, see the Crop Aphids Back Pocket Guide at https://grdc.com.au/CropAphidsBackPocketGuide.

Aphids can impair growth in the early stages of crop and prolonged infestations can reduce tillering and result in earlier leaf senescence. Infestations during booting to milky dough stage, particularly where aphids are colonising the flag leaf, stem and ear, result in yield loss, and aphid infestations during grain-fill may result in low-protein grain. As aphids may compete with the crop for nitrogen (N), crops grown with marginal levels of N can be more susceptible to the impact of an aphid infestation. In barley, aphids can spread *Barley yellow dwarf virus* (BYDV). While this can have a large effect on barley yield in some areas, it is not considered a major problem in Queensland in most seasons. In virus-prone areas, use resistant plant varieties to minimise losses due to BYDV.

7.2.1 Thresholds for control

Inspect for aphids throughout the growing season by monitoring leaves, stems and heads as well as exposed roots. Choose six, widely spaced positions in the crop, and at each position examine five consecutive plants in a row. Research is under way into

3 DAFF (2010) Cutworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/cutworm

damage thresholds and control options for cereal aphids. Some research indicates that aphid infestations can reduce yield by ~10% on average. Current notional thresholds suggest that control is warranted when there are >10–20 aphids on 50% of the tillers.

The decision to control aphids on winter cereals depends on the size of the aphid population and the duration and timing of the infestation. Controlling aphids during early crop development generally results in a recovery of the rate of root and shoot development, but there can be a delay. Aphids are more readily controlled in seedling and pre-tillering crops, which are less bulky than post-tillering crops. Corn aphids in the terminal leaf tend to disappear as crops come into head, and other species usually decline in abundance about this time as natural enemy populations build up. Note that the rice root aphid feeds below-ground and cannot be controlled effectively by non-systemic foliar treatments. [4]

No firm economic thresholds exist (taking into account current costs of control and crop value), but there are thresholds suggested from work in Western Australia and by the Northern Grower Alliance (NGA).

The Western Australian threshold, based on checking crops regularly from late tillering, is, to consider control if the aphid population exceeds 15 aphids/tiller on 50% of tillers.

The NGA work shows that at some sites there is an economic (yield) benefit from controlling aphids early (either seed treatments or at the early tillering stage) using a threshold of 10 aphids/tiller.

In Queensland, several field and glasshouse trials have been conducted over the past four seasons, but entomologists have not been obtained consistent yield loss in trials that tested a range of aphid infestations at different stages of crop development. [5]

Recently the NGA has been involved in a large number of trials to improve industry understanding of the impact of aphids on winter cereal yields and the costs and benefits of different management approaches.

Key findings include:

- A threshold of 10-15 aphids/tiller (and increasing) appears a suitable commercial trigger for aphid management in winter cereals.
- Monitor for early populations of oat aphids by pulling up plants and examining crown and sub-crown regions.
- However, only consider foliar sprays when most oat aphids have moved above-ground into the lower canopy.
- Best results from foliar sprays are obtained when the aphid population is close to threshold and increasing.
- Beneficial insects can provide effective aphid control in winter cereals. Consider beneficial presence or activity before making spray decisions.
- Consider aphid-active seed treatments for use in barley or areas with consistently higher aphid pressure. [6]

More information

GRDC Fact Sheet: http://www.grdc.com.au/uploads/documents/GRDC_FS_CerealAphids1.pdf

7.2.2 Seed dressings

Prophylactic seed dressings may be effective in delaying the build-up of aphid populations in a crop, but because aphids are sporadic (not occurring every season), it can be difficult to decide whether a seed dressing is warranted. A locally wet summer and

4 DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

5 M Miles (2012) Making a decision about control of aphids in winter cereals. Queensland Government, *The Beatsheet*, http://thebeatsheet.com.au/winter-cereals/making-a-decision-about-control-of-aphids-in-winter-cereals/

6 NGA (2011) Aphid management in winter cereals 2009-2010. Results in a Nutshell. Northern Grower Alliance, http://www.nga.org.au/module/documents/download/79

autumn is generally a precursor to an aphid outbreak, as there are abundant alternative hosts to breed on. [7]

7.2.3 Natural enemies

Delay any planned chemical control if rain is forecast, and check again after rain as intense rainfalls can reduce aphid infestations by dislodging aphids from the plants. Foliar insecticides registered for aphid control are generally broad-spectrum, meaning they kill natural enemies (beneficial insects such as ladybird beetles and larvae, hover fly larvae, lacewing larvae or parasitic wasps) as well as aphids. Preserving natural enemies is important in managing aphid populations in the long term. Natural enemies can exert effective control on small to moderate aphid infestations. Large populations of aphid can also be controlled, but often not until the crop is maturing, which may be too late to prevent impact on yield. Natural enemies can also be effective in suppressing aphids that survive post-treatment, preventing the need for subsequent treatments. [8]

More information

GRDC Beneficial insects Back Paddock Guide
http://www.grdc.com.au/BPG-BeneficialInsects-North

Figure 2: Preserving natural enemies is important in managing aphid populations in the long term. (Source: QDAFF)

[7] DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

[8] DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

7.2.4 Oat or wheat aphid (*Rhopalosiphum padi*)

Oat or wheat aphid (Figure 3) is one of the most common aphid-infesting winter cereals. Typically, this species colonises the base and lower portions of the plant. [9]

Figure 3: Oat or wheat aphid (Source: QDAFF)

Table 2: Oat or wheat aphid management summary [10]

Scientific name	*Rhopalosiphum padi*
Description	Adults are 2 mm long, olive-green to black with a red rust patch at the rear end and may have wings. Antennae extend to half the body length. Nymphs are similar but smaller. Wheat and oat aphids are very similar to corn aphids
Distribution	An introduced species found in all states of Australia
Crops attacked	Barley, wheat and oats
Life cycle	A species that produces many generations through the growing season. Winged and non-winged forms occur
Damage	Aphids feed directly on stems, leaves and heads, and in high densities cause yield losses and plants may appear generally unthrifty. This type of damage is rare throughout the grainbelt. Aphids can spread BYDV in wheat and barley
Monitoring and action level	Aphids can affect any crop stage but are unlikely to cause economic damage to cereal crops expected to yield <3 t/ha. Consider treatment if there are 10–20+ aphids on 50% of the tillers
Control	Chemical control: Apply a foliar insecticide in late winter or spring to avoid direct damage to tillers and heads. To prevent losses from BYDV in virus-prone areas, control aphids early in the cropping year. For current chemical control options see Pest Genie or APVMA. Cultural control: There are no known effective cultural control methods
Host-plant resistance	In virus-prone areas, use resistant plant varieties to minimise losses due to BYDV
Natural enemies	Predation by hoverflies, lacewings and ladybeetles and parasitism by wasps can reduce aphid populations, but this does not happen in every season. Heavy rain may reduce aphid populations significantly

9 DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

10 DAFF (2011) Oat aphid, wheat aphid. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/oat-aphid,-wheat-aphid

7.2.5 Corn aphid (*Rhopalosiphum maidis*)

Corn aphid (Figure 4) is also a common species found in winter cereals. It generally colonises the upper parts of the plant, particularly the rolled up terminal leaf. [11]

Figure 4: Corn aphid (Source: QDAFF)

Table 3: Corn aphid management summary [12]

Scientific name	*Rhopalosiphum maidis*
Description	Up to 2 mm long, light to dark olive-green with a purple area at the base of small tube-like projections at the rear of the body. Adults are generally wingless. Antennae extend to about a third of body length. Nymphs are similar, but smaller in size
Similar species	Other species of aphids
Distribution	An introduced species, probably Asiatic in origin, found in all states of Australia
Crops attacked	Sorghum, maize, winter cereals and many grasses. Life cycle on sorghum: Corn aphids breed throughout the summer on sorghum with a life cycle of about 1 week. There can be up to 13 generations on a sorghum crop and 30 generations/year. Life cycle on cereals: A parthenogenetic species that undergoes many generations through the growing season. Both winged and non-winged forms occur

11 DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

12 DAFF (2010) Corn aphid. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/corn-aphid

Damage	In sorghum: Adults and nymphs suck sap and produce honeydew. Very high numbers may turn plants yellow. High populations on heads produce sticky grain and clog harvesters. Rain will readily remove honeydew. Water-stressed dryland crops lose yield. In cereal: Aphids feed on stems, leaves and heads, and in high densities cause yield losses. However, this type of damage is uncommon throughout the cereal belt. Risk period: In sorghum: All stages of the crop are attacked, but the most serious damage occurs when high populations infest heads. In cereals: Most prevalent on cereals in late winter and early spring. High numbers often occur in years when an early break in the season and mild weather in autumn and early winter provide favourable conditions for colonisation and multiplication
Monitoring	Estimate percentage of plants infested and percentage of leaf area covered by aphids
Action level	The action level in the vegetative stage of sorghum is 100% of plants with 80% of the leaf area covered by aphids. On the heads it is 75% of heads with 50% of the head covered by aphids. Aphids are unlikely to cause economic damage to cereal crops expected to yield <3 t/ha. To avoid damage by direct feeding, consider treatment if there are ≥10–20 aphids on 50% of the tillers
Chemical control	Chemical control is cost-effective. See Pest Genie or APVMA for current control options. Conservation of natural enemies: A range of parasitoids and predators will help reduce aphid populations. Predators of aphids include: ladybird larvae, damsel bugs, big-eyed bugs and the larvae of green lacewings and hoverflies. Wasp parasitoids mummify and kill aphids
Host plant resistance	In sorghum, hybrids with open heads are less infested than tight-headed hybrids

7.2.6 Rose-grain aphid (*Metopolophium dirhodum*)

Rose-grain aphid (Figure 5) generally colonises the undersides of the leaves, high in the canopy. [13]

Figure 5: Rose-grain aphid (Source: QDAFF)

[13] DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

Table 4: Rose-grain aphid management summary [14]

Scientific name	*Metopolophium dirhodum*
Description	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. 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
Similar species	Because of its distinctive colour, it is unlikely to be confused with other aphids
Distribution	An introduced species that has been recorded in New South Wales, Queensland, South Australia, Tasmania and Victoria
Crops attacked	Wheat, barley, triticale, oats
Life cycle	Undergoes many generations during the growing season; winged and non-winged forms occur
Damage	Adults and nymphs are sap-suckers. Under heavy infestations, plant may turn yellow and appear unthrifty. Can spread BYDV in wheat and barley
Monitoring and action level	Can affect any crop stage; assess the potential for direct-feeding damage in late winter. Estimate the number of aphids per tiller. Aphids are unlikely to cause economic damage to cereal crops expected to yield <3 t/ha
Control	Chemical control: Apply a foliar insecticide in late winter or spring to avoid damage to tillers. To prevent losses from BYDV in virus-prone areas, control aphids early in the cropping year. For current chemical control options see Pest Genie or APVMA Cultural control: There are no known effective cultural control methods for this aphid
Natural enemies	Predation by hoverflies, lacewings and ladybird beetles, parasitism by wasps and heavy rainfall can reduce aphid populations

14 DAFF (2011) Rose-grain aphid. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/rose-grain-aphid

7.2.7 Rice root aphid (*Rhopalosiphum rufiabdominalis*)

Rice root aphid (Figure 6) colonises the roots of the plants under the soil surface, and colonies may extend up from the roots to the base of the plant. Rice root aphid can be quite abundant on below-ground parts of winter cereals, but are more noticeable during periods of moisture stress. [15]

Figure 6: Rice root aphid (Source: QDAFF)

Table 5: Rice root aphid management summary [16]

Scientific name	*Rhopalosiphum rufiabdominalis*
Description	Fully grown aphids are 1.2–2.2 mm long and dark green to grey-brown in colour. Nymphs are lighter in colour with a reddish area at the tip of the abdomen
Damage	Rice root aphids suck fluids from the plant roots, but only do so when the bases of plants are exposed
Control	Cannot be controlled using contact insecticides because of their below-ground location on plants. Seed dressings may be effective

[15] DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

[16] DAFF (2010) Rice root aphid. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/rice-root-aphid

7.3 Armyworm

Armyworm (Figure 7) is the caterpillar stage of certain moths, and can occur in large numbers, especially after good rain following a dry period. Larvae shelter in the throats of plants or in the soil and emerge after sunset to feed on the leaves of all winter cereals, particularly barley and oats, generally during September and October. Leafy cereal plants can tolerate considerable feeding, and control in the vegetative stage is seldom warranted unless large numbers of armyworms are distributed throughout the crop or are moving in a 'front', destroying young seedlings or completely stripping older plants of leaf. The most serious damage occurs when larvae feed on the upper flag leaf and stem node as the crop matures, or in barley when the older larvae start feeding on the green stem just below the head as the crop matures.

Figure 7: Armyworm (Source: QDAFF)

The most common species are common and northern armyworm (*Leucania convecta* and *L. separata*), and lawn armyworm (*Spodoptera mauritia*). Infestations are evident by scalloping on margins of leaves caused by feeding of the older larvae. Larvae target the stem node as the leaves become dry and unpalatable, and the stem is often the last part of the plant to dry. One large larva can sever up to seven heads of barley a day. One larva/m^2 can cause a grain loss of 70 kg/ha.day (Table 6). A larva takes around 8–10 days to develop through the final, most damaging instars, with crops susceptible to maximum damage for this period (Table 7).

Check for larvae on the plant and in the soil litter under the plant. The best time to do this is late in the day when armyworms are most active. Alternatively, look around the base of damaged plants where the larvae may be sheltering in the soil during the day. Using a sweep net (or swing a bucket), check a number of sites throughout the paddock. Sweep sampling is particularly useful early in an infestation when larvae are small and actively feeding in the canopy. One full sweep with a net samples the equivalent of 1 m^2 of crop.

Table 6: The value of yield loss incurred by armyworm larvae (1 or 2/m².day), based on approximate values for wheat and an estimated loss per larva of 70 kg/ha. Based on these figures, and the relatively low cost of controlling armyworm, populations in ripening crops of >1 large larva/m² warrant spraying

Value of grain (AU$/t)	Value of yield loss ($) per day	
	1 larva/m²	2 larvae/m²
$140	$9.80	$19.60
$160	$11.20	$22.40
$180	$12.60	$25.20
$200	$14.00	$28.00
$220	$15.40	$30.80
$250	$17.50	$35.00
$300	$21.00	$42.00
$350	$24.50	$49.00
$400	$28.00	$56.00

Early recognition of the problem is vital, as cereal crops can be almost destroyed by armyworm in just a few days. Although large larvae do the head lopping, controlling smaller larvae that are still leaf-feeding may be more achievable. Prior to chemical intervention, consider how quickly the larvae will reach damaging size, and the development stage of the crops. Small larvae take 8–10 days to reach a size capable of head-lopping, so if small larvae are found in crops nearing full maturity/harvest, spray may not be needed, whereas small larvae in late crops that are still green and at early seed-fill may reach a damaging size in time to reduce crop yield significantly.

Control is warranted if the armyworm population distributed throughout the crop is likely to cause the loss of 7–15 heads/m². Many chemicals will control armyworms. However, their effectiveness often depends on good penetration into the crop to achieve contact with the caterpillars. Control may be more difficult in high-yielding, thick-canopied crops, particularly when larvae are resting under soil at the base of plants. As larvae are most active at night, spraying in the afternoon or evening may produce the best results. If applying sprays close to harvest, be aware of relevant withholding periods.

Biological control agents may be important in some years. These include parasitic flies and wasps, predatory beetles and diseases. Helicoverpa NPV (nucleopolyhedrovirus) is not effective against armyworm. [17]

17 DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

Table 7: Armyworm management summary [18]

Scientific name	*Leucania convecta*—common armyworm *L. separata*—northern armyworm *L. stenographa*—sugarcane armyworm
Description	Common armyworm: First-instar larvae are about 1 mm long. From the second instar, stripes develop along the top and sides of the larva and become more distinct as the larva grows. Crowded larvae are usually darker than uncrowded. The mature larva grows up to 40 mm in length and has three characteristic pale stripes on the head, collar (segment behind the head) and tail segment. They are smooth-bodied with no distinct hairs. The body of the larva also has lateral stripes. The forewings of the moth have a wingspan of about 40 mm and are fawn or buff coloured. Northern armyworm: Larvae and adults are very similar to the common armyworm. Sugarcane armyworm: Moths have pale forewings with a dark line running the length of the forewing
Similar species	Adults of the common and northern armyworms may be confused. Genitalia dissections by a specialist are required to separate the species. The larval stages likely to be encountered in cereals are all similar in appearance
Distribution	Common armyworm: Native Australian species, recorded in New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia. Northern armyworm: Throughout South-East Asia, New Zealand and in Australia, where it occurs in all states except Tasmania. Sugarcane armyworm: Recorded from Asia and Australia, where it occurs throughout drier parts of the mainland and as an occasional vagrant to Tasmania
Crops attacked	Common armyworm: Damages barley, oats, wheat, native pasture grasses and perennial grass seed crops. Northern armyworm: In Queensland, recorded as damaging sorghum, maize, barley, wheat and rice. Sugarcane armyworm: A minor pest, occasionally damaging some WA grain crops
Life cycle	Common armyworms have three generations per year. The winter and spring generations damage cereals. Moths fly into cereal crops and lay their eggs in the folds of dried or drying leaves on grasses or cereals. Females lay up to 1000 eggs in irregularly shaped masses, cemented in tight folds of foliage. Eggs hatch in as little as 3–4 days after laying and young larvae, with the assistance of wind, disperse through the crop on fine silken threads. The larvae feed on leaves and stems. Larvae usually develop through six instars but sometimes seven. Indicative development times at constant temperature are: egg-laying to hatch, 7 days at 20°C and 2.5 days at 30°C; larval stages (including pre-pupal stage) 34.2 days at 20°C and 17.2 days at 30°C. Larvae pupate in the soil. Pupal stage lasts 20.1 days at 20°C and 10.1 days at 30°C. Development time from neonate to adult emergence is 61 days at 20°C and 41 days at 30°C (Smith 1984). Northern and sugarcane armyworms—similar to common armyworm

18 DAFF (2010) Common, northern and sugarcane armyworms. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/armyworm-overview/common,-northern-and-sugarcane-armyworms

Risk period and damage	Risk period: The greatest risk to cereals is spring. Moth flights occur in September and October, and the later-stage larvae damage cereals often in the weeks prior to harvest. The mature larval stages of the winter generation will sometimes march in cereal crops in late winter and cause serious damage to crops, particularly on the edges of paddocks. Crops directly seeded into standing stubbles are susceptible to severe defoliation during the vegetative stage as the winter generation matures. Damage: There are two distinct periods for economic damage. The first, defoliation during early vegetative development, is less common than the second through ripening. Ripening barley is most susceptible to armyworm damage because the last part of the head to dry off is the green tissue just below the head. Mature larvae feed on that area and thereby sever the head of the cereal, which falls to the ground. One larva can lop many heads very quickly causing large grain losses. Oats are also damaged but the less compact seed head means less damage. In northern Australia, wheat can also be damaged, but in the south the wheat head stays green later and armyworms feed along the heads and damage grain rather than excise the whole head
Monitoring and action level	Large numbers of armyworm moths are attracted to farm lights on warm nights in September and October. This provides the first warning of potential problems in cereals. Armyworm larvae are difficult to find in cereals crops as they hide at the base of plants or under clods of soil during the day. Search at the base of plants and under clods of soil to estimate the number of larvae per m^2. Presence of green-yellow pellet-shaped droppings of the larvae on the ground is usually a reliable sign of larvae. Monitor for larvae at dusk with a sweep net; sweep netting during the day can be unreliable. Two larvae/m^2 for barley. Other cereals are likely to tolerate slightly higher numbers
Control	Chemical control: A range of insecticides is registered for armyworm control in cereals. Insecticides should target larvae 10–20 mm long. Larvae >20 mm long can be difficult to kill and may require higher rates of insecticide. If possible spray late in the day as larvae are active at night. See Pest Genie or APVMA for current control options. Cultural control: Windrowed or swathed crops dry out rapidly, rendering them unattractive to the feeding of armyworm larvae. They are also less susceptible to wind damage (head shattering)
Natural enemies	Armyworm larvae are attacked by a number of parasitoids that may be important in reducing the intensity of outbreaks. However, when armyworms are in numbers likely to cause damage, parasitoids are unlikely to give timely control. Predators include green carab beetles, populations of which increase dramatically in inland Australia in response to abundant noctuid larvae induced by favourable seasons. Other predators include the predatory shield bugs and perhaps common brown earwigs. Fungal diseases are recorded as causing mortality of armyworm

7.4 *Helicoverpa* spp. (*Heliothis*)

Helicoverpa spp. are frequently found in winter cereals, usually at levels too low to warrant control, but occasionally numbers may be sufficiently high to cause economic damage. Virtually all *Helicoverpa* present are *H. armigera* (Figure 8), which has developed resistance to many of the older insecticide groups. It is not unusual to find both *Helicoverpa* and armyworm in cereal crops, so correct identification of the species present is important. *Helicoverpa* do not cause the typical head-cutting damage of armyworms. Larvae tend to graze on the exposed tips of a large number of developing grains, rather than totally consuming a low number of whole grains, thus increasing the potential losses. Most (80–90%) of the feeding and crop damage is done by larger larva (the final two instars).

Figure 8: Helicoverpa armigera (Source: QDAFF)

Check for larvae on the plant throughout the growing season (monitoring can be done in conjunction with sampling for armyworm). Using a sweep net, check a number of sites throughout the paddock (read more about insect sampling methods below, under heading 1.6.3). Larger larvae are more difficult to control than small larvae, and NPV is most effective when larvae <13 mm long are targeted.

No thresholds have been developed for *Helicoverpa* in winter cereals; however, using a consumption rate determined for *Helicoverpa* feeding in sorghum (2.4 g/larva), one larvae/m^2 can cause 24 kg grain loss/ha. Table 8 shows the value of yield loss incurred by a range of larval densities, using an estimated consumption of 2.4 g/larvae and a range of grain values for wheat. Note that larval damage is irrespective of the crops yield potential (i.e. each larva will eat its fill whether it is 1 t/ha crop or a 3 t/ha crop).

Table 8: Value of yield loss ($/ha) incurred by a range of Helicoverpa larval densities

Cereal price ($/t)	Larval density			
	4 larvae/m²	6 larvae/m²	8 larvae/m²	10 arvae/m²
150	14.4	21.6	28.8	36
200	19.2	28.8	38.4	48
250	24.0	36.0	48.0	60
300	28.8	43.2	57.6	72
350	33.6	50.4	67.2	84
400	38.4	57.6	76.8	96
450	43.2	64.8	86.4	108

Based on Table 8, a crop worth $250/twill incur a loss of $6/ha from each larvae. If chemical intervention costs $30/ha (chemical + application costs), the economic threshold or break-even point is 5 larvae/m². These parameters can be varied to suit individual costs, and they can incorporate a working benefit/cost ratio. A common benefit/cost ratio of 1.5 means that the projected economic benefit of the spray will be 1.5 times the cost of the spray. Spraying at the break-even point (benefit/cost ratio of 1) is not recommended.

Small larvae (<7 mm) can be controlled with biopesticides (e.g. NPV) (see Table 9 for management summary). Biopesticides are not effective on larger larvae. *Helicoverpa armigera* has historically had high resistance to pyrethroids, and control of medium-large larvae using pyrethroids is not recommended. Predators of *Helicoverpa* eggs and larvae include spined predatory bug, glossy shield bug, damsel bug and big-eyed bug.

Where winter cereals have previously been treated with broad spectrum insecticides to control aphids, fewer natural enemies may be present and survival of caterpillar pests could be greater than in an untreated field. [19]

Table 9: Management summary for Helicoverpa [20]

Scientific name	*Helicoverpa armigera* (cotton bollworm or corn earworm) and *H. punctigera* (native budworm)
Identification	Eggs are 0.5 mm in diameter and change from white to brown to a black head stage before hatching. Newly hatched larvae are light in colour with tiny dark spots and dark heads. As larvae develop, they become darker and the darker spots become more obvious. Both species look the same at the egg and small larvae stages. Medium larvae develop lines and bands running the length of the body and are variable in colour. *H. armigera* have a saddle of darker pigment on the fourth segment and at the back of the head and dark-coloured legs. *H. punctigera* have no saddle and light-coloured legs. Large larvae of *H. armigera* have white hairs around the head; *H. punctigera* have black hairs around the head. Pupae are found in soil underneath the crop. Healthy pupae wriggle violently when touched. *H. armigera* pupal tail spines are more widely spaced than those of *H. punctigera* Moths are a dull light brown with dark markings and are 35 mm long. *H. armigera* has a small light or pale patch in the dark section of the hindwing, while the dark section is uniform in *H. punctigera*. Forewings are brown in the female and cream in the male

19 DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

20 DAFF (2012) Helicoverpa species. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/helicoverpa/helicoverpa-species

Similar species	Commonly confused species include armyworms and loopers. *Helicoverpa* larvae have a group of four pairs of 'legs' in the back half of the body, whereas loopers can have a group of two, three or four pairs of legs at the rear and loop when walking. Armyworms also have four pairs of prolegs, but are smoother and fatter, with more coloured bands than *Helicoverpa*
Life cycle	*H. armigera* and *H. punctigera* take about 4–6 weeks to develop from egg to adult in summer, and 8–12 weeks in spring or autumn. Moths live for ~10 days, during which time females lay 1000 eggs. Read more about Helicoverpa life cycle and behaviour
Crops attacked	The two *Helicoverpa* species prefer different hosts: *H. punctigera* attacks broadleaf species (e.g. cotton, chickpea, sunflower, soybean, mungbean, navy bean, lucerne, canola, peanut, faba bean, safflower, linseed, azuki bean). It is not found on grass or cereal crops, such as wheat, barley, sorghum or maize. *H. armigera* will attack all field crops, but is less common in wheat and barley. Larvae feed on leaves but are most damaging when feeding on growing terminals, buds or squares, flowers, pods, seed and/or fruit. This includes direct losses through shedding and reduced quality. For more information see IPM in specific crops or visit The Beat Sheet blog
Monitoring	Helicoverpa can be present in crops from the vegetative stage onwards. Very susceptible crops (e.g. cotton) need to be closely monitored from emergence to maturity for eggs and larvae; however, most field crops only need to be monitored closely from budding/flowering through to maturity. Eggs are most commonly laid on the top third of the plant and growing points
Management	To manage *H. armigera* and *H. punctigera* well, it is important to understand the basic differences between the two species. IPM strategies incorporating chemical, cultural and biological methods aim to restrict populations to below damaging levels. *H. armigera* has developed resistance to a wide range of insecticides; however, several products are now registered for both species that have reduced impacts on natural enemies in the crop. Larvae are best targeted when smaller than 7 mm. Read more about key principles of *Helicoverpa* management
Natural enemies	All stages of the *Helicoverpa* lifecycle are attacked by a wide range of predators, parasitoids and pathogens, and conserving these in the crop through the avoidance of broad-spectrum insecticides can help prevent/minimise the need for insecticide treatments. Read more about Helicoverpa's natural enemies

7.5 Mites

7.5.1 Brown wheat mite (*Petrobia latens*)

Brown wheat mite (Figure 9) damage is severe only in dry seasons.

The mature wheat mite is about the size of a pinhead, globe-shaped and brown. It has been a sporadic pest of winter cereals (Table 10). Populations reach troublesome levels only under very dry conditions.

Figure 9: Brown wheat mite (Source: QDAFF)

Table 10: Management summary of brown wheat mite

Scientific name	*Petrobia latens*
Description	Adults are oval, up to 0.6 mm long and have eight legs. The front legs are significantly longer than the others. The mite is brown and appears dark greenish-brown to black when on a green leaf. It is significantly smaller than, and has finer legs than, the blue oat mite. Immature mites are smaller and orange-red
Similar species	A very small mite that is unlikely to be confused with the blue oat mite or redlegged earth mite
Crops attacked	Wheat, barley, triticale, oats, cotton and grasses. Crops are at risk during warm, dry periods
Damage	Adults and nymphs pierce and suck on leaves, resulting in a mottled and ''drought-like' appearance. Crops with heavy infestations appear bronzed or yellowish and seedlings can die
Monitor	Check from planting to early vegetative stage, particularly in dry seasons
Action level	Spray if mottled patches appear throughout the crop and if conditions are dry
Chemical control	Foliar treatments may sometimes be cost-effective. For current chemical control options see Pest Genie or APVMA
Natural enemies	No natural enemies recorded

7.5.2 Blue oat mite (*Penthaleus* spp.)

Blue oat mites (Figure 10) are important pests of seedling winter cereals, but are generally restricted to cooler grain-growing regions (southern Queensland through eastern New South Wales, Victoria, South Australia and southern Western Australia).

Figure 10: Blue oat mite (Source: QDAFF)

Adults and nymph mites pierce and suck leaves, resulting in silvering of the leaf tips. Feeding causes a fine mottling of the leaves, similar to the effects of drought. Heavily infested crops may have a bronzed appearance, and severe infestations cause leaf tips to wither and can lead to seedling death. Damage is most likely during dry seasons when mites in large numbers heighten moisture stress and control may be warranted in this situation.

Check from planting to early vegetative stage, particularly in dry seasons, monitoring a number of sites throughout the field (Table 11). Blue oat mites are most easily seen in the cooler part of the day, or when it is cloudy. They shelter on the soil surface when conditions are warm and sunny. If pale-green or greyish irregular patches appear in the crop, check for the presence of blue oat mite at the leaf base.

Where warranted, foliar application of registered insecticide may be cost-effective. Check the most recent research to determine the likely susceptibility of blue oat mite to the available registered products. Cultural control methods can contribute to reduction in the size of the autumn mite population (e.g. cultivation, burning, controlling weed hosts in fallow, grazing and maintenance of predator populations). Since eggs laid in the soil hibernate throughout winter, populations of the mite can build up over a number of years and cause severe damage if crop rotation is not practiced. The use of control tactics solely in spring will not prevent the carry-over of eggs into the following autumn.

Predators of blue oat mites include spiders, ants, predatory beetles and the predatory anystis mite and snout mite. Blue oat mites are also susceptible to infection by a fungal pathogen (*Neozygites acaracida*), particularly in wet seasons. [21]

The blue oat mite is an important pest of seedling winter cereals. When infestations are severe, the leaf tips wither and eventually the seedlings die. Eggs laid in the soil hibernate over winter, allowing populations to build up over a number of years. This can cause severe damage if crop rotation is not practiced.

21 DAFF (2012) Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

Table 11: Management summary of blue oat mite [22]

Scientific name	*Penthaleus major*
Description	Adults are 1 mm long and have eight legs. Adults and nymphs have a purplish-blue, rounded body with red legs. They move quickly when disturbed. The presence of a small red area on the back distinguishes it from the redlegged earth mite
Similar species	Brown wheat mite, redlegged earth mite
Crops attacked	Mainly a pest of cereals and grass pastures, but will feed on pasture legumes and many weeds
Damage	Adults and nymphs pierce and suck on leaves resulting in silvering of the leaf tips in cereals. When heavy infestations occur, the leaf tip withers and the seedling can die. In canola, leaves are mottled or whitened in appearance
Monitor	Check from planting to early vegetative stage, particularly in dry seasons. Most easily seen in the late afternoon when they begin feeding on the leaves
Control	Foliar applications of insecticides may be cost-effective if applied within 2–3 weeks of emergence in autumn. The use of control tactics solely in spring will not prevent the carry-over of eggs into the following autumn. For current chemical control options see Pest Genie or APVMA
Natural enemies	Thrips and ladybirds

7.5.3 Redlegged earth mites *Halotydeus destructor*

Characteristics and management of redlegged earth mites (Figure 11) are summarised in Table 12.

Figure 11: Adult redlegged earth mites (Source: CESAR)

Table 12: Management summary of redlegged earth mite

Scientific name	*Halotydeus destructor*
Description	Adults are 1 mm long and have eight legs. Adults and nymphs have a black, somewhat flattened body and red legs
Similar species	Similar in appearance to blue oat mite; however, blue oat mite can be distinguished by a small oval red area in the middle of the back
Distribution	Originated in South Africa, now found in New Zealand and Australia. The redlegged earth mite is widely distributed in winter rainfall dominant regions of southern Australia

22 DAFF (2010) Blue oat mite. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/mites-overview/blue-oat-mite

Pest status	Major, widespread, regular, in southern Australia
Crops attacked	Damages all field crops and pastures, especially at seedling stage. A major pest of legume pastures and canola
Damage	Adults and nymphs feeding cause a silver or white discoloration of leaves and distortion of leaf shape. Affected seedlings can die. Seedlings can be killed before emergence. There is also reduced production and quality of older green plants during the growing season and reduced seed yield of legumes in spring
Risk period	Autumn to spring, especially at germination
Life cycle	On winter rainfall pastures: The redlegged earth mite is active in the cool, wet months from May to November. They hatch in autumn at the break of the season, from over-summering eggs that have been in a state of arrested development (diapause) since the end of the previous spring. Hatching is triggered by a significant rainfall event combined with a period of 7–10 days where the mean daily maximum temperature is <21°C Eggs hatch into six-legged larvae and then develop through three nymphal stages into adults. Nymphs and adults have eight legs. During winter, the redlegged earth mite passes through three generations on average, each lasting about 8 weeks. When conditions are favourable, numbers can increase rapidly, with peaks in autumn and/or spring
Monitoring	Monitor pastures regularly from the time of first emergence of seedlings. Approach quietly as mites will disperse quickly if disturbed. If mites are not found on the plants, look carefully at the soil surface. A hand lens will be required to detect newly hatched larvae and young nymphs
Action level	Any sign of mite activity or damage at germination warrants control. At other times of the season, feeding damage to more than 20% of the leaf area may warrant control
Control	Chemical control: Treating seed with systemic insecticide before sowing pastures protects seedlings from attack. Chemical sprays do not kill mite eggs so it is important to time sprays when most mites have emerged. Spraying should be timed for autumn or spring. In autumn, chemicals should be applied after the break of season, and after all of the over-summering eggs have hatched but before adult mites start laying eggs. For current chemical control options see APVMA Cultural control: Heavy grazing in winter and spring reduces mite populations. Control of broadleaf weeds in summer can reduce mite populations in autumn. Natural enemies: A predatory mite, *Anystis wallacei*, was imported from France to Australia in 1965 for biological control and has established at some sites where it has caused significant mortality of redlegged earth mites. Its effectiveness is limited by its slow dispersal

More information

GRDC Insect ID App: https://itunes.apple.com/au/app/insect-id-ute-guide-tablet/id667854493?mt=8

7.6 Insect monitoring techniques for field crops

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 knowledge of, and the ability to identify, the insects present, but also good sampling and recording techniques and a healthy dose of common sense.

7.6.1 Factors that contribute to quality monitoring

Knowledge of likely pests/beneficials and their life cycles is essential when planning a monitoring program. As well as visual identification, you need to know where on the plant to look and the best time of day to get a representative sample.

Monitoring frequency and pest focus should be directed at crop stages likely to incur economic damage. Critical stages may include seedling emergence and flowering/grain formation.

Sampling technique is important to ensure that a representative portion of the crop has been monitored, since pest activity is often patchy. Defining sampling parameters (e.g. number of samples per paddock and number of leaves per sample) helps sampling consistency. Actual sampling technique, including sample size and number, will depend on crop type, age and paddock size, and is often a compromise between the ideal number and location of samples, and what is practical considering time constraints and distance covered.

Random sampling should be balanced with areas of obvious damage. Random sampling aims to give an overall picture of what is happening in the field, but any obvious hot-spots should also be investigated. The relative proportion of hotspots in a field must be kept in perspective with less heavily infested areas.

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	1	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)	(3.4*0.7)=2.4			
Mean estimate of larval number (Adjusted S)+M+L	2.4 0.6 0.2 =3.2			

Adjust for row spacing divide by row spacing (m): 3.2 / 0.75

4.2 Density Estimate per square metre

Figure 12: An example of a field check sheet for chickpeas, showing adjustments for field mortality and row spacings.

7.6.2 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 12). Monitoring record sheets should show the following:

- numbers and types of insects found (including details of adults and immature stages)
- size of insects (particularly important for larvae)
- date and time
- crop stage and any other relevant information (e.g. row spacings, 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 Figuregraphs for later reference.

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)
- amount of product(s) and volume applied per hectare
- method of application including nozzle types and spray pressure
- any other relevant details

7.6.3 Sampling methods

Beat sheet

A beat sheet is the main tool used to sample row crops for pests and beneficial insects. Beat sheets are particularly effective for sampling caterpillars, bugs, aphids and mites. A standard beat sheet is made from yellow or white tarpaulin material with heavy dowel on each end. Beat sheets are generally 1.3–1.5 m wide and 1.5–2.0 m deep (the larger dimensions are 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.

To use the beat sheet, place one edge at the base of plants in the row to be sampled.

Drape the other end of the beat sheet over the adjacent row. This may be difficult in crops with wide row spacing (≥1 m); in this case, spread the sheet across the inter-row space and up against the base of the next row.

Using a 1-m stick, shake the plants in the sample row vigorously in the direction of the beat sheet 5-10 times. This will dislodge the insects from the sample row onto the beat 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 the 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 1-m-long sections of row, taken within a 20-m radius (i.e. 5 beats = 1 sample unit). This should be repeated at six locations in the field (i.e. 30 beats per field).

Increasing the number of samples taken increases the accuracy of the assessment of pest activity, particularly for pests that are patchily distributed, such as pod-sucking bug nymphs.

When is the best time to use the beat sheet?

Pulse crops are at greatest risk from insect attack from budding onwards.

Crops should be checked weekly during the vegetative stage and twice weekly from the start of budding onwards.

Caterpillar pests are not mobile within the canopy, and checking at any time of the day should report similar numbers.

Pod-sucking bugs, particularly green vegetable bugs, often bask on the top of the canopy during the early morning, and they 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.

Most thresholds are expressed as pests per square metre (pests/m^2). Hence, insect counts in crops with row spacing <1 m must be converted to pests/m^2. 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 a row spacing of 0.75 m (75 cm), divide the average pest counts by 0.75.

Other sampling methods

Visual checking is not recommended as the sole form of insect checking; however, 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 of plants in a crop is also important for estimating how the crop is progressing 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 present 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. 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 practical 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.

More information

GRDC Pestlinks: http://www.grdc.com.au/Resources/Links-Pages/PestLinks

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 high purchase cost of the suction machine.

Monitoring with traps (pheromone, volatile, and light traps) can provide general evidence on pest activity and the timing of peak egg-lay events for some species. However, it is no substitute for in-field monitoring of actual pest and beneficial numbers. [23]

[23] DAFF (2012) Insect monitoring techniques for field crops. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/insect-monitoring

SECTION 8

Nematode management

Research trial results

8.1 Durum and Pratylenchus thornei (*P. thornei*)

8.1.1 Resistance (impact of durum varieties on *P. thornei* build-up)

Figure 1 shows a multi-year analysis of variety impact on *P. thornei* build-up.

Figure 2 shows data from a single trial in 2015 where a wider range of durum varieties were evaluated including DBA Lillaroi⦶.

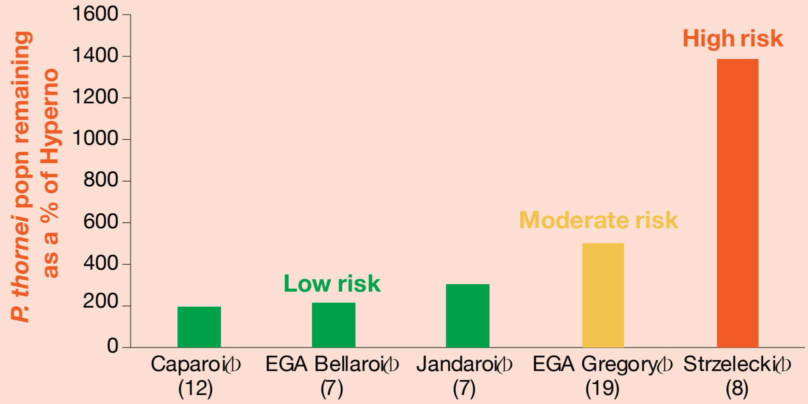

Figure 1: Relative P. thornei build-up following durum and bread wheat varieties, expressed as a percentage of Hyperno⦶. Number in brackets is the actual number of trials for each variety.

NB: Hyperno , Caparoi⦶ and EGA Bellaroi⦶ resulted in significantly lower final populations of *P. thornei* than EGA Gregory⦶ Strzelecki⦶ resulted in significantly larger populations of *P. thornei* than all other varieties graphed.

Data courtesy NGA and NSW DPI field trials 2009-14 with MET analysis conducted by QDAF.

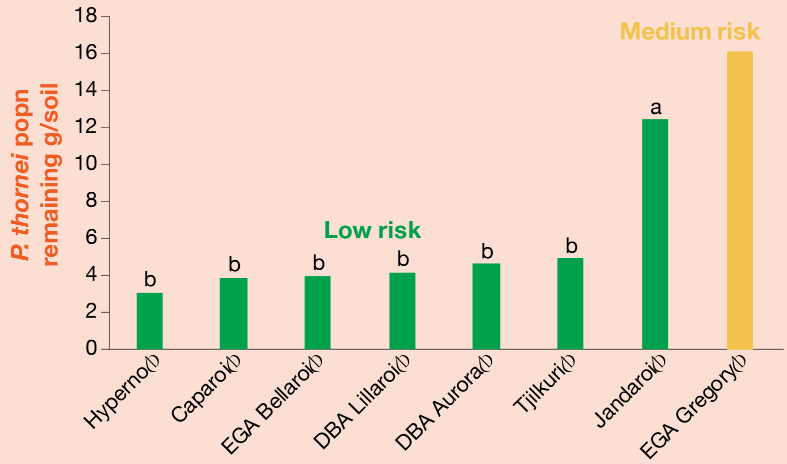

Figure 2: P. thornei populations sampled on 7 Mar 2016 at Macalister, Qld. Starting population of 2.7 P. thornei/g soil on 18 Feb 2015.

NB: EGA Gregory⦶ result is from an adjacent bread wheat trial and is indicative only.

Research trial results

Key Points

Resistance (impact of durum varieties on P. thornei build-up)

Durum varieties consistently show higher levels of resistance to the root-lesion nematode *P. thornei* than bread wheat and barley varieties.

The average *P. thornei* population remaining after a single durum crop is ~40-80% less than after EGA Gregoryⓓ and 80-90% less than after a single season of Strzeleckiⓓ.

Early indications are that DBA Lillaroiⓓ DBA Auroraⓓ and Tjilkuriⓓ have similar levels of *P. thornei* resistance as Caparoiⓓ and EGA Bellaroiⓓ.

Jandaroiⓓ is generally the least *P. thornei* resistant durum but is still similar to the most resistant commercial bread wheat options.

8.1.2 Tolerance (yield impact from *P. thornei*)

Figure 3 shows yield impact due to *P. thornei* from a trial near Yallaroi, NSW, in 2012.

Figure 4 shows yield impact due to *P. thornei* from a trial near Macalister, Qld, in 2015.

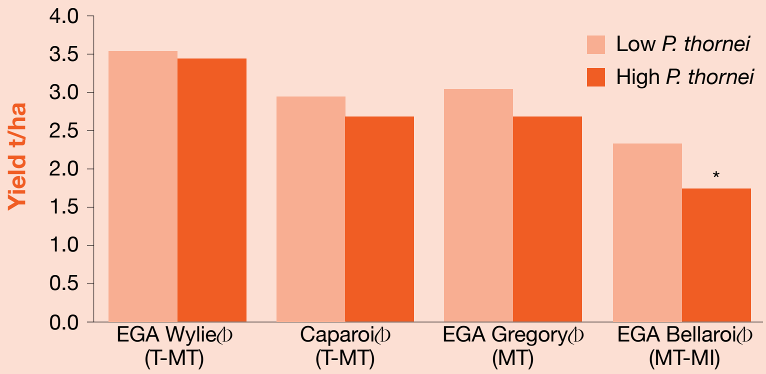

Figure 3: Yield impact from P thornei near Yallaroi in 2012 with varieties ranked from left to right in decreasing P. thornei tolerance ranking. Letters in brackets are the tolerance ranking (2016 Qld Variety Guide).

Dark columns show variety yield with a starting population of 1.9 *P. thornei*/g soil. Lighter columns show yield when starting population was 19 *P. thornei*/g soil.

*= significant yield loss in variety under increased *P. thornei* population, e.g. EGA Bellaroi.

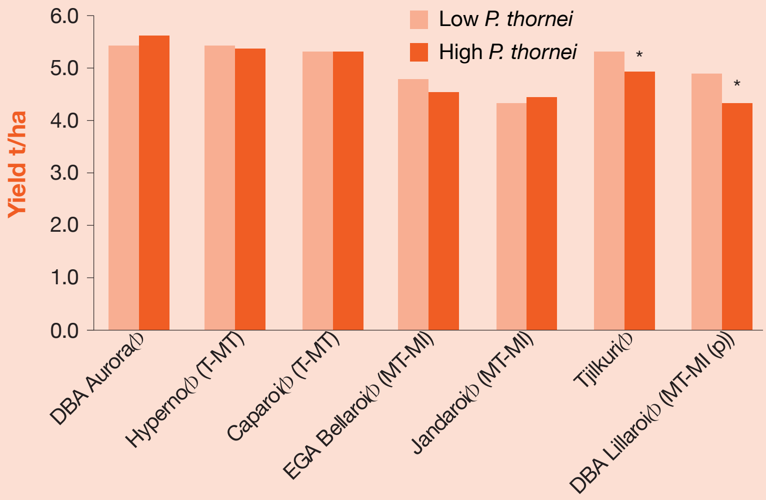

Figure 4: Yield impact from P. thornei near Macalister in 2015 with varieties ranked from left to right in decreasing P. thornei tolerance ranking. Letters in brackets are the tolerance ranking (2016 Qld Variety Guide).

NB: No available tolerance ranking for DBA Auroraⓓ and Tjilkuriⓓ. Dark columns show variety yield with a starting population of 2.7 *P. thornei*/g soil. Lighter columns show yield when starting population was 29 *P. thornei*/g soil.

*= significant yield loss in variety under increased *P. thornei* population, e.g. Tjilkuriⓓ and DBA Lillaroiⓓ.

Research trial results

Key Points

Tolerance (yield impact from P. thornei)

Durum varieties differ in tolerance to *P. thornei*. Significant levels of yield impact were seen in EGA Bellaroi⟑ in 2012 (-0.6t/ha) and DBA Lillaroi⟑ (-0.6t/ha), and in Tjilkuri⟑ (-0.4t/ha) in 2015.

Caparoi⟑ (and potentially Hyperno⟑ and DBA Aurora⟑) may be better options for durum production in paddocks with concerning levels of *P. thornei*.

Root-lesion nematodes (RLN; *Pratylenchus* spp.) are microscopic, worm-like animals that extract nutrients from plants, causing yield loss. In the northern grains region, the predominant RLN, *P. thornei*, costs the wheat industry AU$38 million[1] annually, and including the secondary species, *P. neglectus*, RLN are found in three-quarters of fields tested.

Intolerant crops such as wheat and chickpeas can lose 20–60%[2] in yield when nematode populations are high. Resistance and susceptibility of crops can differ for each RLN species; for example, sorghum is resistant to *P. thornei* but susceptible to *P. neglectus*. A tolerant crop yields well when large populations of RLN are present (the opposite is intolerance). A resistant crop does not allow RLN to reproduce and increase in number (the opposite is susceptibility).[3]

Successful management relies on:

- farm hygiene to keep fields free of RLN
- growing tolerant varieties when RLN are present, to maximise yields
- rotating with resistant crops to keep RLN at low levels[4]

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/How-nematodes-reduce-yield

Nematodes reduce yields in intolerant wheat cultivars and reduce the amount of water available for plant growth.

Nematodes also impose early stress that reduces yield potential despite the availability of water and nutrients.

Maintaining a low nematode population improves crop yields.[5]

8.2 Background

Root-lesion nematodes use a syringe-like 'stylet' to extract nutrients from the roots of plants (Figure 1). Plant roots are damaged as RLN feed and reproduce inside plant roots. *Pratylenchus thornei* and *P. neglectus* are the most common RLN species in Australia. In the northern grains region, *P. thornei* is the predominant species but *P. neglectus* is also present. These nematodes can be found deep in the soil profile (to 90 cm depth) and are found in a broad range of soil types, from heavy clays to sandy soils. Wheat is susceptible to both *P. thornei and P. neglectus*.[6]

1 GM Murray, JP Brennan (2009) The current and potential costs from diseases of wheat in Australia. Grains Research and Development Corporation Report. https://www.grdc.com.au/~/media/B4063ED6F63C4A968B3D7601E9E3FA38.pdf

2 KJ Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes: crop rotations to manage nematodes – key decision points for the latter half of the year, Bellata. GRDC Grains Research Update, July 2013.

3 KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet.

4 R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16/07/2013.

5 GRDC (2014), How nematodes reduce yield. http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/How-nematodes-reduce-yield

6 KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet.

New CSIRO research funded by the Grains Research and Development Corporation (GRDC) is examining how nematodes inflict damage by penetrating the outer layer of wheat roots and restricting their ability to transport water.

Figure 1: Microscope image of a root-lesion nematode. Notice the syringe-like 'stylet' at the head end, which is used for extracting nutrients from the plant root. This nematode is less than 1 mm long. (Image: Sean Kelly, Department of Agriculture and Food, Western Australia)

Fact sheets

[Soil Quality Pty Ltd nematode survey results]

[GRDC Parasitic Plant Nematodes (Northern Region Fact Sheet)]

http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

8.3 Symptoms and detection

Root-lesion nematodes are microscopic and cannot be seen with the naked eye in the soil or in plants. The most reliable way to confirm the presence of RLN is to have soil tested in a laboratory. Fee-for-service testing of soil offered by the PreDicta B root disease testing service of the South Australian Research and Development Institute (SARDI) can determine levels of *P. thornei* and *P. neglectus* present.[7]

Similar results can be obtained by soil testing either by manual counting (under microscopes) or by DNA analysis (PreDicta B), with commercial sampling generally at depths of 0–15 or 0–30 cm.[8]

Vertical distribution of *P. thornei* in soil is variable. Some paddocks have relatively uniform populations down to 30 cm or even 60 cm, some will have highest *P. thornei* counts at 0–15 cm depth, whereas other paddocks will have *P. thornei* populations increasing at greater depths, e.g. 30–60 cm. Although detailed knowledge of the distribution may be helpful, the majority of on-farm management decisions will be based on presence or absence of *P. thornei* confirmed by sampling at 0–15 or 0–30 cm depth.

Signs of nematode infection in roots include dark lesions or poor root structure. The damaged roots are inefficient at taking up water and nutrients—particularly nitrogen (N), phosphorus (P) and zinc (Zn)—causing symptoms of nutrient deficiency and wilting in the plant shoots. Intolerant wheat varieties may appear stunted, with yellowing of

7 KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet.

8 R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16/07/2013.

lower leaves and poor tillering (Figure 2). These symptoms may not be present in other susceptible crops such as barley and chickpea.[9]

Figure 2: Symptoms of root-lesion nematode infection of an intolerant wheat variety include yellowing of lower leaves, decreased tillers and wilting. There are no obvious symptoms in the susceptible chickpea and faba bean plots on either side of the wheat. (Image: Kirsty Owen, DAFF)

Testing service

http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

8.3.1 What is seen in the paddock?

Although symptoms of RLN damage in wheat can be dramatic, they can easily be confused with nutritional deficiencies and/or moisture stress.

Damage from RLN is in the form of brown root lesions but these can be difficult to see or can also be caused by other organisms. Root systems are often compromised, with reduced branching, reduced quantities of root hairs and an inability to penetrate deeply into the soil profile. The RLN create an inefficient root system that reduces the ability of the plant to access nutrition and soil water.

Visual damage above ground from RLN is non-specific. Yellowing of lower leaves is often observed, together with reduced tillering and a reduction in crop biomass. Symptoms are more likely to be observed later in the season, particularly when the crop is reliant on moisture stored in the subsoil.

In the early stages of RLN infection, localised patches of poorly performing wheat may be observed. Soil testing of these patches may help to confirm or eliminate RLN as a possible issue. In paddocks where previous wheat production has been more uniform, a random soil-coring approach may be more suitable. Another useful indicator of RLN presence is low yield performance of RLN-intolerant wheat varieties.[10]

8.4 Management

There are four key strategies for the management of RLN (Figure 3):

1. Test soil 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.
3. Choose tolerant wheat varieties to maximise yields (www.nvtonline.com.au). Tolerant varieties grow and yield well when RLN are present.

[9] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet.

[10] R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16/07/2013.

More information

[http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Latest-nematode-summer-and-winter-crop-rotation-results]

[B Burton (2015), Impact of crop varieties on RLN multiplication.]

4. Rotate with resistant crops to prevent increases in RLN (Table 1, Figure 4). When large 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 so that the yield potential of tolerant varieties is achieved.[11]

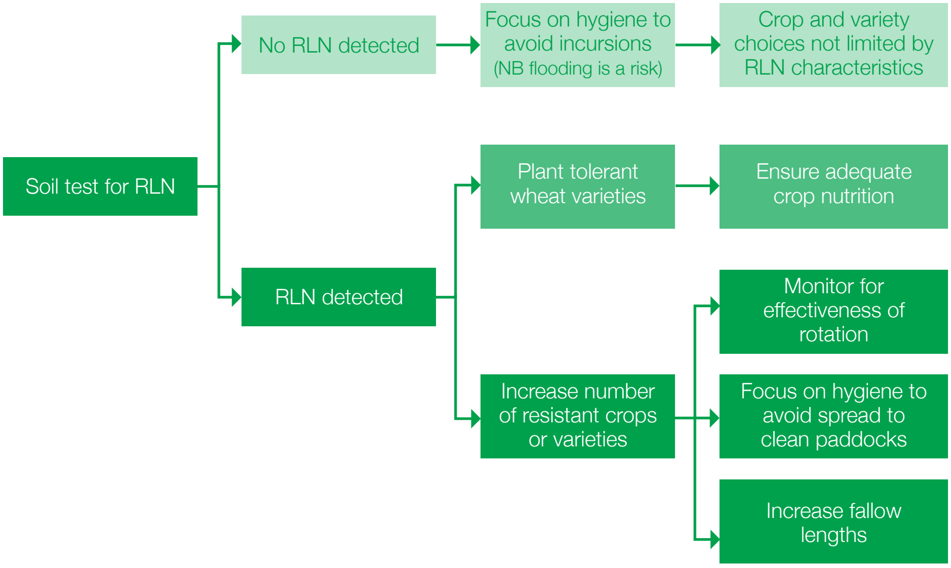

Figure 3: Root-lesion nematode management flow-chart.

[11] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet.

Other considerations include:

- **Nematicides.** There are no registered nematicides for RLN in broadacre cropping in Australia. Screening of potential candidates is 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. Under-fertilising is likely to exacerbate RLN yield impacts; however, over-fertilising is unlikely to compensate for a poor variety choice.
- **Variety choice and crop rotation.** These are currently our most effective management tools for RLN. However the focus is on two different characteristics: tolerance, i.e. ability of the variety to yield under RLN pressure; and resistance, i.e. impact of the variety on RLN build-up. Note that varieties and crops often have varied tolerance and resistance levels to *P. thornei* and *P. neglectus*.
- **Fallow.** Populations of RLN will decrease during a 'clean' fallow, but the process is slow and expensive in lost 'potential' income. Additionally, long fallows may decrease arbuscular mycorrhiza (AM) levels and create more cropping problems than they solve.[12]

Table 1: Susceptibility and resistance of various crops to root-lesion nematodes[13]

RLN species	Susceptible	Intermediate	Resistant
P. thornei	Wheat, chickpea, faba bean, barley, mungbean, navy bean, soybean, cowpea	Canola, mustard, triticale, durum wheat, maize, sunflower	Canary seed, lablab, linseed, oats, sorghum, millet, cotton, pigeon pea
P. neglectus	Wheat, canola, chickpea, mustard, sorghum (grain), sorghum (forage)	Barley, oat, canary seed, durum wheat, maize, navy bean	Linseed, field pea, faba bean, triticale, mungbean, soybean

Figure 4: Crop rotation to manage root-lesion nematodes depends on the nematode species present in your field. Mungbeans (left) are susceptible to P. thornei but resistant to P. neglectus. By contrast, sorghum (right) is resistant to P. thornei but susceptible to P. neglectus. (Image: Kirsty Owen, DAFF)

12 R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16/07/2013.

13 KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet.

Canola is now thought to have a 'biofumigation' potential to control nematodes, and a field experiment has compared canola with other winter crops or clean-fallow for reducing *P. thornei* population densities and improving growth of *P. thornei*-intolerant wheat (cv. Batavia) in the following year.

Immediately after harvest of the first-year crops, populations of *P. thornei* were lowest following various canola cultivars or clean-fallow and highest following susceptible wheat cultivars (1957–5200 *v.* 31,033–41,294 *P. thornei*/kg dry soil). Unexpectedly, at planting of the second-year wheat crop, nematode populations were at more uniform, lower levels (<5000/kg dry soil), regardless of the previous season's treatment, and remained that way during the growing season, which was quite dry.

Growth and grain yield of the second-year wheat crop were poorest on plots previously planted with canola or left fallow due to poor colonisation with AM fungi, with the exception of canola cv. Karoo, which had high AM fungal colonisation and low wheat yields. There were significant regressions between growth and yield parameters of the second-year wheat and levels of AM fungi following the pre-crop treatments.

Canola appears to be a good crop for reducing *P. thornei* populations, but the dependence of subsequent crops on AM fungi should be considered, particularly in the northern grains region.[14]

More information

[J Whish, J Thompson (2016), How long does it take to reduce Pratylenchus thornei (Root lesion nematode) population in the soil?]

[B Burton, L Bailey, K Adhikari (2016), Impact from Pratylenchus thornei, Macalister 2015.]

[N Seymour, G Stirling, J Li (2016), Biological suppression of root lesion nematodes in northern grain growing soils.]

[B Burton, L Bailey, K Adhikari (2015), Impact from Pratylenchus thornei, Macalister 2015.]

8.4.1 Crop Rotation

P. neglectus was found in 32% of paddocks (often in combination with *P. thornei*) in the northern region in a survey of 800 paddocks (Thompson *et al.* 2010). Summer crops that are partially resistant or poor hosts of *P. neglectus* include sunflower, mungbean, soybean and cowpea. When these crops are grown, populations of *P. neglectus* do not increase because the crops do not allow the nematode to reproduce.

In a field experiment, populations of *P. neglectus* increased after growing grain sorghum (Figure 4). Populations increased from 3.1 times after MR32⏀ (4,400 *P. neglectus*/kg soil) to 7.3 times after MRGoldrush⏀ (10,400 *P. neglectus*/kg soil) compared to soil at planting (1,400 *P. neglectus*/kg soil).[15]

Summer crops have an important role in management of RLN. Research shows that when *P. thornei* is present in high numbers, two or more resistant crops in sequence are needed to reduce populations to low enough levels to avoid yield loss in the following intolerant, susceptible wheat crops.[16]

P. thornei populations greater than 40,000 per kilogram at harvest will require 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/kg at harvest will require a single break of around 30 months free of a host to reduce the population below the accepted threshold of 2000 *Pt*/kg. [17]

More information

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

http://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-109-Mar-Apr-2014/Variety-choice-and-crop-rotation-key-to-managing-root-lesion-nematodes

8.4.2 Sowing time

Wheat variety choice can have a great impact on yield loss to *P. thornei* (up to 43% yield loss in intolerant bread wheat varieties in 2011), and yield losses from *P. thornei* can be exacerbated by delayed sowing and drier conditions.[18]

14 KJ Owen, TG Clewett, JP Thompson (2010) Pre-cropping with canola decreased *Pratylenchus thornei* populations, arbuscular mycorrhizal fungi, and yield of wheat. *Crop & Pasture Science* 61, 399–410.

15 http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

16 K Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes: crop rotations to manage nematodes – key decision points for the latter half of the year, Bellata. GRDC Grains Research Update, July 2013.

17 J Whish, J Thompson (2016), How long does it take to reduce Pratylenchus thornei (Root lesion nematode) population in the soil? https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/How-long-does-it-take-to-reduce-Pratylenchus-thornei-populations-in-the-soil

18 S Simpfendorfer, M Gardner, G McMullen (2012) Impact of sowing time and varietal tolerance on yield loss to the root-lesion nematode *Pratylenchus thornei*. GRDC Grains Research Update, Goondiwindi, March 2012.

New South Wales Department of Primary Industries (NSW DPI) winter cereal time-of-sowing trials at Coonamble, Mungindi, Trangie, Come-by-Chance and Gurley, NSW, in 2011 showed the following:

- Winter crop type and variety choice have a large effect on the build-up of nematode populations in the soil due to differences in their resistance to *P. thornei*.
- This was most pronounced in bread wheat where the variety choice;
  - » increased the *P. thornei* population by 1.8–3.6 times (9737 up to 19,719 *P. thornei*/kg soil) at Coonamble, and
  - » decreased the *P. thornei* population by 64% between the most susceptible and most resistant varieties at Mungindi (25,448 *v.* 9050 *P. thornei*/kg soil).
- *Pratylenchus thornei* populations were six times larger in the most susceptible variety, Lincoln⟮D, than in the most resistant variety, Gauntlet⟮D, at Trangie.
- Earlier sowing generally increased the build-up of *P. thornei* populations Trangie, especially in the most susceptible variety.
- The build-up of *P. thornei* populations in the field trial is broadly in line with published resistance ratings, but discrepancies appear to exist, especially with LongReach Spitfire⟮D, which appears better than its current rating of very susceptible.
- Both *P. thornei* and crown rot (caused by *Fusarium pseudograminearum*) cause significant yield loss in intolerant/susceptible varieties alone or in combination, as shown at Gurley.
- *Pratylenchus thornei* and crown rot did not reduce grain protein levels at the Gurley site.
- Some recently released varieties appear to combine improved tolerance to *P. thornei* with increased resistance to crown rot, which provided a yield advantage of up to 109% at the Gurley site in 2012.
- Reliable resistance ratings appear to be produced under both large and moderate starting populations of *P. thornei* at Mungindi. Hence, National Variety Trials (NVT) are a potentially useful source of reliable field-based assessments.[19] Visit www.nvtonline.com.au

Download

Northern grains region trial results Autumn 2015.

Delayed sowing

In two trials conducted in 2011, *P. thornei* was demonstrated to reduce yield by up to 43% under large starting populations with delayed sowing and drier growing conditions. Delayed sowing into late autumn/winter is likely to see crops initially develop under cooler soil temperatures, thus reducing the rate of root development. Conversely, earlier sown crops establish under warmer soil conditions and have more rapid, early root growth if adequate moisture is available.

Drier soil conditions during crop establishment and early growth, for example with the second sowing time (22 June) at Coonamble in 2011, are also likely to restrict early root development. In theory, any restriction to root development is likely to inhibit a crops ability to compensate for *P. thornei* feeding upon these root systems. Variety choice can have a large impact on yield and, hence, profitability when cropping in soils with large populations of *P. thornei*. To date, these trials have only examined the relative tolerance of varieties to *P. thornei*. It should be stressed that a variety's resistance to *P. thornei* (build-up of nematode populations within the soil) should also be an important consideration in variety choice.[20]

Interaction with crown rot

Crown rot remains a significant disease in the region, with losses dependent on soil moisture and temperature stress experienced during flowering and grain-fill. Crown rot caused yield losses of up to 37% in durum varieties at the Coonamble site in 2011, but cooler, wetter conditions limited the expression (yield loss) of this disease at Mungindi

19 NSW DPI (2013) Northern Grains Region trial results autumn 2013. NSW Department of Primary Industries.

20 NSW DPI (2013) Northern Grains Region trial results autumn 2013. NSW Department of Primary Industries.

in 2011. Averaged across the different winter cereal types, crown rot reduced yield by 18 % in barley, 27% in durum wheat and 22% in bread wheat at Coonamble in 2011. Research conducted by NSW DPI and the Northern Grower Alliance (NGA) across 11 sites in northern NSW in 2007 demonstrated that crown rot caused average yield losses of 20% in barley (up to 69% under drier conditions and hotter temperatures during grain-fill), 25% in bread wheat (up to 65%) and 58% in durum (up to 90%).

The Coonamble site trial demonstrates that the tolerance of wheat varieties to crown rot does not appear to be related to their level of tolerance to *P. thornei*. Yield losses to both diseases in intolerant varieties can be significant (up to 43% for *P. thornei* and up to 37% for crown rot at Coonamble in 2011) under high levels of inoculum. However, the benefit obtained from sowing a more tolerant bread wheat variety appears greater for *P. thornei* (up to 43%) than for crown rot (up to 21%). Another way of expressing this is that the difference in tolerance levels between wheat varieties appears larger for *P. thornei* than for crown rot.[21]

GRDC Update Paper

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Impact-of-sowing-time-and-varietal-tolerance-on-yield-loss-to-the-rootlesion-nematode-pratylenchus-thornei

Selecting tolerant varieties

Selecting tolerant wheat varieties is one of the main options for maintaining profit in the presence of high populations of *P. thornei*. By contrast, even the most crown rot resistant/tolerant commercial wheat variety can still suffer up to 50% yield loss under high levels of inoculum when hot/dry conditions occur during grain-fill. Variety selection is not a primary strategy for managing crown rot. Hence, where soil populations of *P. thornei* are large, more emphasis should be placed on a wheat variety's tolerance to *P. thornei* than to crown rot. Rotation to non-host crops remains the primary management tool for crown rot and can also be a valuable strategy to reduce or maintain *P. thornei* populations below the threshold (<2,000 *P. thornei*/kg soil) for yield loss in intolerant wheat varieties.[22]

Survey results

www.nga.org.au/results-and-publications/download/49/surveys/root-lesion-nematode-survey.pdf

Current industry knowledge

In 2010, the NGA conducted a survey of current levels of knowledge about nematodes (particularly RLN) in northern broadacre farming systems and the management practices being employed. The results are being used to prioritise research and development activity.

8.5 Varietal resistance or tolerance

A tolerant crop yields well when large populations of RLN are present (in contrast to an intolerant crop). A resistant crop does not allow RLN to reproduce and increase in number (in contrast to a susceptible crop) (Figure 5.)

There are four possible combinations of resistance and tolerance:	
Tolerant–resistant e.g. sorghum cv. MR43 to *P. thornei* *and wheat breeding lines released for development*	**Tolerant–susceptible** e.g. wheat cv. EGA Gregory to *P. thornei*
Intolerant–resistant *No commercial wheat lines in this category*	**Intolerant–susceptible** e.g. wheat cv. Strzelecki to *P. thornei*

Figure 5: Combinations and examples of tolerance and resistance. [23]

Tolerance and resistance of wheat varieties to RLN are published each year at www.nvtonline.com.au or in *Wheat varieties for Queensland*.

Current GRDC-funded research by the NGA and NSW DPI is examining the importance of crop and variety choice. The NGA has run large and complex trials and results are outlined in the GRDC Update Paper.

21 NSW DPI (2013) Northern Grains Region trial results autumn 2013. NSW Department of Primary Industries.

22 S Simpfendorfer, M Gardner, G McMullen (2012) Impact of sowing time and varietal tolerance on yield loss to the root-lesion nematode *Pratylenchus thornei*. GRDC Grains Research Update, Goondiwindi, March 2012.

23 K Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes: crop rotations to manage nematodes – key decision points for the latter half of the year, Bellata. GRDC Grains Research Update, July 2013.

Growers are advised to recognise that there are consistent varietal differences in *P. thornei* and *P. neglectus* resistance within wheat and chickpea varieties; to avoid crops or varieties that allow the build-up of large populations of RLN in infected paddocks; and to monitor the impact of rotations.

The DAFF and NSW DPI wheat variety guides detail the level of variety tolerance to both species of RLN. Selection of wheat varieties based on these published RLN tolerance rankings is critical to avoid significant yield losses, particularly in paddocks with large populations of *P. thornei*.

GRDC-funded researchers are currently incorporating *P. thornei* resistances found in a wheat line selected from the variety Gatcher and some wheat landraces from West Asia and North Africa into pre-breeding efforts. Excellent resistance to *P. thornei* and *P. neglectus* has been found in synthetic hexaploid wheats.

Resistances are being incorporated into some of the most tolerant wheat varieties, including EGA Gregory and EGA Wylie, to produce parents that are adapted to the northern region.[24]

8.5.1 Tolerance

Wheat breeding has provided a number of varieties with moderate or higher levels of tolerance to *P. thornei*, e.g. Sunvale, Baxter, EGA Wylie and EGA Gregory. These varieties will reduce the level of yield loss due to *P. thornei*.

At a trial site near Yallaroi in 2012, a range of crops and varieties was grown and performance evaluated under relatively 'low' and 'high' starting population densities of *P. thornei* (~2,000 and 19,000 nematodes/kg soil). Figure 6 shows the impact of *P. thornei* on yield of varieties with a range of tolerance levels.

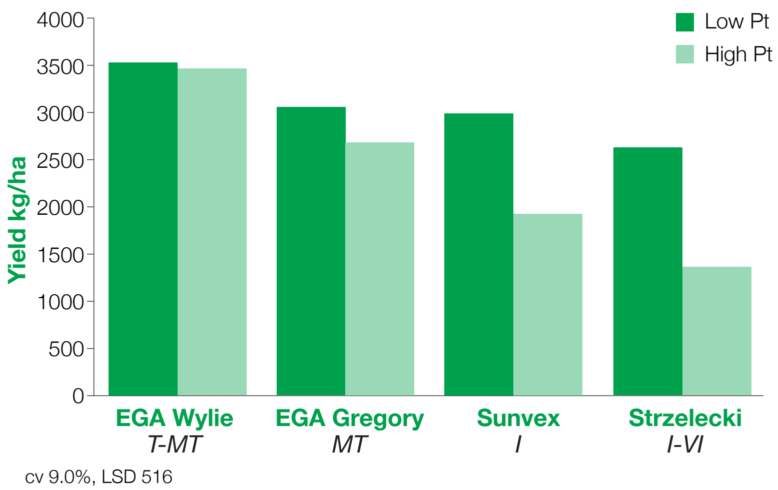

Figure 6: Comparison of wheat variety yields under 'low' and 'high' starting population densities of P. thornei (Pt) near Yallaroi 2012 (Trial RH1213).

*Indicates significant yield difference within a variety between 'low' and 'high' *P. thornei* strips at *P* = 0.05.

Codes below variety names are the DAFF published ratings of *P. thornei* tolerance: T, tolerant; MT, moderately tolerant; I, intolerant; VI, very intolerant.

NB: What was categorised as the 'low' starting population density of *P. thornei* was still equal to the current industry threshold. At this level, significant yield losses (up to 20%) may occur in intolerant wheat varieties. Consequently, the measured yield impact between 'low' and 'high' *P. thornei* in this trial is an underestimate of the full *P. thornei* affect.[25]

The varieties rated as *P. thornei* intolerant (Strzelecki and Sunvex) suffered significant yield reductions of 35–48 % in this trial when grown in the 'high' *P. thornei* plots. Yield losses of ~1–1.25 t/ha were recorded, with economic losses >$250/ha. The two

24 J Thompson, J Sheedy, N Robinson, R Reen, T Clewett, J Lin (2012) Pre-breeding wheat for resistance to root-lesion nematodes. GRDC Grains Research Update, Goondiwindi, March 2012.

25 K Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet.

varieties that were more tolerant (EGA Wylie⍉ and EGA Gregory⍉) did not suffer a significant yield reduction.

Choosing tolerant varieties will limit the yield and economic impact from *P. thornei*; however, some of these varieties still allow high levels of nematode build-up. The second issue to be considered is variety resistance/susceptibility.[26]

8.5.2 Resistance

Resistance is the impact of the variety on RLN multiplication. Eradication of RLN from an individual paddock is highly unlikely, so effective long-term management is based on choosing options that limit RLN multiplication. This involves using crop or varieties that have useful levels of *P. thornei* resistance and avoiding varieties that will cause large 'blow-outs' in *P. thornei* numbers.

Resistance differences between crops

The primary method of managing RLN populations is to focus on increasing the number of resistant crops in the rotation. Knowledge of the species of RLN present is critical, as crops that are resistant to *P. thornei* may be susceptible to *P. neglectus*. Key crops that are generally considered resistant or moderately resistant to *P. thornei* are sorghum, sunflower, maize, canola, canary seed, cotton, field peas and linseed.

Wheat, chickpeas, faba beans, mungbeans and soybeans are generally susceptible, although the level of susceptibility may vary between varieties.

Resistance differences between commercial wheat varieties

Resistance ratings for wheat varieties to RLN have been available for many years; however, the development of high-throughput DNA analysis has enabled an increased amount of testing to compare RLN build-up between varieties under field conditions. These data appear to be a very useful addition to our current knowledge on varietal resistance, with relative variety performance fairly consistent across sites. Figure 7 shows the relative performance of a range of varieties as a percentage of EGA Gregory ⍉ in a wide range of trials during 2009–2012.

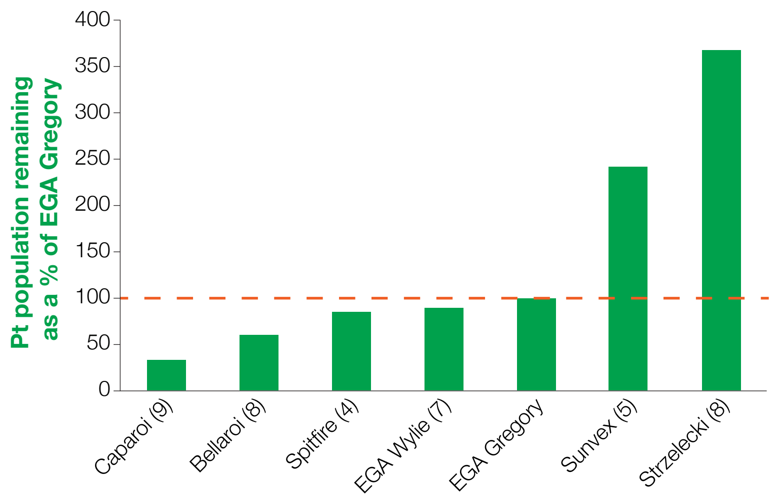

Figure 7: Comparison of P. thornei (Pt) population remaining as a percentage of EGA Gregory⍉, 2009–2012. Values in parentheses are the number of trials in which the variety was compared with EGA Gregory⍉.The red broken line indicates the Pt level remaining after EGA Gregory⍉.

Bread wheats are generally susceptible to *P. thornei* but there are large differences between varieties in the level of susceptibility. Growers with *P. thornei* infestations must avoid 'sucker' varieties that result in very high levels of *P. thornei* multiplication.

[26] R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16/07/2013.

Although durum wheats generally restrict *P. thornei* multiplication compared with bread wheats, they are very susceptible to crown rot.[27]

8.6 Damage caused by nematodes

Pratylenchus thornei is widespread in the northern grains region, with surveys conducted by QDAF and NSW DPI showing its presence in 50–70% of paddocks. It is frequently at concerning levels, being found at >2,000 individuals/kg soil in ~20–30% of paddocks.

Yield losses in wheat of up to 50% are not uncommon when *P. thornei*-intolerant wheat varieties are grown in paddocks infested with *P. thornei*. Yield losses in chickpeas of up to 20% have also been measured in QDAF trials.[28]

More information

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431265/Cereal-pathogen-survey.pdf

8.7 Nematodes and crown rot

The NGA has been involved in 22 field trials since 2007, in collaboration with NSW DPI, 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 that we may be suffering significant yield losses from another 'disease' that often goes unnoticed.

Although the trials were not designed to focus on nematodes, a convincing trend was apparent after 2008 that indicated *P. thornei* was having a frequent and large impact on wheat variety yield.

These trials were designed to evaluate the effect of crown rot on variety yield and quality. However, they strongly suggest that *P. thornei* is also having a significant impact on yield performance. The results do not compare the levels of yield loss due to the two diseases but do indicate that there is a greater range in variety of *P. thornei* tolerance than currently exists for crown rot tolerance.[29]

8.7.1 Importance of variety choice

Root lesion nematodes are a 'disease' that has no obvious visual symptoms in the paddock. To improve management of this disease, growers must take more advantage of nematode testing. An increase in level of awareness of *P. thornei* status in individual paddocks and across properties will assist to:

- Develop sound hygiene practices to help limit further spread and reduce the risk of new infestations
- Provide a measure of the impact of varying management approaches designed to limit or reduce nematode build-up

This knowledge is also likely to provide direct economic gains from sound varietal and crop rotation choices. Soil testing for nematodes may also provide benefits in the identification of other plant parasitic species.[30]

Two durum and 10 bread wheat varieties were evaluated by NSW DPI in the presence of added or no added crown inoculum across 11 field sites in 2013.[31]

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Crown-rot-and-nematodes

27 R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16/07/2013.

28 K Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet.

29 R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16/07/2013,

30 R Daniel, S Simpfendorfer, G McMullen, John Thompson (2010) Root lesion nematode and crown rot – double trouble! Australian Grain, September 2010. http://www.ausgrain.com.au/Back%20Issues/203sogrn10/203sogrn10.pdf

31 GRDC (2014), Crown rot and nematodes. Are you growing the right variety? http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Crown-rot-and-nematodes

SECTION 9

Diseases

For more information, see the *GRDC GrowNotes WHEAT (Northern region),* Section 9: Diseases.

Durum varieties generally have useful levels of resistance to all pathotypes (including the new virulent strains) of the three rusts – stem, leaf and stripe rust - but are very susceptible to crown rot. They are also susceptible to Fusarium head blight, which is common in very wet seasons and in areas where durum is grown in close proximity to maize stubble. [1]

The major diseases of durum wheat are controlled by genetic traits that have been crossed into current varieties. These include tolerance to the major diseases such as stem, leaf and stripe rust. The changing pattern of behaviour of leaf and stem diseases of all cereal crops requires careful monitoring. It is most important to report any irregularities in the behaviour of these diseases to an adviser/agronomist or plant breeder. Yellow leaf spot, another significant disease of winter crops, is largely avoided by not planting cereal crops into previous cereal crop residues; hence, crop rotation is important. Most durum varieties carry useful resistance. [2]

More information

R Graham, N Graham, S Simpfendorfer (2015), Yield impact of crown rot and sowing time on winter cereal crop and variety selection Tulloona 2015.

S Simpfendorfer, R Graham, G Brooke (2015), Yield impact of crown rot on winter cereal crop and variety selection (Nyngan 2015).

A Verrell (2016), Integrated management of crown rot in a chickpea – wheat sequence.

S Simpfendorfer (2016), Crown rot – does cereal crop or variety choice matter?

S Simpfendorfer (2016), Do seed treatments have a place with crown rot.

E Readford, D Tan, R Tokachichu, R Trethowan (2015), The effect of crop rotations on the incidence of crown rot in wheat.

R Graham, S Simpfendorfer, G McMullen, N Graham (2015), p104.

9.1 Crown rot

Crown rot, caused predominantly by the fungus *Fusarium pseudograminearum*, is considered the most important disease of durum wheat in the northern grains region, and is also a major constraint to both bread wheat and barley production. Yield losses attributed to crown rot can exceed 60% in susceptible crops such as durum wheat particularly if moisture stress occurs during grain filling. Crown rot infection is characterised by a honey-brown discolouration at the base of infected tillers. [3] Infection of winter cereals can occur through the crown, sub-crown internode, basal internode and/or lower leaf sheaths. This can occur at any growth stage from seedling emergence through to maturity. Crown rot infection is characterised by a light honey-brown to dark brown discoloration of the base of infected tillers. The fungus survives in cereal and grass weed residues, while yield loss from the production of whiteheads is related to moisture stress post-flowering (Figure 1). [4]

Rotation to non-host pulses (chickpea, faba bean), oilseeds (canola, mustard) or summer crops (sorghum, sunflower, mungbean, cotton) essentially reduces crown rot inoculum levels by starving the fungus of a suitable host and allowing natural decline of cereal residues that harbour the pathogen. The length of rotation needed for effective management of crown rot depends on the rate of decomposition of the infested residues. In particular, canola and mustard provide an effective break crop for crown rot

1 P Matthews, D McCaffery, L Jenkins (2016), Winter crop variety sowing guide 2016. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

2 Primary Industries Science and Research. Tamworth Agricultural Institute—Research projects. Australian durum wheat improvement Program (ADWIP). NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/research/centres/tamworth/research-projects

3 R Graham, S Simpfendorfer, G McMullen, N Graham (2015), Fusarium crown rot of wheat - impact on plant available soil water usage. http://www.agronomy2015.com.au/papers/agronomy2015final00210.pdf

4 S Simpfendorfer,J Kirkegaard, J Holland, A Verrell, R Bambach, K Moore (2004) Managing soil-borne and stubble-borne cereal pathogens in the northern grains belt. In: Proceedings Soil Biology in Agriculture Workshop. pp. 112–119. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/166919/soil-biology-agriculture.pdf

in northern NSW. Furthermore, brassicas would provide an excellent alternative rotation crop to chickpea in areas where adapted varieties are available, as they appear to have an improved capacity to reduce the severity of crown rot in subsequent wheat crops. [5]

Resistance to crown rot must continue to be a major breeding objective if the industry is to expand. There appears very little genetic tolerance to crown rot within the tetraploid (durum) population. This means that durable resistance will most likely have to be bred into durum from the hexaploid (bread wheat) population as a matter of high priority. [6] In 2012, crosses of bread and durum wheat lines were produced showing partial resistance equal to, or better than, the bread wheat parent. [7] Work is under way to boost crown rot resistance in durum wheat.

Figure 1: 'Whiteheads' (left) associated with crown rot infection in a highly susceptible durum variety, and a breeding line with partial resistance to the disease (right).

9.2 Common root rot

Common root rot, caused by the fungus *Bipolaris sorokiniana*, is often found in association with crown rot. Symptoms are a dark brown to black discoloration of whole or part of the sub-crown internode. Severely affected plants are stunted, have fewer tillers and produce smaller heads. Rotation to non-host break crops is essential to the successful management of both of these diseases.

[5] S Simpfendorfer,J Kirkegaard, J Holland, A Verrell, R Bambach, K Moore (2004) Managing soil-borne and stubble-borne cereal pathogens in the northern grains belt. In: Proceedings Soil Biology in Agriculture Workshop. pp. 112–119. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/166919/soil-biology-agriculture.pdf

[6] J Kneipp (2008) Durum wheat production. NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

[7] R Bowman (2012) Durum to partially resist crown rot. GRDC Ground Cover Issue 96, http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-96-January-February-2012/Durum-to-partially-resist-crown-rot#sthash.2xvPfsnB.dpuf

9.3 Fusarium head blight

Fusarium head blight (FHB) is a fungal disease that can occur on many grass species, including both crop and weeds. Where it occurs in crops it is most commonly in wheat, durum and barley. Durum is more susceptible to the disease than bread wheat and barley.

Durum crops should be avoided in areas where there is a likelihood of the disease developing. While FHB can be caused by several species of *Fusarium*, the most common species causing the disease is *Fusarium graminearum*. It can cause significant yield losses and quality reductions. Major yield losses occur mainly from floret sterility.

Additional yield and quality losses can occur when damaged and shrivelled lightweight grains are produced as a result of infection. Quality reductions may also occur from seed discoloration, varying from whitish-grey and pink to brown. Fungal infection can sometimes be associated with the production of a toxin (mycotoxins).

If fungal toxins are produced in infected seed, the grain is often unacceptable for certain end uses and downgraded in the marketplace depending on the concentration of toxin present. Toxin levels and fungal infection cannot be accurately estimated from visual appearance.

More information

http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

Crop rotation is effective in reducing levels of FHB. Corn is a major alternative host for *F. graminearum* and planting durum in and around corn residues will increase the risk of head blight. The best rotational crops for reducing the inoculum level include any non-grass species (e.g. sunflower, cotton, soybean, chickpea, mungbean, faba bean, canola, field peas). Currently, no seed dressings are registered for control of seedling blight caused by the FHB pathogens. [8]

9.4 Varietal resistance or tolerance

More information

R Long (2015), Crown rot tolerance in new wheat cultivars - is there enough to base varietal decisions on?

New wheat lines are offering hope for providing partial resistance to crown rot disease in durum wheat. The finding is important because durum wheat is particularly susceptible to crown rot. The pathogen causes annual crop losses in Australia estimated at $79 million, or $6.63/ha.

Research funded by the Grains Research and Development Corporation (GRDC) shows that partial crown rot resistance in bread wheat lines could be transferred into durum wheats. Crosses of bread (hexaploid) and durum wheat lines have been produced that show levels of partial resistance equal to, or better than, the bread wheat parent Sunco.

Development of new durum varieties with partial resistance to crown rot could increase yields and quality, and ultimately allow for expansion of Australia's durum industry.

Partial resistance needs to be coupled with an integrated approach to managing the disease, as there is no total resistance to crown rot fungus infection in durum or other cereals. The genes involved provide partial resistance, which appears to slow the rate of it spreading through tissue. [9]

8 DAFF (2012) Fusarium head blight, or head scab. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

9 R Bowman (2012) Durum to partially resist crown rot. GRDC Ground Cover Issue 96, http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-96-January-February-2012/Durum-to-partially-resist-crown-rot

Stem rust

Caparoi exhibits an excellent foliar disease resistance package. It has also been observed to be genetically diverse from EGA Bellaroi and Jandaroi. This broadening of the genetic base of durum varieties is important for long-term sustainable crop production. Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi are fully resistant to all existing field strains of stem rust. While stem rust infection is not expected, a new virulent strain may occur.

Leaf rust

Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi possess slow rusting resistance to all field strains of leaf rust. A small level of infection may be evident as the plant approaches maturity; however, this disease level will not affect yield.

More information

S Simpfendorfer (2015), Wheat rust in 2015 – where are we heading?

Stripe rust

The current durum varieties all express adequate resistance to field strains of this disease at present. The breeding program endeavours to predict virulence changes in all three rust organisms and incorporate appropriate resistance genes into future varietal releases, to remain one or two virulence changes ahead of the rust. The earliest possible detection of new virulent strains, in the unlikely event that they arise, will greatly assist disease-resistance breeding activities. When such a strain is found, steps can be taken to warn growers of a new virulence change and suggest changes to variety recommendations. It is crucial to maintain effective resistance to all field strains of each rust organism in each of the released varieties. Such a comprehensive effective resistance will significantly reduce the build-up of inoculum, leading to less disease both within and between growing seasons. In addition and more importantly, the likelihood that a new virulent strain will arise is greatly reduced. By reducing the chance of the development of a new virulence, the life of the current resistances is greatly prolonged. This amounts to effective conservation of our valuable genetic resources. If breeders are not required to spend considerable breeding resources on developing improved resistant varieties, those resources can be redirected to the improvement of other economically important traits.

Yellow leaf spot

All current northern varieties, EGA Bellaroi, Caparoi and Jandaroi, are rated MR-MS for yellow leaf spot. As yellow leaf spot inoculum is carried over on wheat straw, durum is a better proposition for avoiding yellow leaf spot in stubble-retained situations. [10]

9.5 Management of disease

9.5.1 In-crop fungicides and timing

A NSW DPI study into fungicide use in durum to control FHB shows that timing of fungicide application is critical to efficacy. Although Folicur® still provided measurable suppression of FHB, Prosaro® clearly provided superior levels of control. Prosaro application at GS61 reduced FHB severity by 81%, compared with only 56% control with the application of Folicur at the same timing. This translated into a 130% yield benefit (2.37 t/ha) with Prosaro and 66% (1.20 t/ha) with Folicur compared with the nil fungicide control treatment.

The timing of fungicide application was critical to the efficacy of both fungicides. Spraying 7 days before flowering (flowering, GS61) reduced control levels and the associated yield benefit compared with application at GS61 (+0 days). The anthers (flowers) are the primary infection site for *F. graminearum*, so spraying before flowering provides reduced protection of these plant structures.

Although not examined in that study, overseas research has demonstrated the importance of spray coverage in FHB control, with twin nozzles (forward and backward

[10] R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

facing) angled to cover both sides of a wheat head and high volumes of water (≥100 L/ha) being critical to efficacy. Aerial application has reduced efficacy for FHB control based on overseas studies.[11]

More information

See the NSW DPI publication 'Northern grains region trial results 2013', pp. 132–136: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

www.apvma.gov.au

11 S Simpfendorfer (2013) Control of *Fusarium* head blight in durum wheat using the fungicide Prosaro®. In: Northern grains region trial results, pp. 132–136. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

SECTION 10

Plant growth regulators and canopy management

More information

http://www.grdc.com.au/Resources/Publications/2014/01/Advancing-the-management-of-crop-canopies

10.1 What is canopy management?

Much of the research on topdressing nitrogen (N) in northern New South Wales (NSW) has focused on the role of in-crop N to respond to seasons in which yield potentials have increased significantly due to above-average rainfall conditions.

In these situations, research has shown that positive responses can be achieved, especially when good rainfall is received after N application (*Australian Grain* July/August 2007). Recently, though, there has been significant interest in the role of 'canopy management' principles for crop production in the northern grains region. [1]

Canopy management deals with the green surface area of the crop canopy in order to optimise crop yield and inputs. It is based on the premise that the crop's canopy size and duration determine its photosynthetic capacity and therefore its overall grain productivity.

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. [2]

The concept of canopy management was primarily developed in Europe and New Zealand—both distinct production environments from those typically found in most grain-producing regions of Australia and especially the northern grains region.

Canopy management includes a range of crop-management tools for crop growth and development, to maintain canopy size and duration and thereby 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 input is tactically delayed until later in the growing season. This delay tends to reduce early crop canopy size but the canopy is maintained for longer, as measured by green leaf retention, during the grain-filling period.

Can it work under Australian conditions—especially in the shorter growing season of northern NSW? Results from southern regions have been encouraging, especially in areas with high yield potential and therefore higher N inputs, but further research was required to test and validate the principles in northern NSW. [3]

1 G McMullen (2009) Canopy management in the northern grains region—the research view. Consultants Corner, Australian Grain, July 2009, 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

2 N Poole (2005) Cereal growth stages. GRDC, http://www.grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf

3 G McMullen (2009) Canopy management in the northern grains region—the research view. Consultants Corner, Australian Grain, July 2009, 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

More information

http://irec.org.au/farmer_f/pdf_182/Canopy%20management%20for%20high%20production%20cereals.pdf

10.1.1 Canopy management in a nutshell

1. Select a target head density for your environment (350 to 400 heads per square metre should be sufficient to achieve optimum yield even for yield potential of 7 tonnes per hectare).
2. Adjust canopy management based on paddock nutrition, history and seeding time to achieve target head density.
3. Established plant populations for wheat of between 80 and 200 plants/m^2 would cover most scenarios.
4. Lower end of range (80–100 plants/m^2) – earlier sowings/high fertility and or low yield potential low-rainfall environments.
5. Higher end of the range (150–200 plants/m^2) – 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); and
   - 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 WSCs.

The timing of the applied N during GS30–33 window can be adjusted to take account of target head number; earlier applications in the window (GS30) 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 less tillers surviving to produce a head.[4]

10.1.2 Research on the Liverpool Plains

Since 2006, trials have been conducted by a collaborative research group including NSW DPI, Northern Grower Alliance (NGA), AgVance Farming, and Nick Poole from the Foundation for Arable Research (FAR), New Zealand. This work, funded by GRDC, has focused on the effect of delayed applications of N in high-yielding crops on the Liverpool Plains.

To test whether canopy management principles did improve crop performance in northern wheat crops, trials were established under overhead irrigation systems to supplement water supply at the critical growth stages when urea was applied to the soil surface. Nitrogen was applied at three times through the season in various combinations: at sowing, into the seedbed (SB), during early stem elongation (GS31), or after flag leaf emergence (GS39). Details of the research sites and treatments are presented in Tables 1 and 2.

Nitrogen volatilisation

The risk of N volatilisation remains a significant concern when applying in-crop N; particularly in northern NSW, where lower rainfall incidence compared with southern regions and the presence of soil carbonates significantly increase the risk of N loss. Despite the risk factors being well understood, there is little quantitative information on the effect of soil properties, different N fertilisers and, most importantly, field conditions on potential losses of N. The NSW DPI and NGA have been conducting laboratory-based comparisons of the effect of differing soil properties and N fertilisers on the potential losses of N due to volatilisation.

[4] GRDC (2014), Advancing the management of crop canopies. http://www.grdc.com.au/CanopyManagementGuide

The laboratory-based work has verified that the presence of calcium carbonates at the soil surface significantly increases the potential losses of N, while some N-fertiliser products can reduce the potential losses (e.g. urea ammonium nitrate liquid, liquid ammonium nitrate, and urea treated with a urease inhibitor—GreenUrea®) (Figure 1). Field-based estimates of volatilised N are to commence in the coming spring under a GRDC funded project. [5]

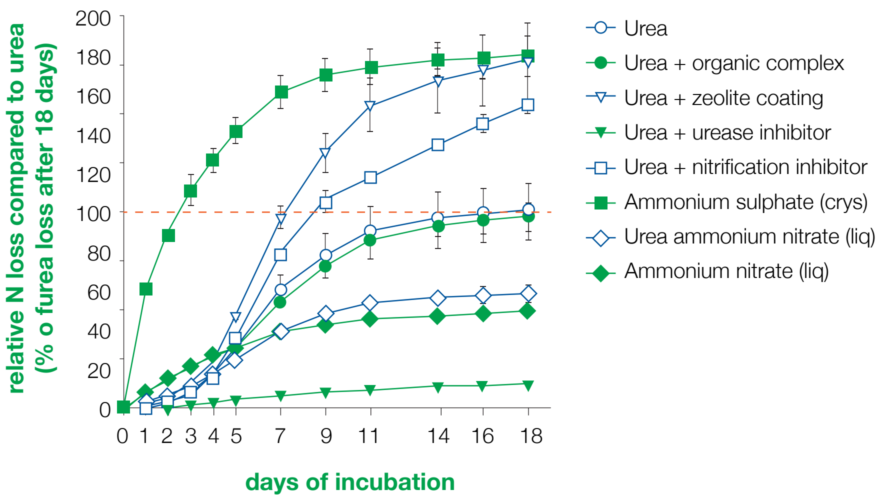

Figure 1: Cumulative volatilisation loss of nitrogen applied as fertiliser to the surface of an alkaline soil containing 7% CaCO3.

For more information, see *Section 5. Nutrition and fertiliser*.

Summary

Results from 3 years of supplementary-irrigated research have provided important pointers for the use of canopy management principles in northern NSW. Tactically delaying N is a management system that allows flexibility to respond to seasonal conditions and manage climate variability. Research has shown that N fertiliser could be delayed until stem elongation (GS31) without yield loss and usually with increased grain protein when conditions are suitable. This means that growers are able to apply a portion of the expected N requirement and then assess yield potential, as influenced by soil water and seasonal forecasts, later in the season and respond accordingly. To date, the best results with this approach have been seen in early-sown, long-season varieties with high yield potential that are very N-responsive with high N fertiliser inputs.

Further research in 2009 again showed impressive responses and examined the use of tactically delayed N in durum crops to improve yield and protein. The research group is also looking at using crop reflectance to assist in making N fertiliser decisions. So far, crop reflectance (measured as normalised difference vegetation index, NDVI) at key growth stages has shown strong relationships to crop structure and yield. [6]

10.1.3 The commercial view

Based on the results of three years of trials carried out by AgVance Farming, NSW DPI and NGA with input from Nick Poole (FAR, New Zealand), it was concluded that delaying all N until GS30–31 had a detrimental effect on main-season wheat plantings.

Yield was maximised in the treatments where all N was applied early (SB), or split 50–50 (between SB and GS30–31). NSW DPI/NGA demonstrated in one recent season that

[5] G McMullen (2009) Canopy management in the northern grains region—the research view, Consultants Corner, Australian Grain, July 2009, 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

[6] G McMullen (2009) Canopy management in the northern grains region—the research view. Consultants Corner, Australian Grain, July 2009, 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

this may be different for longer season varieties, but this remains to be proven over a number of years.

Generally, a full profile of moisture receives sufficient N at the start to provide the entire crop requirement to the predicted yield level. If yield potential is higher due to favourable seasonal conditions, there is generally an opportunity to apply small amounts of N later to increase yield but usually this is not necessary.

In a lower moisture profile situation, N can be applied at a rate less than the target yield-level requirement and topped up before rainfall, as opportunities present. This requires careful planning and preparation by the grower, in order to take advantage of impending rainfall, sometimes in short time-frames.

The 50–50 split application of N extends the period that N can be applied through the season without a 'cliff face' drop in yield if the N is not applied at precisely GS30–31. Effectively, it improves the margin of error available to the grower if rainfall does not occur at GS30–31.

More information

http://www.grdc.com.au/ApplyingPA

Where growers are set up for, and using, precision agriculture, a 70–30 application can be used when there is a full soil moisture profile and a 50–50 application where soil moisture is likely to be limiting. This is where a proportion of the predicted N requirement is held back until after NDVI imaging has taken place and N is applied based on NDVI results. This also requires a high level of organisation and planning.

Limitations of tactical nitrogen application

The main limitation to tactical N application in the north is the ability to reliably apply N before a rain event, to enable roots to access soluble N in the root-zone.

An analysis of rainfall events comparing Clare (South Australia) and Wagga Wagga (southern NSW) with Quirindi (North West Slopes of NSW) showed that Quirindi had only 30% of the opportunities to apply N that the southern locations had, and that the predictability of rainfall events >3 days before rain was very unreliable.

Predicted rain fronts may pass without yielding anything; therefore, dependably applying N throughout the season is risky. This becomes increasingly difficult further north and west of the Liverpool Plains to locations such as Moree and Walgett.

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.

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.

While traditional views of canopy management are based on southern experiences, northern region growers and agronomists are developing guidelines for the northern cropping zone. 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 throughout the northern cropping zone would be further aided by development of efficient, in-soil N-application equipment. [7]

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Varieties-and-agronomy-for-maximising-irrigated-wheat-yields-in-the-northern-region

10.1.4 Irrigated wheat in north-eastern Australia

Growers of irrigated cotton in north-eastern Australia have recently grown record areas of irrigated wheat (Figure 2) (notably in 2008) in response to increased grain prices, but wheat yields in the region have been severely constrained by lodging. Irrigated experiments were conducted at Gatton in 2009 and 2011 to assess the ability of canopy-management techniques of delayed N application and low plant populations to decrease lodging risk in the northern region. High leaf area index at the end of tillering

[7] P McKenzie (2009) Canopy management in the northern grains region—the commercial view. Consultants Corner, Australian Grain, July 2009, 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

was associated with increased lodging. Maximum yields for irrigated experiments were generally achieved when soil + fertiliser N at sowing was <100 kg/ha, with low-N treatments having less lodging and yield increases of up to 1 t/ha compared with high N treatments. Increasing plant density to >100 plants/m^2 increased lodging and decreased yield in high-N treatments. The highest yielding treatments had the least lodging, a harvest index of 0.45, and <450 tillers/m^2 at the end of tillering. Therefore, canopy-management techniques can be used to increase yields and decrease lodging in irrigated wheat in the northern region, but the techniques will be different from those used for irrigated wheat growing in southern Australia. The responses observed may have been reliant on irrigation during tillering to ensure that low levels of N were fully available to the crop. Further study is needed to determine the importance of early-season irrigation in maintaining yield on low-N paddocks.[8]

Figure 2: Wheat under irrigation.

10.2 Key cereal growth stages for disease control and canopy management

10.2.1 Why is growth stage important in making fungicide decisions?

Five to 10 years ago, it would have been common to make decisions on fungicide applications for stripe rust based on thresholds of infection; these thresholds varied from 1 to 5% plants infected. A problem soon became apparent to growers and advisers that, in the paddock, it was difficult to calculate whether this disease threshold had been reached, not least because of the sporadic nature of the initial foci of the disease. In addition, by the time growers realised that the threshold had been reached and carried out the spray operation, the crops were badly infected. When crops that are badly infected with stripe rust are treated with fungicides, the control is poor, since fungicides work better as protectants than as curatives.

Trials on stripe rust control (GRDC project SFS00006) quickly established that foliar fungicide applications based on growth stages and applied between second node (GS32) and flag-leaf emergence (GS39) or at both timings gave good control of the

8 A Peake, K Bell, N Poole, J Lawrence (2012) Nitrogen stress during tillering decreases lodging risk and increases yield of irrigated bread-wheat (*Triticum aestivum*) in north-eastern Australia. Australian Agronomy Conference 2012, Australian Society of Agronomy/The Regional Institute Ltd, http://www.regional.org.au/au/asa/2012/crop-development/8120_peakeas.htm#TopOfPage

disease. These growth-stage-based timings also gave growers the opportunity to plan disease management strategies for susceptible cultivars. [9]

10.2.2 Why do these growth-stage timings work for stripe rust control?

The primary reason for these timings working is that the growth stages between GS32 and GS39 coincide with the emergence of the top three leaves of the crop canopy in wheat, meaning that fungicides are applied to leaves shortly after they have emerged and before tissue becomes heavily infected. However, it is also important to note that foliar fungicide applied at first or second node (GS31–32) does not protect the flag leaf or the leaf beneath it (flag-1), since they have not emerged at this early stem-elongation growth stage. Equally, a foliar fungicide applied at flag leaf (GS39) may protect the flag leaf but may be too late to protect flag-2, which emerged 2–3 weeks earlier. [10]

Yield loss to disease at different growth stages of disease onset

Although growth-stage timings of fungicide applications can ensure that the top three leaves of the plant are adequately protected, the growth stage of disease onset dictates the level of economic response to a fungicide. For the construction of the Rustman model, a simple relationship (derived from trial results) linked expected yield losses to the onset of stripe rust infection at particular growth stages (Table 1). This simple chart (whilst complicated by the presence of adult plant resistance, APR) remains a useful guide to potential yield loss with susceptible cultivars at different growth stages.

Table 1: Expected yield losses (%) based on different growth stages of disease onset (stripe rust)

Disease onset		Stripe rust reaction			
Growth Stage		Susceptible	Moderately Susceptible	Moderately Resistant	Resistant
GS31	First node	85	75	55	25
GS39	Flag leaf	75	45	15	5
GS45	Booting	65	25	7	2
GS49	1st awns	50	10	3	1
GS55	Mid Heading	40	5	2	0
GS65	Mid Flower	12	2	1	0

Source: ICAN Cereal Foliar Disease Workshops for Advisers (G. Murray, July 2004)

This guide to yield loss is based on the premise that yield loss to stripe rust is dependent on:

1. The extent of stripe rust by early grain development
2. The temperature during grain-fill (responses in the table assume average temperatures; if hotter, the yield loss (due to disease) is less than expected)

The complication with APR in Table 1 is that some cultivars, such as Gregory⚘ (rated as resistant (R) to stripe rust), may display infection at GS30 but have never recorded losses as great as 25% with the current pathotypes, since APR in the plant switches on ensuring that the disease does not develop in the resistant cultivar. Indeed, it is unlikely that a cultivar could be rated as resistant if it were subject to yield losses of 25% from an early infection. For this reason, the table is a useful guide for losses at particular growth stages for more susceptible cultivars, but not the resistant ones.

9 N Poole (2011) Cereal growth stages and decision making for fungicide timing. GRDC Update Papers 7 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Cereal-growth-stages-and-decision-making-for-fungicide-timing

10 N Poole (2011) Cereal growth stages and decision making for fungicide timing. GRDC Update Papers 7 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Cereal-growth-stages-and-decision-making-for-fungicide-timing

Otherwise, the data illustrate that the earlier the disease infects the crop, irrespective of variety resistance rating, the greater the expected loss. [11]

Influence of disease onset on optimum timings of fungicide spray for very susceptible cultivars

The time of disease onset (stripe rust) not only influences the expected return from foliar fungicides, it also influences the timing of fungicide applications in order to create the greatest return.

What difference does it make to fungicide strategy if stripe rust infects the crop at GS32 (second node) *v.* GS39 (flag leaf emergence on the main stem)?

This scenario presented during research work in Young, NSW, with the very susceptible cultivar H45⏀ in 2004 (GRDC project SFS0006). Stripe rust arrived in the district at the beginning of October. One research trial had been established in early July, another in early June. The early-sown trial was infected at flag leaf emergence (GS39), while the later sown trial was infected at second node (GS32). So if one unit of fungicide were available, in this case 145 mL/ha of Folicur®, what would be the best use?

1. Spray both crops at flag leaf (GS39), since this is the most cost-effective timing in most fungicide trials?
2. Split the fungicide active between two timings, the first applied at GS32 and the other at GS39?
3. Or treat the two crops with a different strategy?

Figure 3: Flag leaf. (Source: Foundation of Arable Research)

The answer to the question posed was that where stripe rust infection occurred at second node (GS32), the two-spray program was optimal, but with a later flag-leaf infection, there was no advantage to applying fungicide twice. It is arguable that since fungicides are insurance inputs, the more consistent program of the two trials (in terms of disease control and yield response) was fungicide applied at both second node stage GS32 and at flag-leaf stage GS39.

11 N Poole (2011) Cereal growth stages and decision making for fungicide timing. GRDC Update Papers 7 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Cereal-growth-stages-and-decision-making-for-fungicide-timing

Would the result be the same if a cultivar had a low level of APR rather than a very susceptible (VS) rating for stripe rust?

The questions to be answered were:

- Would later sowing exhibit greater disease resistance than earlier sowings, acknowledging that later sowings develop later in the season in a climate that is usually warming and therefore less conducive to stripe rust infection and fungicide response? Might it also encourage greater APR if the switches for APR genes were linked to temperature, a feature of APR expression in some cultivars? or
- Would stripe rust onset be the same for all crops in the district, later sown crops being infected at earlier growth stages and therefore giving greater response to fungicide?

To hear Nick Poole discuss canopy management, visit http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2009/07/Disease-management-and-crop-canopies.

10.3 Use of plant growth regulators

Plant growth regulators (PGR) may be used to minimise crop lodging and maximise yield, particularly in high-N situations. A combination of two PGRs increased yield by 16% when applied at GS31 (Table 2). This experiment was configured with 30-cm row spacing sown into a 2-m flat bed.

Approximately 150 seedlings emerged and the site was irrigated via flood furrow. 180 kg/ha N was applied at sowing and the site had less than 30 kg/ha residual soil nitrate/90 cm soil. Despite the fact that no lodging was observed in this experiment, a significant positive effect on yield was achieved using the products in this experiment when applied at the booting stage of crop growth. This trend has been consistent through several experiments conducted using these products and mixtures. [12]

Table 2: Comparison of plant growth regulators, timing, rate, and mixtures, ACRI Narrabri, 2011—wheat cv. EGA Gregory

Treatment	Application timing (Zadoks growth stage)	Yield (t/ha)	
1. Untreated check		5.8	bc
2. Product X @ 50 g a.i./ha	GS31	6.0	ab
3. Product X @ 100 g a.i./ha	GS31	6.1	ab
4. Product X @ 50 g a.i./ha + Cycocel 750 A @ 756.6 g a.i./ha	GS31	6.9	a
5. Product X @ 50 g a.i./ha	GS37	5.4	bc
6. Product X @ 100 g a.i./ha	GS37	5.0	c
7. Product X @ 50 g a.i./ha + Cycocel 750 A @ 756.6 g a.i./ha	GS37	5.7	bc
l.s.d. (P = 0.05)		0.8	

Means followed by same letter are not significantly different (P > 0.05)

For more information on registered plant growth regulators, visit www.apvma.gov.au

[12] B Griffiths, L Bailey, C Guppy, N Hulugalle, C Birchall (2013) Managing resources and risk for 8-tonne cereal-crops. GRDC Update Papers 5 March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Managing-resources-and-risk-for-8-tonne-cereal-crops

SECTION 11

Crop desiccation/spray out

Not applicable to this crop.

SECTION 12

Harvest

For more information, see the *GRDC GrowNotes WHEAT (Northern region),* Section 12: Harvest.

12.1 Dry harvest issues and management

Attention to detail at harvest is required for durum wheat. Premiums are only paid when grain is large and undamaged, not mottled or bleached and, most importantly, not contaminated by other grains, and meets all other delivery specifications. Therefore, issues of grain-harvester machine settings, careful segregation and clean, insect-free grain storage must receive attention. Damaged, contaminated or insect-infested grain will be downgraded. Durum wheat is a high-quality product trading into a high-quality food market and attention to detail at harvest is critical. [1]

EGA Bellaroi⦶ is marginally more difficult to thresh than Hartog and Sunco, but easier than Sunlin; consequently, concave adjustments may be necessary. These durum varieties are not prone to shelling, a factor of significance when wind and rain prevail at harvest. All grain should be retained in the head despite these weather conditions. Care needs to be exercised when threshing the crop, as the very hard grain has a greater tendency to fracture than grain of bread wheats. The crop should be stripped as soon as the grain reaches dead ripe maturity. Buyers of durum grain consider grain appearance important and pay premiums for large, well-filled, hard, vitreous grain with a low percentage of mottled and bleached seeds. [2]

Black point is a dark discoloration at the germ end of otherwise healthy grain. In wheat, the discoloration occurs in the outer portions of the seed and, in some severe cases, may extend along the groove on the underside of the grain. [3] Jandaroi⦶ and EGA Bellaroi⦶ are significantly more resistant to the problem than Kamilaroi⦶, but this resistance may not offer sufficient protection in prolonged wet seasons. Ensure that all grain handling equipment (e.g. headers, bins, augers, silos etc.) are free of contaminant grain, as the presence of foreign seeds (maximum 3% bread wheat seed) can downgrade the crop grain. [4]

Although durums have slightly better resistance to pre-harvest sprouting than current bread wheats, they may be downgraded to feed due to bleaching and softening of the grain in prolonged wet harvest seasons. [5]

1 J Kneipp (2008) Durum wheat production. NSW Department of Primary Industries, http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-NSW-Durum-Wheat-Production.pdf

2 Hare, R, (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

3 DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

4 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

5 DAFF (2012) Durum wheat in Queensland. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/durum-wheat

12.2 Receival standards

Six aspects of grain quality are considered at receival:

1. Protein
2. Test weight
3. Screenings
4. Falling number
5. Black point
6. Weed seed contamination

The endosperm section of the grain is the important part, as it is this fraction that is processed into semolina (a coarse flour) and, in turn, mixed with a little water to form a stiff dough under vacuum and extruded under pressure into pasta, forming various shapes—both long and short goods. The endosperm is the food supply or life-support system for the developing embryo. The endosperm and embryo are 'wrapped up' in several layers of tissue called the aleurone, pericarp and testa. The embryo and outer grain layers are removed during milling, into the bran and pollard fractions, while the endosperm is reduced to semolina. The endosperm is composed of numerous constituents including starch, sugars, proteins, amino acids, minerals, fats, vitamins, enzymes, pigments and fibre. A large, well-filled grain with bright amber colour and oval shape with minimal crease length is required at receival. [6]

Durums express a satisfactory level of resistance to pre-harvest sprouting compared with current bread wheat varieties. Weather-affected grain is soft, which reduces the semolina extraction in the mill. Weathered semolina gives low pasta-dough strength due to the partial enzymatic breakdown of starches and proteins. These small protein and starch molecules have reduced cohesive properties. Weak doughs make inferior pasta. High-protein durum grain with a bright amber bloom is certain to attract the best available premium price. It is not advisable to leave your durum harvest until last, relying on its weathering resistance. Its resistance is only relative to other varieties and will eventually fail. Weathered durum is not valuable and may be received as feed grain. [7]

Black point is a discoloration of sections of the external layers of the grain (i.e. pericarp/testa). A small percentage of discoloured seeds will be present following a wet pre-harvest period when the problem is most active. This level of incidence should be below the minimum dockage limits in most seasons. Black point tolerances are 3% for ADR1 and 3–5% for ADR2 and ADR3. Because small fragments of bran are included in semolina, discoloured grain will leave small black specks, which can be seen in the vitreous (translucent) pasta. The overall appearance of pasta with black specks is diminished and there is some consumer reluctance to purchase the product. Black specks can be perceived as contaminants (e.g. soil, insect parts). If sown, grain with black point will germinate satisfactorily. EGA Bellaroi⦶ is significantly more resistant to black point than Kamilaroi⦶ and many of the current bread wheats. Research findings suggest that black point is not a disease caused by fungi, but a physiological character resulting from the formation of dark compounds in the outer layers of the grain. Some varieties are more prone to develop these dark compounds when appropriate conditions prevail (e.g. warm and moist). [8]

6 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

7 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

8 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

Protein content is an important factor in grain classification at receival, with classifications and premiums as follows:

- ADR1 attracts a premium around APH or better
- ADR2 attracts a premium around AH or better [9]

Grain with adequate protein is very hard, vitreous and free from mottling. For milling, a small percentage of mottled grains can be tolerated in top grades, but a greater proportion will result in downgrading and a reduced premium. Vitreous grain contains sufficient protein to combine all the starch granules; however, a shortage of protein will give a mottled, softer grain. Protein can be envisaged as the equivalent of cement, which binds the starch granules or the aggregate together. With insufficient cement, the aggregate will not all bind and thus the concrete will be weak and break down readily. The same is the case with mottled sectors in grain. The degree of mottling in individual grains, together with the percentage of mottled grains in the seed lot, both contribute to the 'flour' formation and consequent milling losses. 'Flour' or 'fines' has a lower economic value than that of semolina. Hard, vitreous grains shatter into rough aggregates and produce a high semolina yield. [10]

For pasta making, the canning industry specifies high-protein semolina for canned pasta. High-protein pasta withstands the high pressure/temperature cooking and retorting processes in acidic tomato pasta. Further, this pasta retains its consistency on warming and serving by the consumer. Dry pasta manufacturers require acceptable levels of protein but not as high as those required by the canning industry. Low-protein semolina is unsuitable for pasta making as it has insufficient protein to give the product acceptable keeping, cooking and eating consistency. EGA Bellaroi⦶ and the newer varieties, Jandaroi and Caparoi, are highly suitable for pasta and couscous production which are regarded by many Italian manufacturers as being equivalent to the best in the world. [11]

The protein content of grain is largely under environmental control. Plants growing in soils with adequate nitrogenous fertility will lay down acceptable protein levels in the grain. EGA Bellaroi⦶ and Jandaroi⦶ have the genetic capability to achieve higher protein content (up to 1%) than Caparoi⦶. [12]

The grain protein comprises a large number and complex range of protein types. The proteins range from short molecules to long, folding molecules. The long molecules adhere to each other and form an interlocking network, which prevents the starch and other components from moving freely. The degree of interlocking (chemical bonds) between these long-chained proteins determines the mobility of the pasta dough, which is called the 'dough strength'. Pasta dough strength, or the resistance of the dough to move under work (force), is mainly under genetic control. Cultivars that offer strong to very strong pasta doughs have been released. The dough strength, which is equivalent to protein strength, is a key determinant of pasta quality through its effect on the internal consistency of extruded products. Pastas made from strong protein doughs retain their shape and consistency on cooking and eating. Weaker pastas tend to break down

9 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

10 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

11 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

12 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

during cooking to a rather unpalatable mess. Bread wheat pastas are of this undesirable type. [13]

The colour of pasta is a factor in consumer acceptance. Pale to white or brown pastas do not have a pleasing appearance and they are passed over for the bright, clear yellow pasta by the consumer. Only durum wheat can provide this colour without the addition of expensive synthetic pigments or egg products. The addition of artificial colours is banned in Italy and France. Law dictates that durum wheat must be used for dry pasta in these countries. Pasta colour is principally under genetic control; therefore, only highly coloured varieties are released. The pre-release varieties from the DBA program offer significantly improved colour compared with Bellaroi⦶, Caparoi⦶ and Jandaroi⦶. [14]

12.3 Harvest weed-seed management

It is most important to control weeds in the crop, as some weed species, such as bindweed and New Zealand spinach, have small black seeds that can be difficult to remove from the grain. These seeds have the same effect on consumer acceptance as black point contamination. The black seeds shatter during milling to leave numerous small black fragments mixed in the semolina. [15]

For more information about the growing area of weed seed control, see the *GRDC GrowNotes WHEAT (Northern region)*, Section 12: Harvest.

13 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

14 R Hare (2006Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

15 R Hare (2006) Agronomy of the durum wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi. Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

SECTION 13

Storage

An on-farm storage system designed for good hygiene that includes aeration and sealable silos for fumigation is essential for growers who wish to maximise their returns from wheat. Without sealable silos, growers could be contributing to Australia's problem of insect resistance to phosphine, the most common fumigant used in the Australian grain industry. Without aeration, growers risk excluding themselves from markets that will not accept chemically treated grain.

In conjunction with sound management practices, which include checking grain temperatures and regular monitoring for insect infestations, an on-farm storage system that is well designed and maintained and properly operated provides the best insurance a grower can have on the quality of grain to be out-turned.

Figure 1: Storage with aeration is important for protecting Australia's markets. (Source: QDAFF)

Grain Trade Australia (GTA) stipulates standards for heat-damaged, bin-burnt, storage-mould-affected or rotten wheat, all of which can result in the discounting or rejection of grain. GTA has nil tolerance to live, stored grain insects for all grades of wheat from premium milling grades to feed. [1] Effective management of stored grain can eliminate all of these risks to wheat quality.

In grain storages in Queensland, including central Queensland, and New South Wales, target grain temperatures of stored wheat should be 20–23°C during summer and less

1 Grain Trade Australia (2013) Wheat Standards, 2013/2014 season. GTA, August 2013.

than 15°C in winter. [2] In northern NSW and southern Queensland, including the Darling Downs, aerated silos properly managed, should allow growers to target an average summer time grain storage temperature of 20°C.

13.1 How to store wheat on-farm

Video

Watch this GRDC Ground Cover TV clip to find out more: http://www.youtube.com/watch?v=iS3tUbJZl6U

According to the Kondinin Group National Agricultural Survey 2011, silos account for 79% of Australia's on-farm grain storage, compared with 12% for bunkers and pits and 9% for grain bags.

Aerated silos that can be sealed during fumigation are widely acknowledged as the most effective way to store wheat on-farm (Table 1). There is now an Australian standard (AS2628) for sealable silos that manufacturers in Australia can choose to use as a construction standard to ensure reliable fumigation results.

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 atmosphere options to control insects • Easily aerated with fans • Fabricated on-site or off-site and transported • Capacity from 15 tonnes up to 3000 tonnes • Up to 25 year plus service life • Simple in-loading and out-loading • Easily administered hygiene (cone base particularly) • Can be used multiple times in-season	• Requires foundation to be constructed • Relatively high initial investment required • Seals must be regularly maintained • Access requires safety equipment and infrastructure • Requires an annual test to check gas-tight sealing
Non-sealed silo	• Easily aerated with fans • 7–10% cheaper than sealed silos • Capacity from 15 tonnes up to 3000 tonnes • Up to 25 year plus service life • Can be used multiple times in-season	• Requires foundation to be constructed • Silo cannot be used for fumigation —see phosphine label • Insect control options 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 all ground operated • Can accommodate high-yielding seasons	• Requires purchase or lease of loader and unloader • Increased risk of damage beyond short-term storage (typically three months) • Limited insect control options, fumigation only possible under specific protocols • Requires regular inspection and maintenance which needs to be budgeted for • Aeration of grain in 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
Grain storage sheds	• Can be used for dual purposes • 30 year plus service life • Low cost per stored tonne	• Aeration systems require specific design • 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

2 P Burrill (2013) Grain Storage Future pest control options and storage systems 2013–2014., GRDC Update, July 2013.

More information

GRDC Grain Storage Facilities: Planning for efficiency and quality. A Grains Industry Guide http://www.grdc.com.au/~/media/5F5E5727E4C04BD48BC3DAA5A3015786.pdf

Growers should pressure-test sealable silos once a year to check for damaged seals on openings. Storages must be able to be sealed properly to ensure high phosphine gas concentrations are held long enough to give an effective fumigation.

At an industry level, it is in growers' best interests to only fumigate in gas-tight sealable storages to help stem the rise of insect resistance to phosphine. This resistance has come about because of the prevalence of storages that are poorly sealed or unsealed during fumigation. [3]

The Kondinin Group National Agricultural Survey 2009 revealed that 85% of respondents had used phosphine at least once during the previous 5 years, and of those users, 37% used phosphine every year for the past 5 years. A GRDC survey during 2010 revealed that only 36% of growers using phosphine applied it correctly—in a gas-tight, sealable silo.

Research shows that fumigating in a storage that is not gas-tight does not achieve a sufficient concentration of fumigant for long enough to kill pests at all life-cycle stages. For effective phosphine fumigation, a minimum gas concentration of 300 parts per million (ppm) for 7 days or 200 ppm for 10 days is required (Figure 2). Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3 ppm close to the leaks (Figure 3). The rest of the silo also suffers from reduced gas levels. [4]

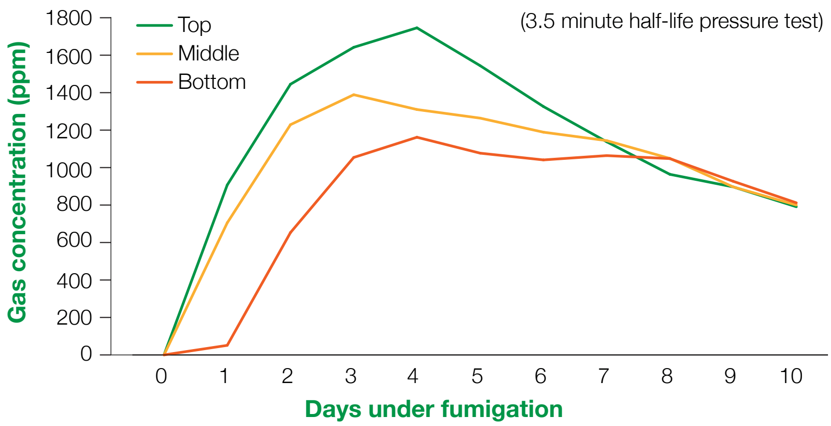

Figure 2: Gas concentration in gas-tight silo. (Source: QDAFF)

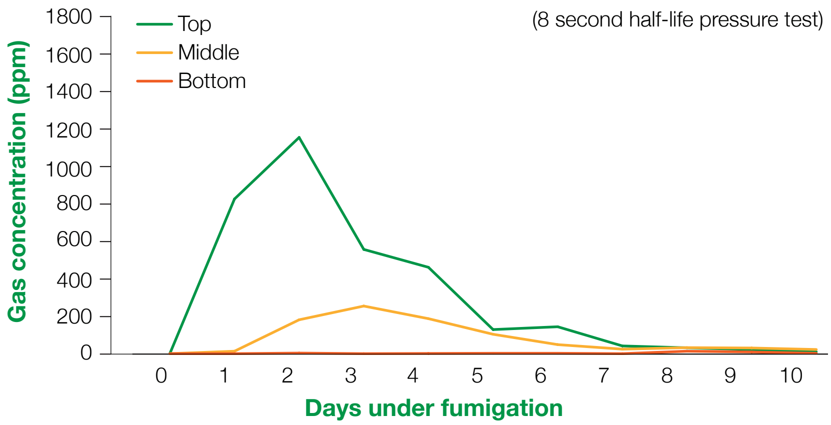

Figure 3: Gas concentration in a non-gas-tight silo. (Source: QDAFF)

[3] C Warrick (2011) Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once: A Grains Industry Guide. GRDC Stored Grain Project, January 2011 (reprinted June 2013).

[4] P Botta, P Burrill, C Newman (2010) Pressure testing sealable silos. GRDC Grain Storage Fact Sheet, September 2010.

To find out more about how to pressure-test silos, visit 'Fumigating with phosphine, other fumigants and controlled atmospheres' at: http://www.grdc.com.au/~/media/FC440FBD7AE14140A08DAA3F2962E501.pdf

Aeration of stored wheat is the key non-chemical tool used to minimise the risk of insect infestations and spoiling through heat and/or moisture damage.

Aeration controllers that automatically monitor air temperature and humidity are designed to turn fans on and off at the optimum times. The controller reduces the risk of having fans running on storages at times that may potentially cause grain damage. Most aeration controllers have hour meters fitted, so run-times can be checked to ensure they are within range of the expected total average hours per month, for example, 100 hrs/month.

It is important to separate aeration systems commonly used for "aeration cooling" and aeration systems designed specifically to achieve reliable "aeration drying". Serious grain damage has occurred when fan performance has not met the required airflow rates as measured in litres per second per tonne (L/s.t). If aeration drying of grain is attempted with elevated moisture levels using an inadequate airflow rate and/or a poor system design, sections of the storage can develop very high moisture and grain temperatures. With low airflow rates moisture drying fronts move too slowly to prevent grain spoilage. Grain-quality losses from moulds and heat occur rapidly. This type of damage often makes the grain difficult to sell and may cause physical damage to the silo itself. [5]

More information

A GRDC Fact Sheet explaining how to build and use an A-Flow is available at: http://www.grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

Researchers in Australia have developed a device that measures working airflow rates of fans fitted to grain storage. Called the 'A-Flow', it has been validated under controlled conditions, using an Australian Standard fan-performance test rig, to be within 2.6% of the true fan output. The device was used on a typical grain storage that was in the process of aerating recently harvested grain. A fan advertised to provide 1000 L/s (equivalent to 6.7L/s.t on a full 150-t silo) was tested and shown to be producing only 1.8 L/s.t. Because of this test, the farmer recognised a need to make changes to his current aeration system design.

A number of changes may be required if airflow rates are not suitable for efficient aeration cooling or drying. A new fan that is better suited to the task could be installed, or the amount of grain in the silo reduced to increase flow rate per tonne of grain.

More information

http://storedgrain.com.au/wp-content/uploads/2013/07/GRDC-GS-FACILITIES-Booklet-2013_Final.pdf

Detailed information about selecting, siting and fitting-out silos, grain storage bags, sheds and bunkers is contained in the GRDC Grains Industry Guide 'Grain storage facilities: Planning for efficiency and quality'.

13.2 Hygiene

Effective grain hygiene and aeration cooling can overcome 75% of pest problems in stored grain. All grain residues should be cleaned out when silos and grain-handling equipment are not in use to help minimise the establishment and build-up of pest populations.

In one year, a bag of infested grain can produce more than one million insects, which can walk and fly to other grain storages where they will start new infestations. Meticulous grain hygiene involves removing any grain residues that can harbour pests and allow them to breed. Grain pests live in protected, sheltered areas in grain handling equipment and storage and breed best in warm conditions. Insects will also breed in outside dumps of unwanted grain. Try to bury grain or spread out unwanted grain to a shallow depth of less than 20 mm so insects are exposed to the daily temperature extremes and other insect predators.

5 P Burrill, A Ridley (2012) Performance testing aeration systems. GRDC Research Update Northern Region, Spring 2012, Issue 66.

Figure 4: Poor grain hygiene undermines effective stored grain insect control. (Source: QDAFF)

A trial in Queensland revealed more than 1000 lesser grain borers (*Rhyzopertha dominica*) (Figure 5) in the first 40 L of grain through a harvester at the start of harvest; this harvester was considered reasonably clean at the end of the previous season. [6] Further studies in Queensland revealed that insects are least mobile during the colder winter months of the year. Cleaning around silos in the winter months before spring can reduce insect numbers before they become mobile.

[6] P Burrill, P Botta, C Newman, B White, C Warrick (2013) Northern and southern regions—Grain storage pest control guide. GRDC Grain Storage Fact Sheet, June 2013.

Figure 5: Ryzopertha dominica. (Source: QDAFF)

Successful grain hygiene involves cleaning all areas where grain residues become trapped in storages and equipment. Grain pests can survive in a tiny amount of grain, which can go on to infest freshly harvested clean grain. Harvesters and grain-handling equipment should be cleaned out thoroughly with compressed air after use.

After grain storages and handling equipment are cleaned, they should be treated with a structural treatment. Diatomaceous earth (DE) is an amorphous silica also commonly known as the commercial product 'Dryacide'™ and is widely used for this purpose. It acts by absorbing the insect's cuticle or protective waxy exterior, causing death by desiccation. If applied correctly with good coverage in a dry environment, DE can provide up to 12 months' protection by killing most species of grain insects and with no known risk of resistance. It can be applied as a dry dust or slurry spray.

While many cereal grains buyers accept approved chemical insecticide structural treatments to storages, growers should avoid using them, or wash the storage out, before storing oilseeds and pulses. As there are now a number of export and domestic markets that require "pesticide residue free" grain (PRF), growers are advised to check with potential grain buyers before using grain protectants or structural treatments.

To find out more about what to use and when and how to clean equipment and storages to minimise the chance of insect infestation, visit www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments to download the GRDC's Grain Storage Fact Sheet 'Hygiene and structural treatment for grain storages' (June 2013).

13.3 Grain protectants and fumigants

Grain Trade Australia is aware of cases where various chemicals have been used to treat stored grain that are not approved for grain or that particular grain type. When they are detected, an entire shipload can be rejected, often with serious long-term consequences for important Australian grain markets.

Markets that require PRF ('pesticide residue free') grain do not rule out the use of some fumigants, including phosphine. However, PRF grain should not have any chemical residues from treatments that are applied directly to the grain as grain protectants. Before using a grain protectant or fumigant, growers need to check with prospective buyers, as the use of some chemicals may exclude grain from certain markets.

Although phosphine has resistance issues, it is widely accepted as having no residue issues. 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. The break is provided by moving the grain to eliminate pockets where the fumigant may fail to penetrate, and by retreating it with an alternative disinfestant or protectant. [7]

Figure 6: Phosphine is widely accepted as having no residue issues. (Source: QDAFF)

Recent research has identified the genes responsible for insect resistance to phosphine. A genetic analysis of insect samples collected from south-eastern Queensland between 2006 and 2011 has allowed researchers to confirm the increasing incidence of phosphine resistance in the region. Whereas few resistance markers were found in insects collected in 2006, by 2011 most collections had insects that carried the resistance gene. Further testing with DNA markers that can detect phosphine resistance is expected to identify problem insects before resistance becomes entrenched, and thereby help to prolong phosphine's effective life, as well as increasing the usefulness of the break strategy. [8]

7 P Collins (2009) Strategy to manage resistance to phosphine in the Australian grain industry. Cooperative Research Centre for National Plant Biosecurity Technical Report.

8 D Schlipalius (2013) Genetic clue to thwart phosphine resistance. GRDC Ground Cover, Issue 102, Jan.–Feb. 2013.

Table 2: Resistance and efficacy guide for stored grain insects (northern and southern regions) in cereal grains

Treatments	WHP (days)	Lesser grain borer *(Rhyzopertha dominica)*	Rust-red flour beetle *(Tribolium castaneum)*	Rice weevil *(Sitophilus oryzae)*	Saw-toothed grain beetle *(Oryzaephilus surinamensis)*	Flat grain beetle *(Cryptolestes ferrugineus)*	Psocids (booklice) *(Order Psocoptera)*	Structural treatments
Grain disinfectants - used on infested grain to control full life cycle (adults, eggs, larvae, pupae).								
Phosphine (eg Fumitoxin®)[1,3] when used in gas-tight, sealable stores	2							
Sulfuryl fluoride (eg ProFume®)[10]	1							
Dichlorvos (eg Dichlorvos 1140®)[11]	7-28							9
Grain protectants – applied post harvest. Poor adult control if applied to infested grain.								
Pirimiphos-methyl (eg Actellic 900®)	nil[2]							
Fenitrothion (eg Fenitrothion 1000®)[4]	1-90							
Chlorpyrifos-methyl (eg reldan Grain Protector®)[5]	nil[2]							
Methoprene (Grain Star 50®)	nil[6]		7		7			
'Combined products' (eg Reldan Plus IGR Grain Protector)	nil[2]							
Deltamethrin (eg K-Obiol®)[10]	nil[2]							
Diatomaceous earth, amorphous silica – effective internal structural treatment for storages and equipment. Specific use grain treatments.								
Diatomaceous earth, amorphous silica (eg Dryacide®)[8]	nil[2]							

WHP Withholding Period

- Not registered for this pest
- High-level resistance in flat grain beetle has been identified, send insects for testing if fumigation failures occur
- Resistant species likely to survive this structural treatment for storage and equipment
- Resistance widespread (unlikely to be effective)
- Effective control

[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, eg Fenitrothion at label rate
[8] Do not use on stored maize destined for export, or on grain delivered to bulk-handling authorities
[9] Dichlorvos 500g/L registration only
[10] Restricted to licensed fumigators or approved users
[11] Restricted 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

According to research results from scientists at Queensland's Department of Agriculture, Fisheries and Forestry (QDAFF), sulfuryl fluoride (SF) has excellent potential as an alternative fumigant to control phosphine-resistant grain storage pests (Table 2). It is currently registered in Australia as a grain disinfestant. Supplied under the trade name 'ProFume', SF can only be used by a licenced fumigator.

Field trials have shown that SF can control strong phosphine-resistant populations of Rusty grain beetle (*Cryptolestes ferrugineus*). Monthly sampling of fumigated grain has revealed no live insects for three consecutive months in large-scale bunker (pad) storages after the fumigation.

Annual resistance-monitoring data was analysed to assess the impact of using SF as an alternative fumigant to phosphine. This revealed that after the introduction of SF in central storages across the northern and southern grain regions in 2010, there was a 50% reduction in the incidence of strongly phosphine-resistant populations of rusty grain beetle at the end of the first year, and the downward trend is continuing. Complimentary laboratory experiments have shown that phosphine resistance does not show cross-resistance to SF, which is an additional advantage of using SF. [9]

Effective phosphine fumigation can be achieved by placing the chemical at the rate directed on the label onto a tray and hanging it in the top of a pressure-tested, sealable silo. A ground-level application system is also an efficient application method and can be combined with a silo recirculation system on larger silos to improve the speed of gas distribution. After fumigation, grain should be ventilated for a minimum of 1 day with aeration fans running, or 5 days if no fans are fitted. A minimum withholding period of 2 days is required after ventilation before grain can be used for human consumption or stock-feed. The total time required for fumigating ranges from 7 to 20 days depending on grain temperature and the storage structure.

To find out more, visit 'Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once: A Grains Industry Guide': http://www.grdc.com.au/~/media/FC440FBD7AE14140A08DAA3F2962E501.pdf

Two new grain protectants are now available. These are:

- K-Obiol (active ingredients deltamethrin 50 g/L, piperonyl butoxide 400 g/L): Features acceptable efficacy against the common storage pest lesser grain borer, which has developed widespread resistance to current insecticides. Insect resistance surveys in the past consistently detected low levels of deltamethrin-resistant insect strains in the industry. This is a warning that resistant populations could increase quickly with widespread excessive use of one product. A 'product stewardship' program has been developed to ensure correct use of the product. [10]
- Conserve On-Farm: Has three active ingredients (chlorpyrifos-methyl 550 g/L, S-methoprene 30 g/L, spinosad 120 g/L) to control most major insect pests of stored grain, including the resistant lesser grain borer. The MRLs have been established with key trading partners and there are no issues with meat residue bioaccumulation.

A grain disinfestant combined with carbon dioxide gas, currently has some limitations.

- VAPORMATE (active ingredient ethyl formate 166.7 g/kg): Approved for use in stored cereals and oilseeds. It is registered to control all life-stages of the major storage pest insects: lesser grain borer, rust-red flour beetle (*Tribolium* spp.), sawtoothed beetle, flat grain beetles, storage moths and psocids (booklice). However does not fully control all stages of rice weevil. It must only be used by a licenced fumigator.

Controlled atmosphere/non-chemical treatment options include:

- Carbon dioxide (CO_2): Involves displacing the oxygen inside a gas-tight silo with a high concentration of CO_2 combined with a low oxygen atmosphere lethal to grain pests. To achieve a complete kill of all grain pests at all life-stages, CO_2 must be maintained at a minimum concentration of 35% for 15 days.
- Nitrogen (N_2): Provides insect control and quality preservation without chemicals. It is safe to use and environmentally acceptable, and the main operating cost is electricity used by the equipment to produce nitrogen gas. The process uses

9 M Nayak (2012) Sulfuryl fluoride—A solution to phosphine resistance? GRDC Research Update Northern Region, Spring 2012, Issue 66.

10 P Burrill (2013) Grain Storage Future pest control options and storage systems 2013–2014. GRDC Update, July 2013.

pressure swing adsorption (PSA) technology to produce N_2, thereby modifying the atmosphere within the grain storage to create a very high concentration of N_2, and starving insect pests of oxygen. [11]There are no residues, so grains can be traded at any time.

Silo bags as well as silos can be fumigated. Research conducted by Andrew Ridley and Philip Burrill from DAFF Queensland and Queensland farmer Chris Cook found that sufficient concentrations of phosphine can be maintained for the required time to successfully fumigate grain in a silo bag. Trials on a typical, 75 m long bag containing approximately 230 t of grain successfully controlled all life stages of the lesser grain borer.

Figure 7: Silo bags can also be fumigated. (Source: QDAFF)

When using phosphine in silos or silo bags it is illegal to mix phosphine tablets directly with grain due to tablet residue issues. As trays in silo bags are not practical, tablets are placed in perforated conduit to contain tablets and spent dust. The 1 m tubes are speared horizontally into the silo bag and removed at the end of the fumigation. Trial results suggest that the spears should be no more than 7 m apart and fumigation should occur over 12–14 days. (Figure 8). In previous trials when spears were spaced 12 m apart, the phosphine gas took too long to diffuse throughout the whole bag. [12]

11 C Warrick (2011) Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once: A Grains Industry Guide. GRDC Stored Grain Project, January 2011 (reprinted June 2013).

12 P Burrill, A Ridley (2012) Silo bag fumigation. GRDC Research Update Northern Region, Spring 2012, Issue 66.

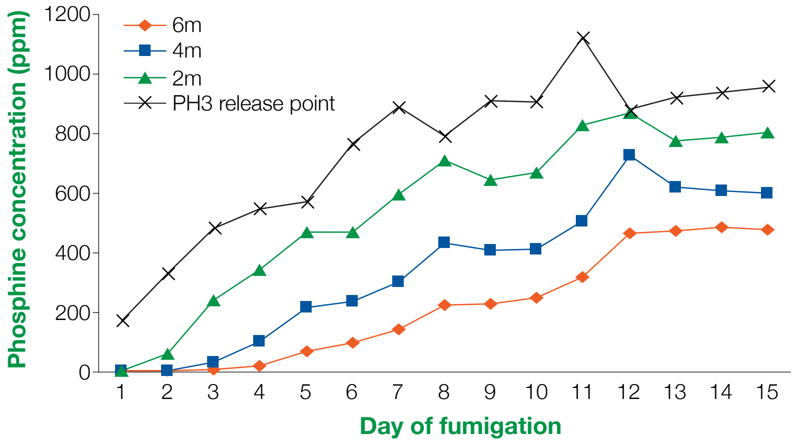

Figure 8: Spread of phosphine gas in a silo bag from a release point to gas monitoring lines at 2, 4 and 6 m along a silo bag.

More information

http://www.grdc.com.au/~/media/DAF5F438D9644D90B9A4FA9716B2014E.pdf

13.4 Aeration during storage

Aeration has a vital role in both maintaining grain quality attributes and reducing insect pest problems in storage. Most grain in storage is best held under aeration cooling management with the silo having appropriate roof venting. As a general rule, silos should only be sealed up during a fumigation operation which typically lasts for one or two weeks.

Aeration typically reduces stored grain temperatures by more than 10°C during summer which significantly reduces the threat of a serious insect infestation. Producers in the Darling Downs and northern New South Wales regions should achieve grain temperatures in storage of 20–23°C during summer storage and less than 15°C in winter. [13]

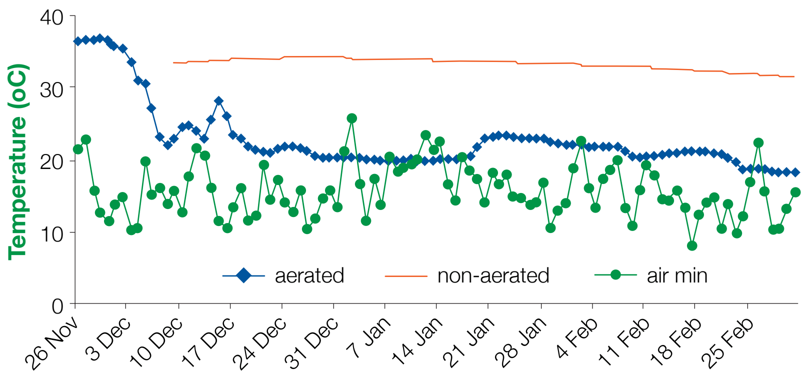

Figure 9: Comparison of wheat grain temperatures in aerated and non-aerated silos

As soon as grain is harvested and put in storage, run the aeration system 24 hours per day for the first 5 days to reduce grain temperatures and produce uniform moisture conditions in the grain bulk. Without aeration, grain holds it heat as it is an effective insulator and will maintain its warm harvest temperature for a long time (Figure 9). Wheat at typical harvest temperatures of 28–35°C and moisture content greater than 13–14% provides ideal conditions for mould and insect growth (Table 3). [14]

[13] P Burrill (2013) Grain Storage Future pest control options and storage systems 2013–2014. GRDC Update, July 2013.

[14] :P Burrill, P Botta, C Newman, B White, C Warrick (2013) Dealing with high-moisture grain. GRDC Grain Storage Fact Sheet, June 2013.

More information

http://storedgrain.com.au/wp-content/uploads/2013/07/GSFS-1A_GSPestControl_NS_2013_LR_Final.pdf

Table 3: The effect of grain temperature on insects and mould

Grain temperature (°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 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)

Although adult insects can still survive at low temperatures, most storage pests' life cycle stages are very slow or stopped at temperatures below 18–20°C. One of the more cold tolerate pests, the common rice weevil, does not increase its population with grain temperatures below 15°C. Insect pest lifecycles (egg, larvae, pupae and adult) are lengthened from the typical 4 weeks at warm temperatures (30–35°C) to 12–17 weeks at cooler temperatures (20–23°C).

Research also shows that wheat at 12% moisture content stored for 6 months at 30–35°C (unaerated grain temperature) will have reduced germination percentage and seedling vigour.

A national upper limit for moisture of 12.5% applies to wheat at receival, but deliveries are usually in the range 10.5–11%. [15] Special measures must be taken to minimise the risk of insect infestations or heat damage if the wheat is harvested in damp conditions.

Research by the NSW Department of Primary Industries has shown that grain temperature should be kept below 15°C to protect seed quality and stop all major insect infestations, and aeration slows the rate of deterioration of seed if the moisture content is kept at 12.5–14%. [16]

A trial by DAFF Queensland revealed that high-moisture grain generates heat when put into a confined storage, such as a silo. Wheat with 16.5% moisture content at a temperature of 28°C was put into a silo with no aeration. Within hours, the grain temperature reached 39°C and within 2 days reached 46°C, providing ideal conditions for mould growth and grain damage (Figure 10). [17]

15 Wheat Quality Objectives Group (2009) Understanding Australian wheat quality. GRDC, http://www.grdc.com.au/~/media/6F94BAEDAAED4E66B02AC992C70EB776.pdf

16 NSW Department of Primary Industries District Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

17 P Burrill, P Botta, C Newman, B White, C Warrick (2013) Dealing with high-moisture grain. GRDC Grain Storage Fact Sheet, June 2013.

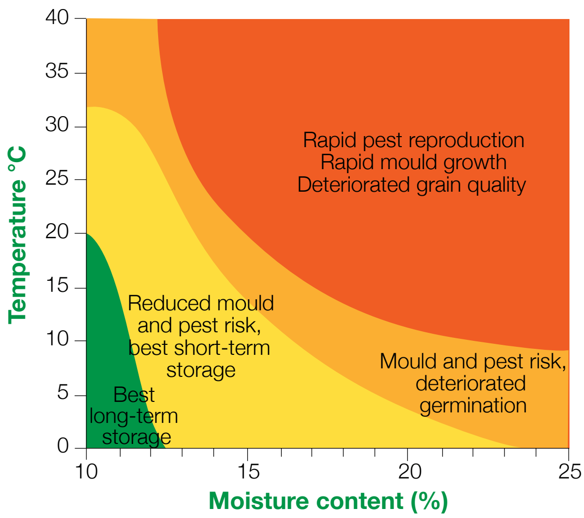

Figure 10: Effects of temperature and moisture on stored grain.

(Source: CSIRO Ecosystems sciences as published in http://www.grdc.com.au/~/media/36D51B725EF44EC892BCD3C0A9F4602C.pdf)

If use of a grain dryer is not an option, grain that is over the standard safe storage moisture content of 12% and up to the moderate moisture level of 15% can be managed by aerating until drying equipment is available. Blending with low-moisture grain and aerating is also a commonly used strategy (Figure 11).

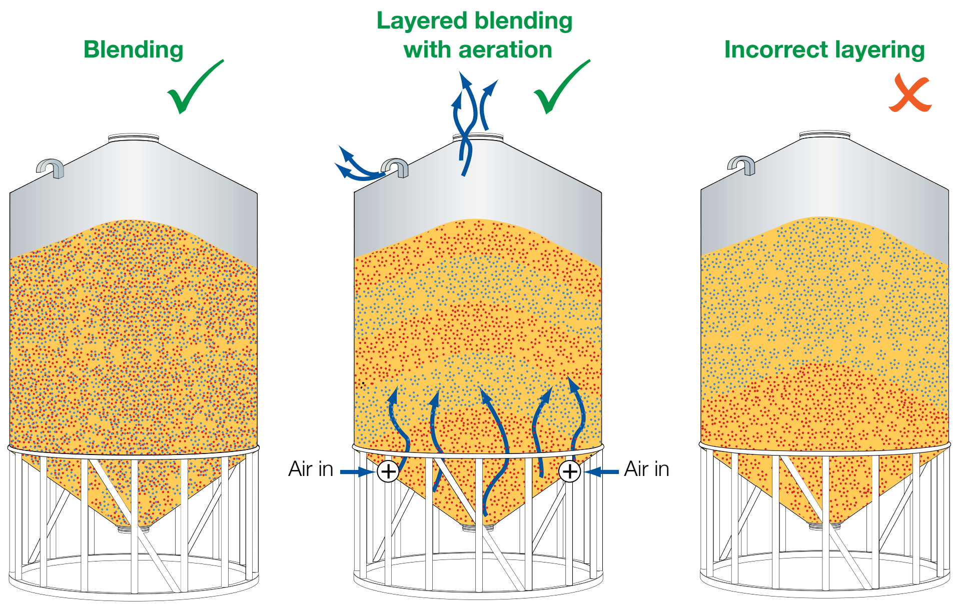

Figure 11: Correct blending. (Source: Kondinin Group)

Aeration drying forces large volumes of air through the grain in storage and slowly removes moisture. Supplementary heating can be added when ambient conditions typically have high humidity. Aeration drying can be done in a purpose-built drying silo or a partly filled silo with high-capacity aeration fans.

Dedicated driers can be used to dry wheat in batches or with continuous-flow, before it is put into silos, but excessive heat applied post-harvest can reduce the quality of milling wheat.

A wet harvest or damp conditions can make drying prior to storage a necessity. These rules will help you to decide whether it is safe to store your wheat without drying:

More information

GRDC Fact Sheet, 'Dealing with high-moisture grain' from: http://www.grdc.com.au/~/media/36D51B725EF44EC892BCD3C0A9F4602C.pdf

- Wheat that does not exceed the maximum moisture level of 12.5% can be aeration cooled without drying to slow insect development and maintain quality during storage.
- Grain of up to 15% moisture can be safely held under continuous aeration for a number of weeks until a hot air drier or an aeration drying process can take place to reduce the moisture for safe longer term storage. Blending with dry grain and aerating may also be feasible.
- Grain of more than 15% moisture should be dried to a safe storage moisture immediately, then held under normal aeration cooling for maintenance.

13.5 Monitoring wheat

Growers are advised to monitor all grain in storage at least monthly. During warm periods in summer, if grain moisture content is near the upper end of the safe storage moisture content, monitoring every two weeks is advisable. Insect pests present in the on-farm storage environment must be identified so growers can exploit the best use of both chemical and/or non-chemical control measures to control them.

Wheat for domestic or export use must not contain live storage pests, and feed grades can lose nutritional value and palatability through infestations. Keeping storage pests out of planting seed grain is also important because they can reduce the germination and vigour quality of seed with serious consequences for the next wheat crop.

When monitoring stored grain through sieving, trapping and quality inspections, growers should keep records of findings. If possible, grain temperature should also be checked regularly. Any grain treatments applied need to be recorded. [18]

Figure 12: Keep records of findings from stored grain insect monitoring. (Source: QDAFF)

The lesser grain borer and rust-red flour beetle are some of the most common insect pests found in stored cereals. Other common species to watch for include weevils (*Sitophilus* spp.), the saw-toothed grain beetle (*Oryzaephilus* spp.), flat grain beetles and rusty grain beetle (*Cryptolestes* spp.), psocids (booklice) Indian meal moth (*Plodia*

[18] P Burrill, P Botta, C Newman (2010) Aeration cooling for pest control. GRDC Grain Storage Fact Sheet, September 2010.

interpunctella) and Angoumois grain moth (*Sitotroga cerealella*). Another dozen or so beetles, and mites are sometimes present as pests in stored cereal grain.

Photographs and descriptions of these pests can be found in the GRDC Grain Storage Fact Sheet entitled 'Northern and southern regions stored grain pests—Identification'. Or, GRDC "Stored grain pest identification – The Back Pocket Guide". Download it from: http://storedgrain.com.au/northern-southern-regions-grain-storage-pest-control-guide/ or http://www.grdc.com.au/GRDC-FS-StoredGrainPestID

This Fact Sheet also outlines how to monitor stored grain for infestations. Here are some basic points to follow when monitoring for insect pests in your grain:

- Sample and sieve grain from the top and bottom of grain storages every month (4 weeks) for early pest detection. Pitfall traps installed in the top of the grain store will also help early detection of storage pests.
- Holding an insect sieve in the sunlight will encourage insect movement, making pests easier to see. Sieve samples on to a white tray, again to make small insects easier to see. Sieves should have 2 mm mesh and need to hold at least 1 L of grain.
- To help identify live grain pests, place them into a clean glass container. Briefly warm the jar in the sun to encourage insect activity. Weevils and saw-toothed grain beetles can walk up the walls of the glass easily, but flour beetles and lesser grain borer cannot. Look closely at the insects walking up the glass—weevils have a curved snout at the front and saw-toothed grain beetles do not. [19]

Recent research in southern and central Queensland has shown that industry may need to consider an area-wide approach to pest and resistance management. The research indicates flight dispersal by the lesser grain borer and the rust-red flour beetle, both of which are major insect pests of stored grain. The research involved setting beetle traps along a 30-km transect in the Emerald district and showed that the lesser grain borer flies all year round in Central Queensland, whereas the flour beetle appeared to be located mainly around storages during the winter months, spreading into the surrounding district in summer. This study highlights the importance of finding and dealing with infestations to limit the number of pests that can infest clean grain. In another study, beetles were found to be flying between farms on a scale of at least 100 km. [20]

NOTE: Exotic pests including Karnal bunt (*Tilletia indica*) and Khapra beetle (*Trogoderma granarium*) are a threat to the Australian grains industry—report sightings immediately.

More information

http://storedgrain.com.au/northern-southern-regions-grain-storage-pest-control-guide/

http://www.grdc.com.au/GRDC-FS-StoredGrainPestID

[19] P Burrill, P Botta, C Newman, B White, C Warrick (2013) Northern and southern regions stored grain pests—Identification. Grain Storage Fact Sheet, June 2013.

[20] G Daglish, A Ridley (2012) Stored grain insects: How they spread and implications for resistance. GRDC Research Update Northern Region, Spring 2012, Issue 66.

SECTION 14

Environmental issues

More information

[B Zheng, S Chapman, J Christopher, T Frederiks, K Chenu (2015), Predicting heading date and frost impact in wheat across Australia.]

[K Barlow, B Christy, G O'Leary, J Nuttall (2015), Modelling the impact of frost on wheat production in Australia.]

14.1 Frost resistance in cereals after head emergence

Spring radiant frost damage to cereals post head-emergence causes significant crop losses in Australia and internationally. The problem arises in areas where the heat and drought of summer restrict the cropping season to winter and spring. Typically, during the growing season, daytime temperatures are ideal for growth but night-time temperatures can fall to potentially damaging levels. Wheat can be affected when the canopy air temperature reaches -3.5°C (D Woodruff unpublished data), with damage increasing as the temperature falls further. Barley is generally considered more resistant than wheat, whereas triticale appears less tolerant.

To lower the risk of frost damage, winter cereals are planted 'late' so that heading and grain development occur when warmer temperatures prevail. Unfortunately, this delay increases the likelihood of drought and high temperatures during grain-filling, dramatically reducing yield potential. Yield declines of as much as 16% for each week that flowering is delayed past the optimum time have been reported. Optimum flowering time and maximised yields are achieved, in the long term, when a compromise between the effects of frost and drought is reached.

On nights when still, cold air, clear skies and low humidity combine, temperatures drop rapidly, resulting in radiant frost. Freezing of crops is a physical process moderated by factors such as plant development stage and temperature. The crop temperatures experienced and recorded can vary widely due to differences in topography, micro-environment and recording method. To assist with early assessment of frost damage, accurate maximum–minimum field thermometers measuring temperatures at crop head height are useful. Minimum air temperatures measured at crop head height can be several degrees colder than temperatures measured in the Stevenson screen, as reported by the Bureau of Meteorology. For best results, at least two or three field thermometers are required to give representative temperatures throughout a crop. In undulating country, more thermometers should be used at various heights in the landscape (Woodruff *et al.* 1997). [1]

[1] T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

14.1.1 Effect of frost damage on different growth stages—better field identification of frost damage

Young crops

Major economic damage prior to stem elongation is uncommon. Young crops will usually regrow from damage, particularly if good follow-up rain is received [2]. Rarely, very severe frosts (lower than -7°C canopy air temperature) may result in damage to the developing crown of the plant. [3]

Advanced crops—not showing ears or awns

In addition to leaf and stem damage, booting crops can experience damage to developing ears. This damage usually shows as bleached sections with incomplete ear structures (Figure 1). [4]

Figure 1: Frost damage prior to head-emergence.

2 M Afanasev 1966. Frost injury in wheat. Plant Disease Reporter 50, 929–930

3 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

4 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

Advanced crops—ears or awns visible

During and after ear emergence, the plant becomes much more susceptible to frost injury. In wheat, the breaking of the boot is critical for heads to become fully susceptible to frost. Frost damage after head-emergence often results in severe stem and head damage, and frequently occurs at milder temperatures. Damage is most easily identified in the 30 mm of stem above the top node. Damaged stem tissue develops a water-soaked, dark green colour, later shrivelling, drying out and bleaching. If this happens, connection between the head and the rest of the plant is severed, and the head dies [5] (Figure 2).

Figure 2: Stem frosting (Woodruff et al. 1997).

Frosting of developing grain, after flowering, is difficult to assess. Damaged grain may continue to swell, and to all outward appearances seem relatively 'normal'. However, these damaged grains eventually dry back to shrivelled (potentially) harvestable grains, which may cause down grading (Figure 3). To assess this damage, 7–14 days after a frost look for discoloured, shrunken, water-soaked or hollow grains that, when squeezed, exude a straw-coloured transparent, rather than milky, opaque liquid. [6]

Figure 3: Effect on developing grains of a severe –5.5°C frost 2 weeks after flowering.

More information

GRDC Update Paper: http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

5 M Afanasev 1966. Frost injury in wheat. Plant Disease Reporter 50, 929–930

6 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

14.1.2 Field screening—varietal differences

Elite varieties with improved frost resistance would have a major impact on cropping in the northern grains region, by reducing yield losses to frosts, and/or by allowing earlier flowering and higher yield potential. The aim of this research is to identify useful sources of post head-emergence frost resistance in winter cereals. Winter cereals are being screened using two strategies:

1. Small-scale nationally coordinated frost trials
2. Screening diverse winter cereals for potential sources of improved post head-emergence frost resistance [7]

Trials by the (former) Department of *Employment, Economic Development and Innovation* Queensland (DEEDI) provide a focus on screening methods and aim to:

- provide a framework to allow results to be compared between regions
- compare a small number of promising barley lines with wheat and barley controls
- use standardised meteorological stations at each site to characterise frost events

Results:

- Ten lines, very closely matched in flowering date, are tested at each site each year.
- There is little evidence that any line consistently outperforms controls. [8]

In addition to small-scale national trials, diverse wheat and barley types are being screened. Testing in the field is labour-intensive and expensive; however, the reliability of screening in artificial freezing chambers is yet to be demonstrated. A field screening method has been refined and developed over more than four decades of frost research. Using this method, diverse wheat and barley lines are being assessed, with the aim of identifying new sources of resistance.

Screening results:

- Screening methodologies are key to maximising research effort—a rigorous screening method is required that minimises frost escapes and false positives.
- The method allows lines with different flowering habit (phenology) to be compared following a single frost event, enabling diverse sources for resistance to be screened.
- To date, no tested line significantly outperformed controls.

As no lines with useful levels of resistance have so far been identified, additional genotypes are being evaluated. [9]

7 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

8 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

9 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

14.1.3 The need for a better understanding—how and when plants freeze

Given that identifying winter cereals with improved frost resistance has proven difficult, a more fundamental approach may be needed to improve understanding of frost and frost damage.

Frost-sensitive plants, although not damaged by cold temperatures alone, show freezing damage when ice formation occurs in the tissues. These plants can supercool (without ice formation) below 0°C and avoid damage. As this supercooled water in plants freezes, a small amount of heat is released. This heat can be detected using infrared imaging and used to observe ice formation. Infrared thermal imaging was successfully used to observe freezing in wheat under field conditions (Figure 4). It is hoped that with a better understanding of how and when plants freeze, better strategies or varieties to minimise frost damage can be identified. [10]

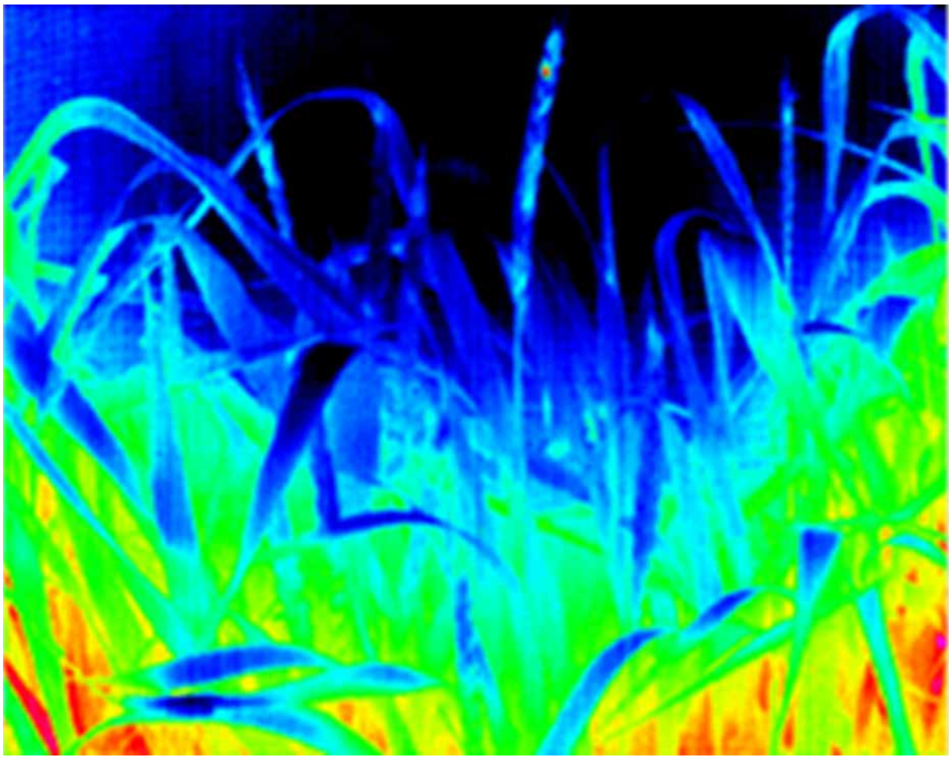

Figure 4: Artificially coloured infrared image (coldest dark blue, through blue, green, yellow, and red for warmest), 16 July 2010, showing an individual wheat floret freezing.

14.2 Waterlogging/flooding issues

14.2.1 Winter cereals pathology

Three drivers influence the incidence of plant disease:

- the host
- the environment
- the pathogen

Aspects of the host promoting disease are the growing of susceptible crop varieties, and widespread and sequential sowings of hosts susceptible to specific pathogens.

[10] T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

The environment influences disease incidence through moisture, both the frequency and duration of events, temperature and wind.

For disease to occur, the pathogen must have virulence to the particular variety, inoculum must be available and easily transported, and favourable conditions are needed for infection and disease development. [11]

Legacy of the floods and rain

The legacy of the floods and rain included transport of inoculum (crown rot, nematodes, leaf spots through movement of infected stubble and soil), development of sexual stages (leaf spots, head blights), survival of volunteers (unharvested material and self-sown plants in double-crop situations) and weather-damaged seed. Cereal diseases that need living plants over-season on volunteer (self-sown) crops; this particularly applies to rusts and mildews. Diseases such as yellow spot, net blotches and head blights survive on stubble. Crown rot and nematodes over-season in soil.

Problems are recognised through inspection of plants. Leaf and stem rusts produce visible pustules on leaves, while stripe rust survives as dormant mycelium with spores not being produced until temperatures favour disease development. Presence of leaf spots is recognised by the presence of fruiting bodies (pseudothecia) on straw and lesions on volunteers. Head blights produce fruiting bodies (perithecia) on straw, whereas crown rot survives mainly as mycelium in straw. Soil-borne nematodes are detected through soil tests.[12]

Management options

Management options for disease control include elimination of volunteers, if possible producing a 4-week period that is totally host-free, crop rotation with non-hosts, growing resistant varieties, reduction of stubble, and fungicides.

Fungicides are far more effective as protectants than as eradicants, so are best applied prior to, or very soon after, infection. Systemic fungicides work within the sprayed leaf, providing 3–5 weeks of protection. Leaves produced after this spraying are not protected. Spray to protect the upper three or four leaves, which are the most important as they contribute to grain-fill. In general, rusts are easier to control than leaf spots. Fungicides do not make yield; they can only protect the existing yield potential.

The application of fungicides is an economic decision, and in many cases, a higher application rate can give a better economic return through greater yield and higher grain quality. Timing and rate of application are more important than product selection. Bear in mind that stripe rust ratings in variety guides are for adult plant response to the pathogen, and may not accurately reflect seedling response. [13]

Strategies

The incidence and severity of disease will depend on the environment, but with known plentiful inoculum present, even in a season with average weather, disease risks will be significant.

Strategies include:

- using the best available seed
- identifying your risks
- formulating management strategies based on perceived risk

[11] DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology

[12] DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology

[13] DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology

- monitoring crops regularly
- timely intervention with fungicides [14]

14.2.2 Nutritional and structural impact of flooding on soil

A temporary loss of soil structure prevents clay particles from aggregating and forming channels for water infiltration, so despite flooding, some soil moisture profiles are not full as might be expected. This reduction in infiltration is also affected by which crop was grown most recently, with persistent roots forming channels in the soil, aiding water entry. Cultivation, either prior to or during planting of the next crop, will help break up surface crusting.

Flooding has also affected nutrient levels. Flooding and long periods of waterlogging have resulted in the depletion of nutrients. Nitrogen (N) levels are very low in many soils tested. Soil testing has shown that N has been lost throughout the entire soil profile in many cases. It appears to have been denitrified and lost from the system. Very little has been leached through the profile and deposited at depth. [15]

Implications for following seasons

The implications for the coming season are that it is not a typical season in which growers could use historical information, cropping history and experience to develop fertiliser programs. Soil testing will be a very important management tool this season to ensure that crop nutritional demands are adequately met. Crops will also need to be monitored through the production period for signs of nutrient stress. [16]

Soil testing

Ideally, soil testing should be performed at the same place each time, and on the dominant soil type of the paddock. In most years, this information, combined with yield and protein levels, will guide N requirements, but the coming year is very different. Placement of N fertiliser is important, with application on alternate rows close to planting time being a good option. [17]

14.2.3 Soil erosion and waterlogging due to flooding

According to satellite images, over 100,000 ha of land was inundated from the Condamine River due to flooding in early 2011. The river was 7 km wide at the widest point. There has been significant damage on riverbanks as a result, but in general perhaps less erosion than might be expected. This is probably due to:

- increased use of no-till and summer cropping
- wet conditions leading up to the major flood event, resulting in green cover
- the protective effects of 'failed', unharvested winter crops

In some cases, contour banks were poorly maintained due to years of drought conditions.[18]

[14] DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology

[15] DAFF (2013) Nutritional and structural impact of flooding on soil. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/nutritional-and-structural-impact-of-flooding-on-soil

[16] DAFF (2013) Nutritional and structural impact of flooding on soil. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/nutritional-and-structural-impact-of-flooding-on-soil

[17] DAFF (2013) Nutritional and structural impact of flooding on soil. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/nutritional-and-structural-impact-of-flooding-on-soil

[18] DAFF (2013) Soil erosion and waterlogging due to flooding. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/soil-erosion-and-waterlogging-due-to-flooding

Preventing future damage

A number of approaches can be used to prevent damage in the future. Contours running down a hill generally spread the flow of water and reduce flow rates, although with the intensity of the flooding this year, that was not always the case. Wheel tracks can be used like raised beds to assist drainage. These wheel tracks need to be maintained and managed for effectiveness. Wide tyres for spraying and tracks for harvesters and tractors are options to reduce compaction.

14.2.4 Weed management following floods

Floodwater affects soil, stubble/trash, weed seed and plant movement. Differences may have been seen between conventional and minimum tillage farming systems due to differences in ground cover, soil type and, ultimately, intensity of floodwater. Because of flooding, growers might expect to see new weed incursions and removal of topsoil.

New weeds could be species not previously seen on a property, or new species in specific fields from other fields or non-cultivated areas. There is also the potential for the introduction and movement of herbicide-resistant weeds. The removal of topsoil could lead to the exposure of previously buried seed and, hence, the resurrection of buried problems. It is hard to predict where weed seeds will settle, but a concentration is likely where water and trash have settled. [19]

Potential problem weeds

A number of specific weed species are likely to be a problem in some areas. Potential problem winter weeds include fleabane and sowthistle, which may have been seeding at the time of the floods and may be establishing now.

Potential problem winter grasses include wild oats and paradoxa grass, which may have set seed prior to floods and may be buried in soil. Winter hard-seeded broadleaf species such as buckwheat that may have previously been buried may now be exposed.

Potential problem summer weeds also include fleabane and sowthistle, which in recent years have become nearly year-round problems.

Problem summer grasses (e.g. awnless barnyard grass and feathertop Rhodes grass) were likely to have been seeding at the time of the floods and existing seed may have moved. Hard-seeded summer broadleaves include bladder ketmia, peachvine and bindweed, and previously buried seed may now be exposed.

Species of weeds in which herbicide resistance has been identified in the northern agricultural region include wild oats, sowthistle, fleabane, barnyard grass and liverseed grass. The problem is not currently widespread. [20]

Implications for the coming season

The implication for the coming season is that integrated weed management principles still apply. These principles include diligent monitoring, targeting small weeds with robust rates of herbicide, rotating herbicides with different modes of action, and preventing seed-set and seed-bank replenishment. This approach will prevent herbicide resistance from becoming a problem.

For cropping, aim for a clean start with effective knockdown control (e.g. using a 'double-knock' strategy). Use residual herbicides to minimise in-crop weed emergences. To control weeds in-crop, grow a competitive crop and use correct application and timing of in-crop herbicides. Stop seed-set on survivors after harvest.

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19 DAFF (2011) Weed management following floods. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/weed-management-following-floods

20 DAFF (2011) Weed management following floods. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/weed-management-following-floods

More information

Weed management in field crops for information about managing summer grasses, managing fleabane and sowthistle, and herbicide resistance: http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops

More information

J Watson, B Zheng, S Chapman, K Chenu (2015), Impact of projected climates on drought occurrence in the Australian wheatbelt.

In fallows, weed seedlings should be effectively controlled with robust herbicide rates and/or a double-knock strategy. An early application of a residual herbicide will minimise subsequent flushes. Be diligent in control of survivors of herbicide applications.

In non-crop areas, seed may have been captured around fence lines and sheds and these may become sources of ongoing infections. Monitor these areas and stop seed set. [21]

14.3 Heat stress

Heat is a key abiotic stress. The effects of heat on grain yield are equally as important as drought and frost. Varieties that are better adapted also generally perform better in heat-stress conditions.

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 grain yield of wheat can occur for every 1°C increase in average temperature above 15°C. Field data suggest 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.

The reproductive stages of growth have greater sensitivity to elevated temperatures, with physiological responses including premature leaf senescence, reduced photosynthetic rate, reduced seed set, reduced duration of grain-fill, and reduced grain size, all ultimately leading to reduced grain yield. Such elevated temperatures are a normal, largely unavoidable occurrence during the reproductive phase of Australian crops in September and October. [22]

21 DAFF (2011) Weed management following floods. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/weed-management-following-floods

22 P Telfer, J Edwards, H Kuchel, J Reinheimer, D Bennett (2013) Heat stress tolerance of wheat. GRDC Update Papers 7 February 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Heat-stress-tolerance-of-wheat

SECTION 15

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.

GRAIN SELLING - Best practice in conversion of tonnes to dollars

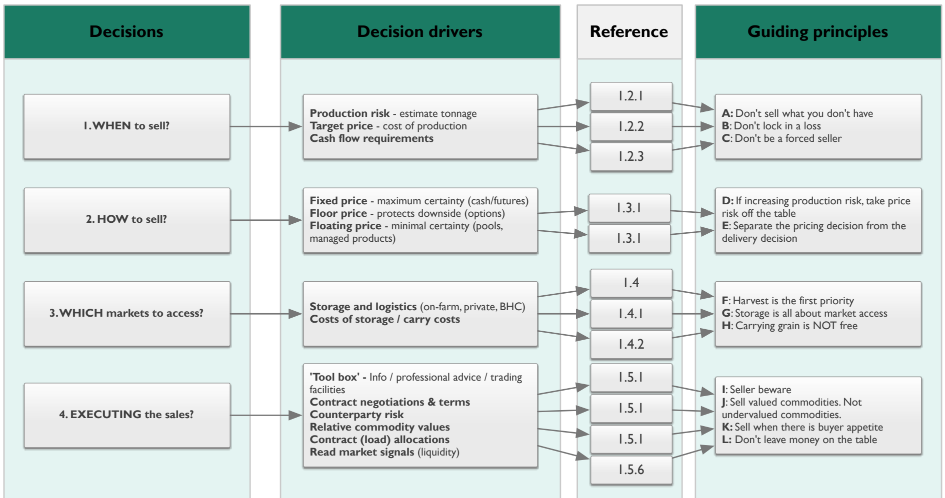
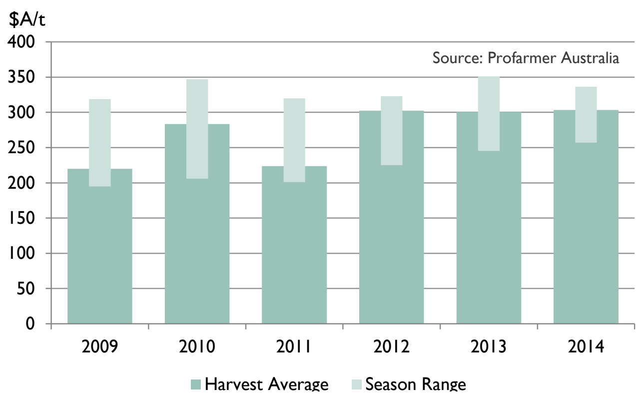


Figure 1: Grain selling flow chart.

Figure 1 shows a grain selling flow chart that summarises:

- The decisions to be made
- The drivers behind the decisions
- The guiding principles for each decision point

References are made to the section of the GrowNote you will find the detail.



Note to figure:
Newcastle APW1 wheat prices have varied A$70-$150/t over the past 6 years (25-60% variability). For a property producing 1,000 tonne of wheat this means $70,000-$150,000 difference in income depending on price management skill.

Figure 2: Selling principles.

15.1 Selling principles

The aim of a selling program is to achieve a profitable average price (the target price) across the entire business. This requires managing several unknowns to establish the target price and then work towards achieving that target price.

Unknowns include the amount of grain available to sell (production variability), the final cost of that production, and the future prices that may result. Australian farm gate prices are subject to volatility caused by a range of global factors that are beyond our control and difficult to predict.

The skills growers have developed to manage production unknowns can be used to manage pricing unknowns. This guide will help growers manage and overcome price uncertainty.

15.1.1 Be prepared

Being prepared and having a selling plan is essential for managing uncertainty. The steps involved are forming a selling strategy and a plan for effective execution of sales.

A selling strategy consists of when and how to sell.

When to sell

This requires an understanding of the farm's internal business factors including:

- production risk
- a target price based on cost of production and a desired profit margin
- business cash flow requirements

How to sell?

This is more dependent on external market factors including:

- time of year determines the pricing method
- market access determines where to sell
- relative value determines what to sell

The following diagram lists key selling principles when considering sales during the growing season.

Grower commodity selling principles timeline

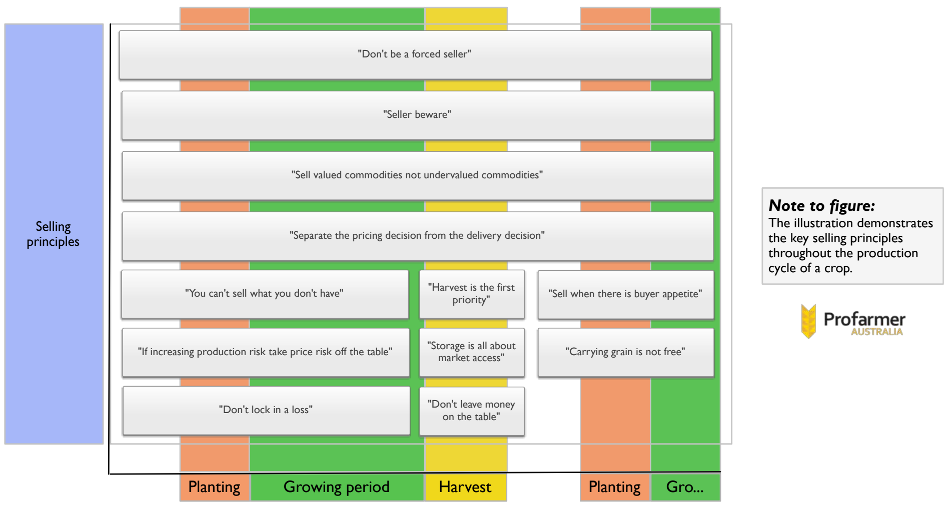


Figure 3: Grower commodity selling principles timeline.

15.1.2 Establish the business risk profile (when to sell?)

Establishing your business risk profile allows the development of target price ranges for each commodity and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify those risks during the production cycle are described below.

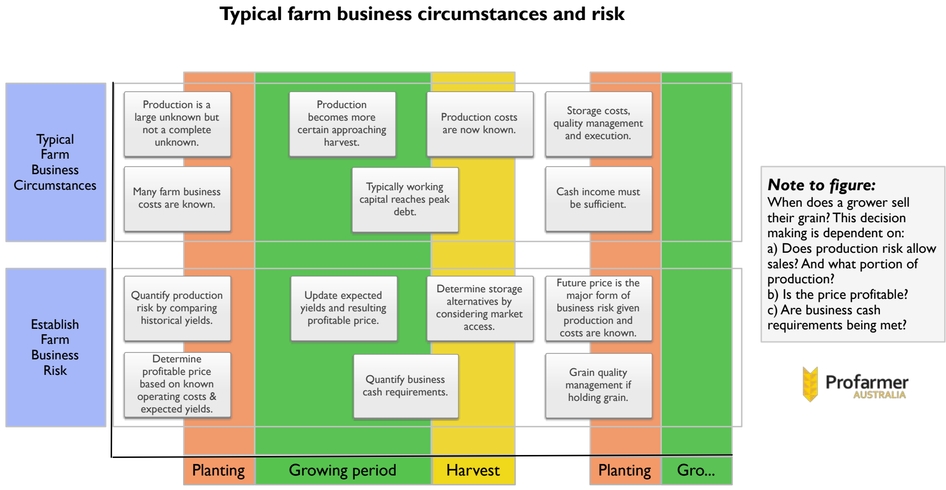


Figure 4: Typical farm business circumstances and risk.

Production risk profile of the farm

Production risk is the level of certainty around producing a crop and is influenced by location (climate and soil type), crop type, crop management, and time of the year.

Principle: "You can't sell what you don't have" – Don't increase business risk by over committing production.

Establish a production risk profile by:

1. Collating historical average yields for each crop type and a below average and above average range.
2. Assess the likelihood of achieving average based on recent seasonal conditions and seasonal outlook.
3. Revising production outlooks as the season progresses.

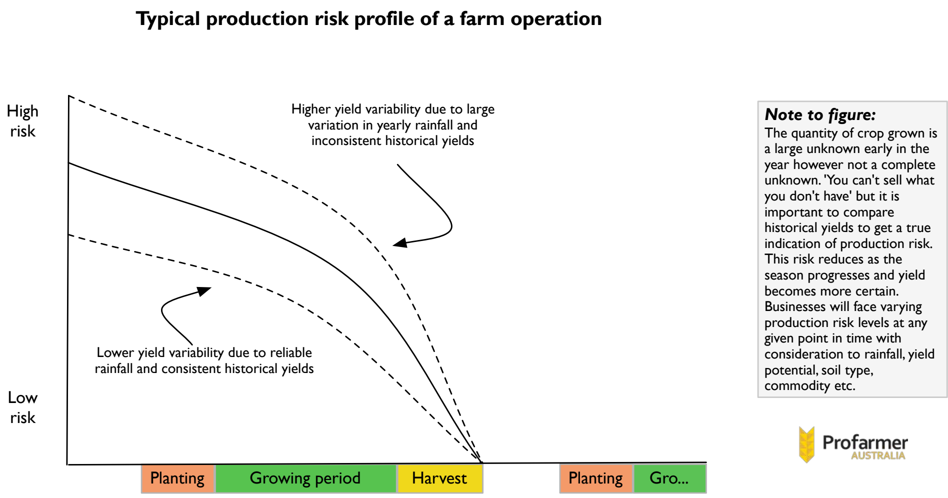


Figure 5: Typical risk profile of farm operation.

Farm costs in their entirety, variable and fixed costs (establishing a target price).

A profitable commodity target price is the cost of production per tonne plus a desired profit margin. It is essential to know the cost of production per tonne for the farm business.

Principle: "Don't lock in a loss" – If committing production ahead of harvest, ensure the price is profitable.

Steps to calculate an estimated profitable price based on total cost of production and a range of yield scenarios is provided below.

Estimating cost of production - Wheat	
Planted Area	1,200 ha
Estimate Yield	2.85 t/ha
Estimated Production	3,420 t
Fixed costs	
Insurance and General Expenses	$100,000
Finance	$80,000
Depreciation/Capital Replacement	$70,000
Drawings	$60,000
Other	$30,000
Variable costs	
Seed and sowing	$48,000
Fertiliser and application	$156,000
Herbicide and application	$78,000
Insect/fungicide and application	$36,000
Harvest costs	$48,000
Crop insurance	$18,000
Total fixed and variable costs	$724,000
Per Tonne Equivalent (Total costs + Estimated production)	$212 /t
Per tonne costs	
Levies	$3 /t
Cartage	$12 /t
Freight to Port	$22 /t
Total per tonne costs	$37 /t
Cost of production Port track equiv	$248.70
Target profit (ie 20%)	$50.00
Target price (port equiv)	**$298.70**

Step 1: Estimate your production potential. The more uncertain your production is, the more conservative the yield estimate should be. As yield falls, your cost of production per tonne will rise.

Step 2: Attribute your fixed farm business costs. In this instance if 1,200 ha reflects 1/3 of the farm enterprise, we have attributed 1/3 fixed costs. There are a number of methods for doing this (see M Krause "Farming your Business") but the most important thing is that in the end all costs are accounted for.

Step 3: Calculate all the variable costs attributed to producing that crop. This can also be expressed as $ per ha x planted area.

Step 4: Add together fixed and variable costs and divide by estimated production

Step 5: Add on the "per tonne" costs like levies and freight.

Step 6: Add the "per tonne" costs to the fixed and variable per tonne costs calculated at step 4.

Step 7: Add a desired profit margin to arrive at the port equivalent target profitable price.

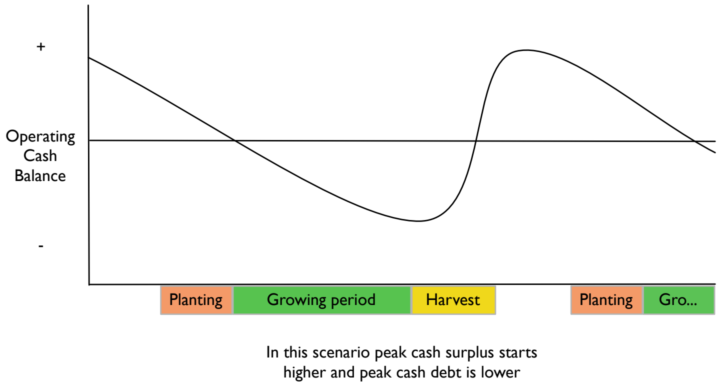
Figure 6: GRDC's Farming the Business Manual also provides a cost of production template and tips on grain selling vs grain marketing.

Income requirements

Understanding farm business cash-flow requirements and peak cash debt enables grain sales to be timed so that cash is available when required. This prevents having to sell grain below the target price to satisfy a need for cash.

Principle: "Don't be a forced seller" – Be ahead of cash requirements to avoid selling in unfavourable markets.

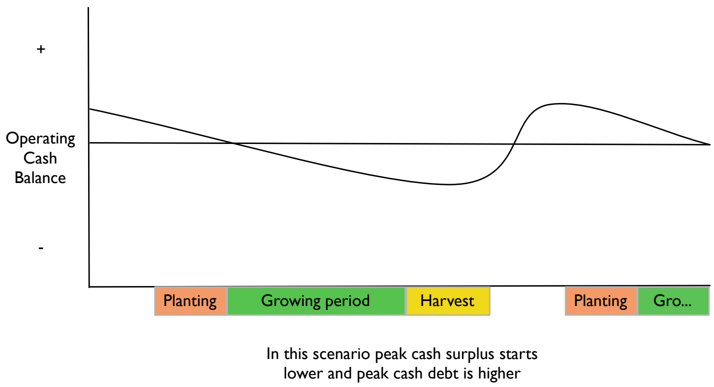
A typical cash-flow to grow a crop is illustrated below. Costs are incurred upfront and during the growing season with peak working capital debt incurred at or before harvest. This will vary depending on circumstance and enterprise mix. The second figure demonstrates how managing sales can change the farm's cash balance.



Note to figure: The chart illustrates the operating cash flow of a typical farm assuming a heavy reliance on cash sales at harvest. Costs are incurred during the season to grow the crop, resulting in peak operating debt levels at or near harvest. Hence at harvest there is often a cash injection required for the business. An effective marketing plan will ensure a grower is 'not a forced seller' in order to generate cash flow.

Profarmer AUSTRALIA

Figure 7: Typical operating cash balance (assuming harvest cash sales).



Note to figure: By spreading sales throughout the year a grower may not be as reliant on executing sales at harvest time in order to generate required cash flow for the business. This provides a greater ability to capture pricing opportunities in contrast to executing sales in order to fulfil cash requirements.

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Figure 8: Typical operating cash balance cash sales spread throughout the year).

When to sell revised

The “when to sell” steps above result in an estimated production tonnage and the risk associated with that tonnage, a target price range for each commodity, and the time of year when cash is most needed.

15.1.3 Managing your price (how to sell?)

The first part of the selling strategy answers the question “when to sell” and establishes comfort around selling a portion of the harvest.

The second part of the strategy addresses “how to sell”.

Methods of price management

Principle: “If increasing production risk, take price risk off the table” – When committing unknown production, price certainty should be achieved to avoid increasing overall business risk.

Table 1: Pricing products provide varying levels of price risk coverage.

	Description	Wheat	Barley	Canola	Oats	Lupins	Field peas	Chick peas
Fixed price products	Provides the most price certainty	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash	Cash	Cash	Cash
Floor price products	Limits price downside but provides exposure to future price upside	Options on futures, floor price pools	Options on futures	Options on futures	none	none	none	none
Floating price products	Subject to both price upside and downside	Pools	Pools	Pools	Pools	Pools	Pools	Pools

Principle: "Separate the pricing decision from the delivery decision" – Most commodities can be sold at any time with delivery timeframes negotiable, hence price management is not determined by delivery.

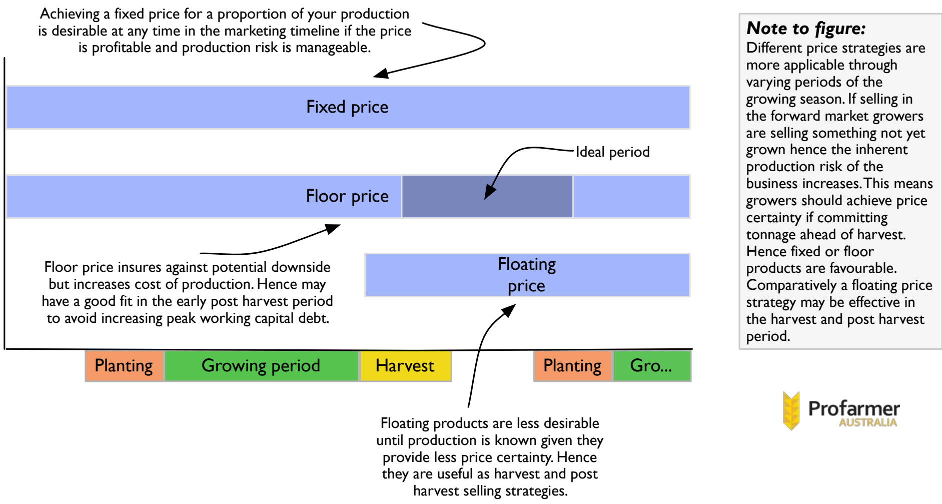


Figure 9: Summary of where different methods of price management are suited for the majority of farm businesses.

Fixed price

A fixed price is achieved via cash sales and/or selling a futures position (swaps).

It provides some certainty around expected revenue from a sale as the price is largely a known except when there is a floating component in the price. For example, a multi-grade cash contract with floating spreads or a floating basis component on futures positions.

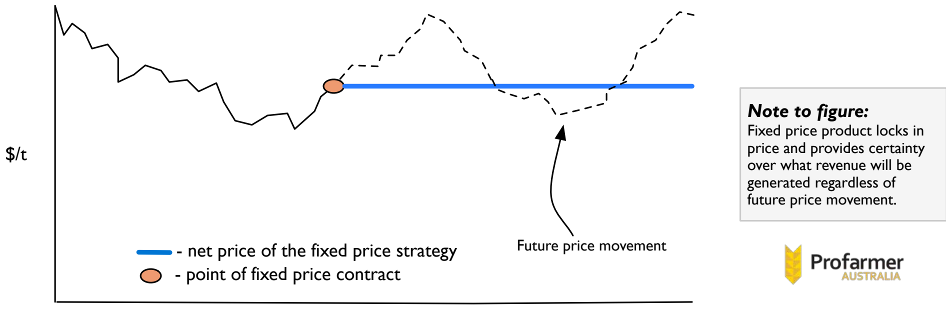


Figure 10: Fixed price strategy.

Floor price

Floor price strategies can be achieved by utilising “options” on a relevant futures exchange (if one exists), or via a managed sales program product by a third party (i.e. a pool with a defined floor price strategy). This pricing method protects against potential future downside whilst capturing any upside. The disadvantage is that the price ‘insurance’ has a cost which adds to the farm businesses cost of production.

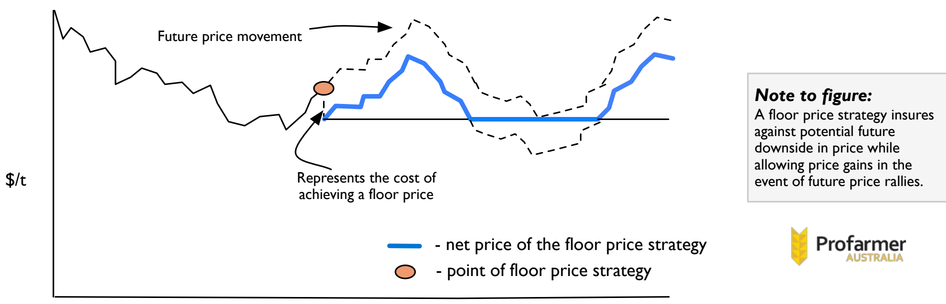


Figure 11: Floor price strategy.

3. Floating price

Many of the pools or managed sales programs are a floating price where the net price received will move both up and down with the future movement in price. Floating price products provide the least price certainty and are best suited for use at or after harvest rather than pre harvest.

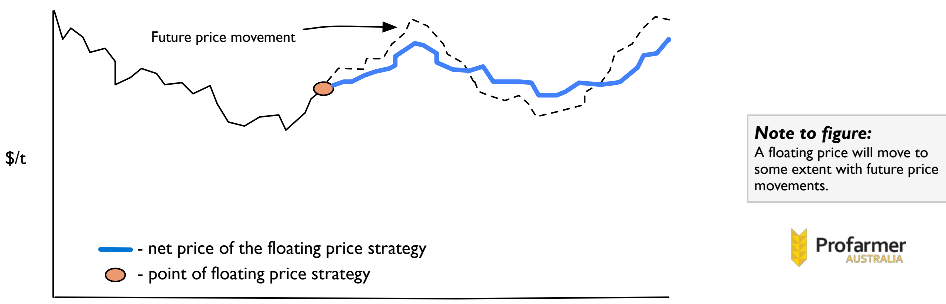


Figure 12: Floating price strategy.

How to sell revised

Fixed price strategies include physical cash sales or futures products and provide the most price certainty but production risk must be considered.

Floor price strategies include options or floor price pools. They provide a minimum price with upside potential and rely less on production certainty but cost more.

Floating price strategies provide minimal price certainty and are best used after harvest.

15.1.4 Ensuring access to markets

Once the selling strategy of when and how to sell is sorted, planning moves to storage and delivery of commodities to ensure timely access to markets and execution of sales. At some point growers need to deliver the commodity to market. Hence planning on where to store the commodity is important in ensuring access to the market that is likely to yield the highest return.

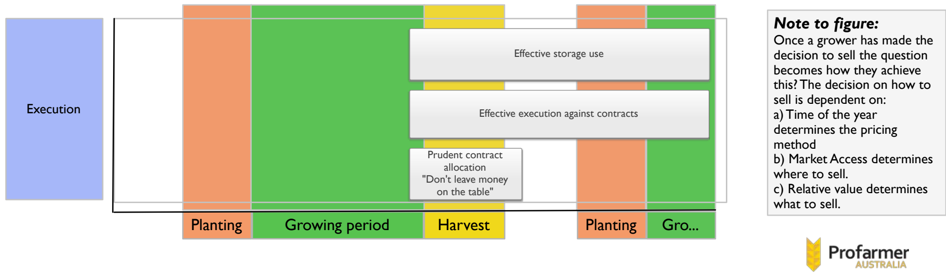


Figure 13: Effective storage decisions.

Storage and Logistics

Return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access to maximise returns as well as harvest logistics.

Storage alternatives include variations around the bulk handling system, private off farm storage, and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity.

Principle: "Harvest is the first priority" – Getting the crop in the bin is most critical to business success during harvest, hence selling should be planned to allow focus on harvest.

Bulk Export commodities requiring significant quality management are best suited to the bulk handling system. Commodities destined for the domestic end user market, (e.g feed lot, processor, or container packer), may be more suited to on-farm or private storage to increase delivery flexibility.

Storing commodities on-farm requires prudent quality management to ensure delivery at agreed specifications and can expose the business to high risk if this aspect is not well planned. Penalties for out-of-specification grain on arrival at a buyer's weighbridge can be expensive. The buyer has no obligation to accept delivery of an out-of-specification load. This means the grower may have to incur the cost of taking the load elsewhere whilst also potentially finding a new buyer. Hence there is potential for a distressed sale which can be costly.

On-farm storage also requires prudent delivery management to ensure commodities are received by the buyer on time with appropriate weighbridge and sampling tickets.

Principle: "Storage is all about market access" – Storage decisions depend on quality management and expected markets.

References:

For more information on on-farm storage alternatives and economics refer Section 13 Grain Storage.

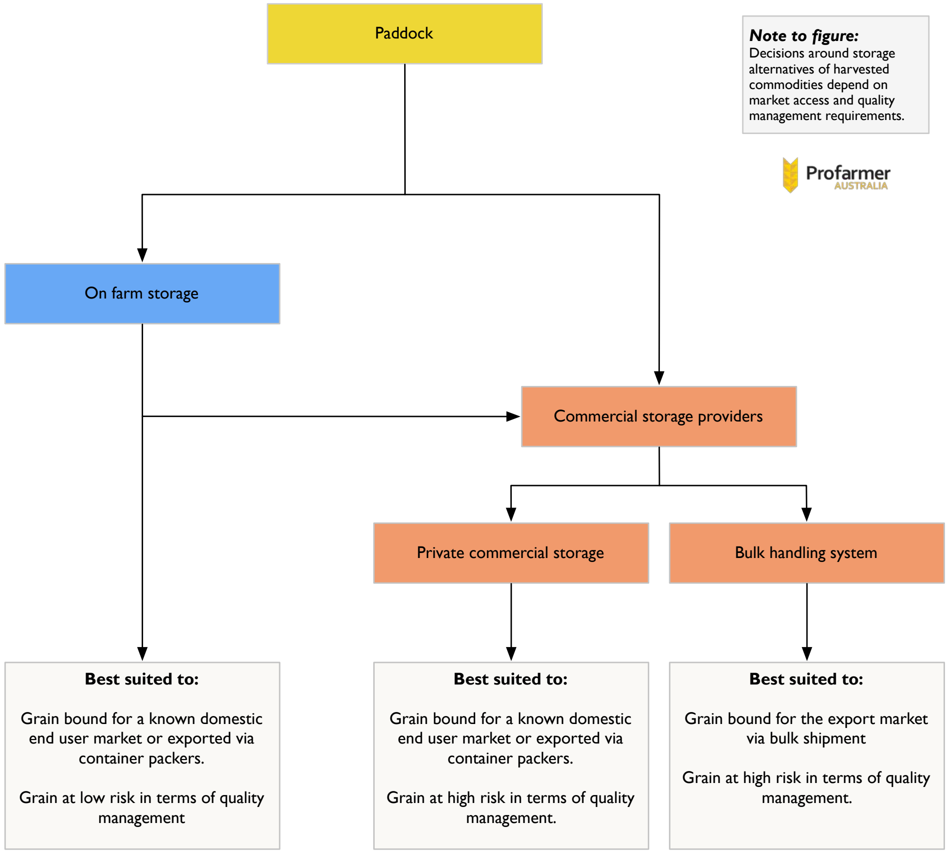


Figure 14: Grain storage decision-making.

Cost of carrying grain

Storing grain to access sales opportunities post-harvest invokes a cost to “carry” grain. Price targets for carried grain need to account for the cost of carry.

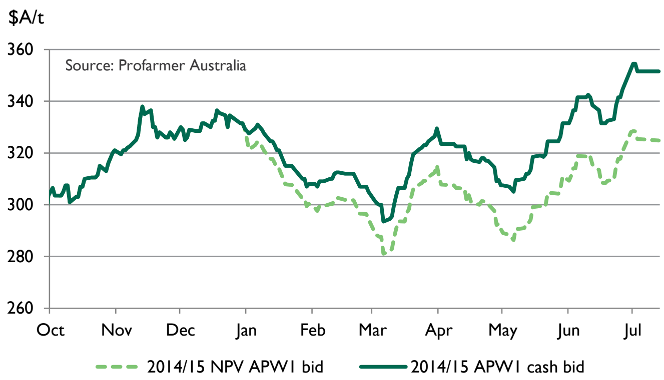
Carry costs are typically $3-4/t per month consisting of:

- monthly storage fee charged by a commercial provider (typically ~$1.50-2.00/t per month)
- the interest associated with having wealth tied up in grain rather than cash or against debt (~$1.50-$2.00/t per month depending on the price of the commodity and interest rates

The price of carried grain therefore needs to be $3-4/t per month higher than what was offered at harvest.

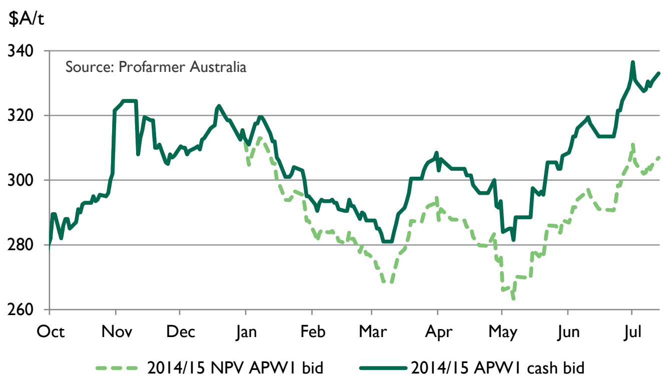
The cost of carry applies to storing grain on farm as there is a cost of capital invested in the farm storage plus the interest component. $3-4/t per month is a reasonable assumption for on farm storage.

Principle: “Carrying grain is not free” – The cost of carrying grain needs to be accounted for if holding grain and selling it after harvest is part of the selling strategy.



Note to figure:
If selling a cash contract with deferred delivery, a carry charge can be negotiated into the contract. For example in the case of a March sale of APW1 wheat for March-June delivery on buyers call at $300/t + $3/t carry per month, if delivered in June would generate $309/t delivered.

Figure 15: Brisbane APW2 cash vs NPV.



Note to figure:
If selling a cash contract with deferred delivery, a carry charge can be negotiated into the contract. For example in the case of a March sale of APW1 wheat for March-June delivery on buyers call at $300/t + $3/t carry per month, if delivered in June would generate $309/t delivered.

Figure 16: Newcastle AWPI cash vs NPV.

15.1.5 Ensuring market access revised

Optimising farm gate returns involves planning the appropriate storage strategy for each commodity to improve market access and cover carry costs in pricing decisions.

15.1.6 Executing tonnes into cash

This section provides guidelines for converting the selling and storage strategy into cash by effective execution of sales.

Set-up the tool box

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox includes:

1. Timely information

This is critical for awareness of selling opportunities and includes:

- market information provided by independent parties
- effective price discovery including indicative bids, firm bids, and trade prices
- other market information pertinent to the particular commodity.

2. Professional services

Grain selling professional service offerings and cost structures vary considerably. An effective grain selling professional will put their clients' best interest first by not having conflicts of interest and investing time in the relationship. Return on investment for the farm business through improved farm gate prices is obtained by accessing timely information, greater market knowledge and greater market access from the professional service.

3. Futures account and bank swap facility

These accounts provide access to global futures markets. Hedging futures markets is not for everyone however strategies which utilise exchanges such as CBOT can add significant value.

References:

The link below provides current financial members of Grain Trade Australia including buyers, independent information providers, brokers, agents, and banks providing over-the-counter grain derivative products (swaps).

http://www.graintrade.org.au/membership

The link below provides a list of commodity futures brokers.

http://www.asx.com.au/prices/find-a-futures-broker.htm

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 a level of risk management:

- Price - Future price is largely unpredictable hence devising a selling plan to put current prices into the context of the farm business is critical to manage price risk.
- Quantity and Quality -When entering a cash contract you are committing to delivery of the nominated amount of grain at the quality specified. Hence production and quality risk must be managed.
- Delivery terms -Timing of title transfer from the grower to the buyer is agreed at time of contracting. If this requires delivery direct to end users it relies on prudent execution management to ensure delivery within the contracted period.
- Payment terms- In Australia the traditional method of contracting requires title of grain to be transferred ahead of payment; hence counterparty risk must be managed.

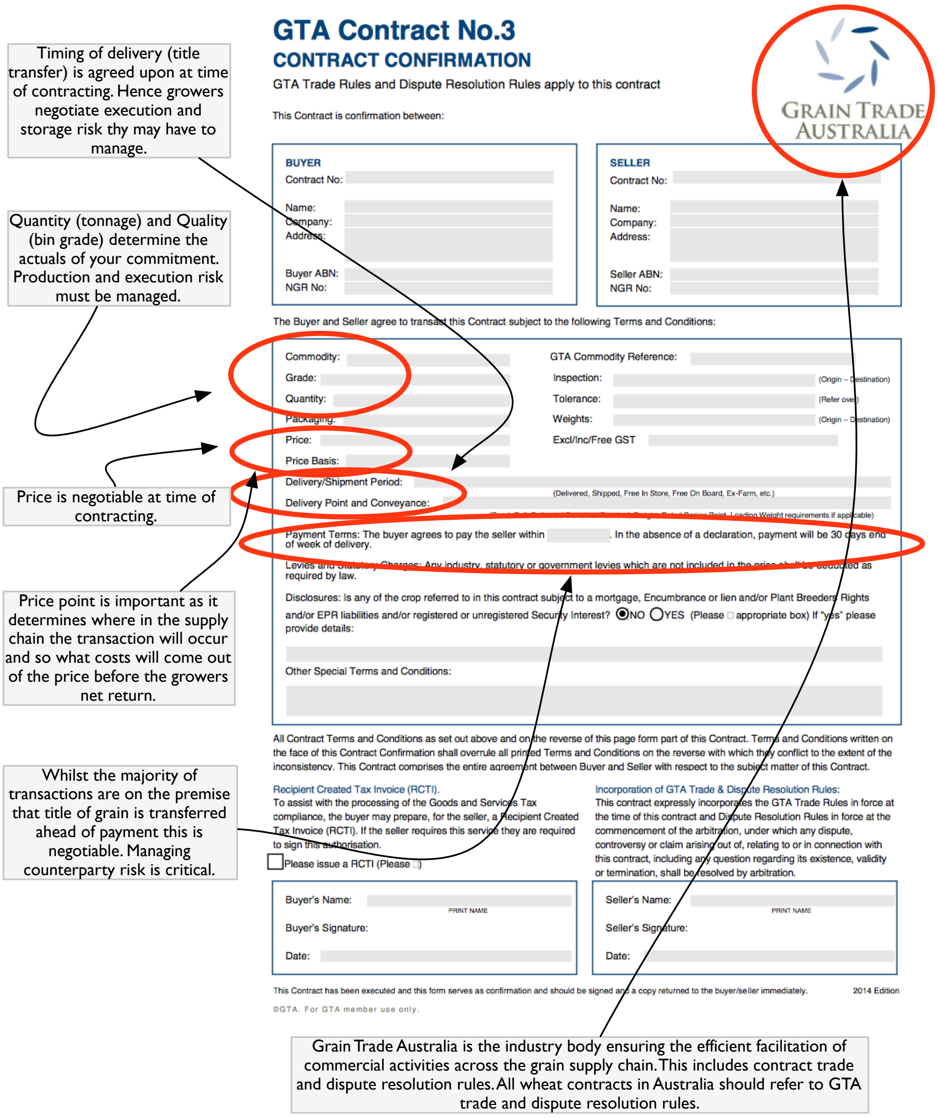


Figure 17: Typical cash contracting.

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. The below image depicts the terminology used to describe pricing points along the grain supply chain and the associated costs to come out of each price before growers receive their net farm gate return.

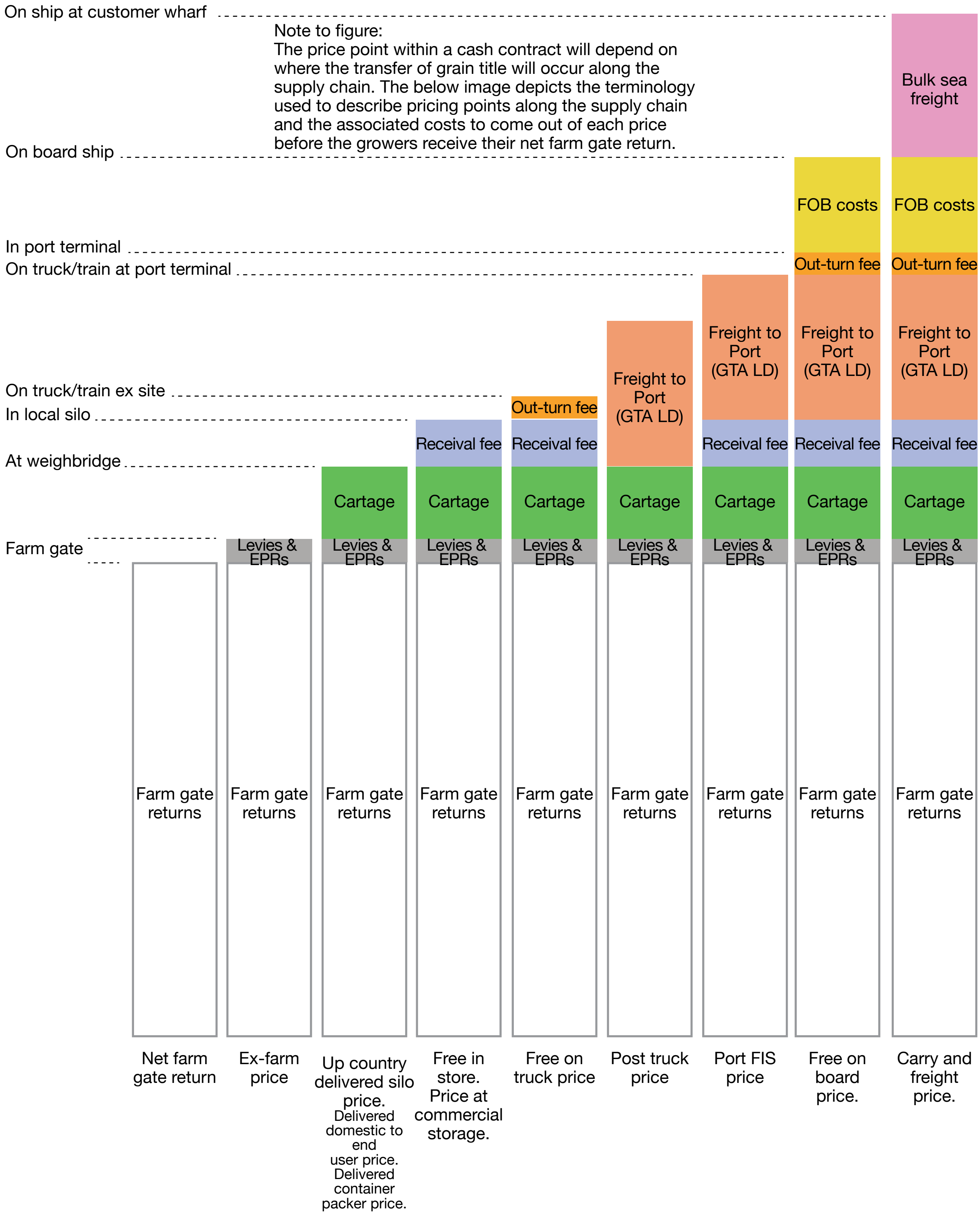


Figure 18: Cost and pricing points throughout the supply chains.

Cash sales generally occur through three methods:

- Negotiation via personal contact - Traditionally prices are posted as a “public indicative bid”. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and available for all commodities.
- Accepting a “public firm bid” - Cash prices in the form of public firm bids are posted during harvest and for warehoused grain by merchants on a site basis. Growers can sell their parcel of grain immediately by accepting the price on offer via an online facility and then transfer the grain online to the buyer. The availability of this depends on location and commodity.
- Placing an “anonymous firm offer” - Growers can place a firm offer price on a parcel of grain anonymously and expose it to the entire market of buyers who then bid on it anonymously using the Clear Grain Exchange, which is an independent online exchange. If the firm offer and firm bid matches, the parcel transacts via a secure settlement facility where title of grain does not transfer from the grower until funds are received from the buyer. The availability of this depends on location and commodity. Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

References:

http://www.australiangrainexport.com.au/docs/Grain%20Contracts%20Guide.pdf

http://www.graintrade.org.au/contracts

http://www.graintrade.org.au/commodity_standards

http://www.graintransact.com.au

http://www.grainflow.com.au

http://emeraldgrain.com/grower-logins/

https://www.cleargrain.com.au/terms-and-conditions

https://www.cleargrain.com.au/get-started

Counterparty risk

Most sales involve transferring title of 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.

Principle: “Seller beware” – There is not much point selling for an extra $5/t if you don’t get paid.

Counterparty risk management includes:

- Dealing only with known and trusted counterparties.
- Conduct a credit check (banks will do this) before dealing with a buyer they are unsure of.
- Only sell a small amount of grain to unknown counterparties.
- Consider credit insurance or letter of credit from the buyer.
- Never deliver a second load of grain if payment has not been received for the first.
- Do not part with title of grain before payment or request a cash deposit of part of the value ahead of delivery. Payment terms are negotiable at time of contracting, alternatively the Clear Grain Exchange provides secure settlement where-by the grower maintains title of grain until payment is received by the buyer, and then title and payment is settled simultaneously.

Above all, act commercially to ensure the time invested in a selling strategy is not wasted by poor counterparty risk management. Achieving $5/t more and not getting paid is a disastrous outcome.

References:

GTA managing counterparty risk 14/7/2014 http://www.graintrade.org.au/sites/default/files/Grain%20Contracts%20-%20Counterparty%20Risk.pdf

Clear Grain Exchange title transfer model – https://www.cleargrain.com.au/get-started

GrainGrowers Guide to Managing Contract Risk www.graingrowers.com.au/policy/resources

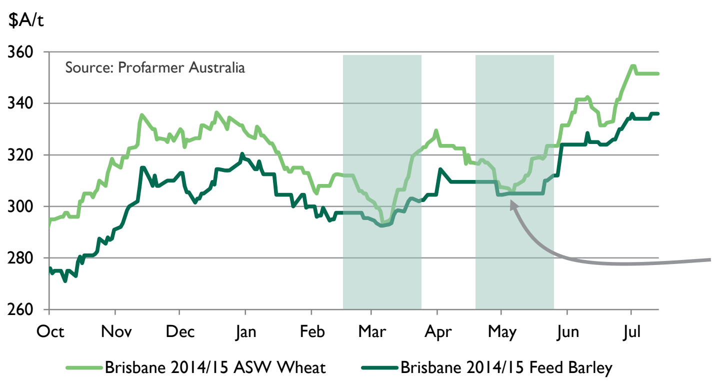
Counterparty risk: A producer perspective, Leo Delahunty http://www.graintrade.org.au/sites/default/files/GTA_Presentations/Counterparty%20risk%20-%20a%20producer's%20perspective%20-%20Leo%20Delahunty.pdf

Relative values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well and hold commodities that are not well priced at any given time. That is, give preference to the commodities of the highest relative value. This achieves price protection for the overall farm business revenue and enables more flexibility to a grower's selling program whilst achieving the business goals of reducing overall risk.

Principle: "Sell valued commodities; not undervalued commodities" – If one commodity is priced strongly relative to another, focus sales there. Don't sell the cheaper commodity for a discount.

An example based on wheat and barley production system is provided below.



Note to figure:
Price relativities between commodities is one method of assessing which grain types 'hold the greatest value' in the current market.

Example:
Feed barley prices were performing strongly relative to ASW wheat values (normally ~15% discount) hence selling feed barley was more favourable than ASW wheat during this period.

Figure 19: Brisbane ASW Wheat vs Feed Barley.

If the decision has been made to sell wheat, CBOT wheat may be the better alternative if the futures market is showing better value than the cash market

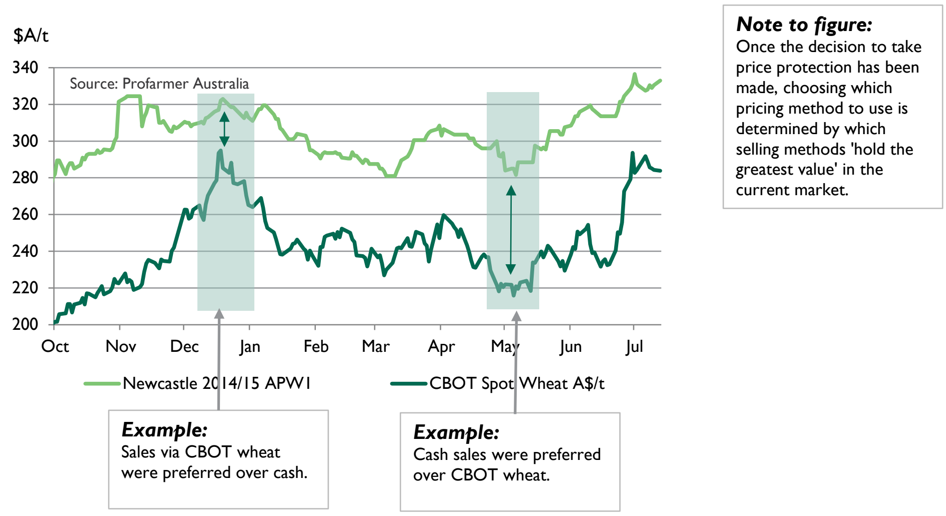


Figure 20: Newcastle ASWI vs CBOT Wheat A$/t.

Contract allocation

Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (price, premiums-discounts, oil bonuses etc.), and optimising your allocation reflects immediately on your bottom line.

Principle: "Don't leave money on the table" - Contract allocation decisions don't take long, and can be worth thousands of dollars to your bottom line.

To achieve the best average wheat price growers should:

- Allocate your lower grades of wheat to contracts with the lowest discounts.
- Allocate higher grades of wheat to contracts with the highest premiums.

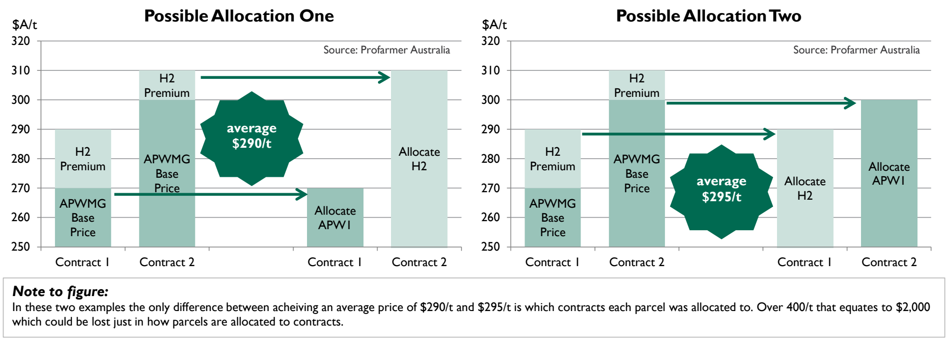


Figure 21: Possible allocation.

Read market signals

The appetite of buyers to buy 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 that interested in buying the commodity.

Principle: "Sell when there is buyer appetite" – When buyers are chasing grain, growers have more market power to demand a price when selling.

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 buyer appetite is strong. However if there is one buyer $5/t above the next best bid, it may mean cash prices are susceptible to falling $5/t if that buyer satisfies their buying 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. The chart below plots actual trade prices on the Clear Grain Exchange against the best public indicative bid on the day.

15.1.7 Sales execution revised

The selling strategy is converted to maximum business revenue by:

- Ensuring timely access to information, advice and trading facilities
- Using different cash market mechanisms when appropriate
- Minimising counterparty risk by effective due diligence
- Understanding relative value and selling commodities when they are priced well
- Thoughtful contract allocation
- Reading market signals to extract value from the market or prevent selling at a discount

15.2 Northern durum – market dynamics and execution

15.2.1 Price determinants for Northern durum

Durum is a specialty wheat used primarily for the production of pasta products. Due to its specialised use, demand for durum tends to be inelastic and finite. That is to say there is a relatively fixed requirement for durum year on year and there are few substitutes.

Whilst durum values are influenced by the price of bread wheats such as APW1, these two wheat varieties ultimately have different markets and hence at times the price relativities between the two can separate reflecting differences in the supply and demand dynamics of each market.

For example, during the 2014/15 season, untimely rains saw European Union durum production fall to historically low levels, and their import requirement rose to its highest level in five years. This coincided with weather damaged crops in Canada and the United States, and a smaller crop in Australia. Hence the production of durum wheat globally was not adequate to cover demand resulting in a $200/t+ premium for durum wheat in Australia over APW1 varieties, despite ample supply of Australian bread wheats.

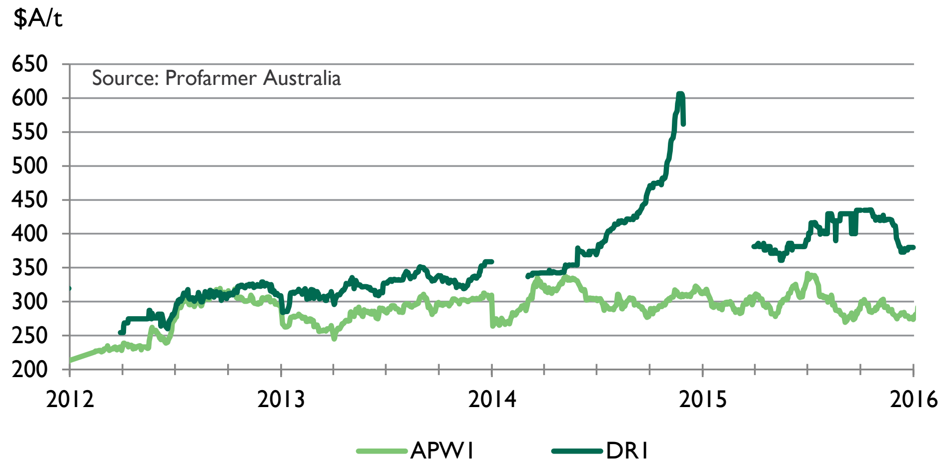


Figure 22: Newcastle DRI vs APWI values.

The major producing nations of durum are Canada, European Union (predominantly France and Italy), North Africa and Australia, whilst the major consumers are the European Union and North Africa. Australian production is split between South Australia at 40-50 percent and Northern NSW / Southern Queensland making up the remaining 50-60 per cent of the crop. In a typical year Australia exports 60-70 per cent of its durum production with a small number of local food manufacturers consuming the remaining 30-40 per cent.

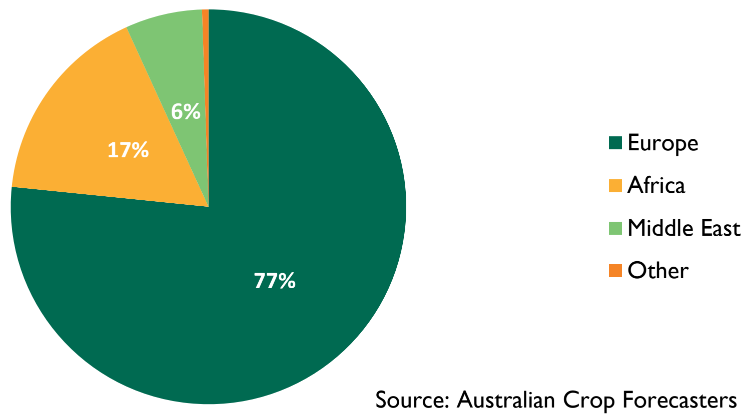


Figure 23: Export destinations for Australian durum.

In years when global durum exceeds the finite demand, Australian durum values tend to be weak relative to bread wheat varieties as Australian durum is discounted to compete for a smaller amount of international trade activity, as well as competing for alternate homes in the domestic market (eg. Stock feed markets).

Alternatively, when global durum supply fails to meet demand durum can trade at strong premiums to bread wheat as the market competes to secure their demand requirements from a smaller global crop.

Hence a major determinant of Australian durum values is the price at which international trade is transacting. This is influenced by;

1. Global supply vs demand
2. Quality of the global crop
3. Timing of the Australian export program

15.2.2 Ensuring market access for Northern durum

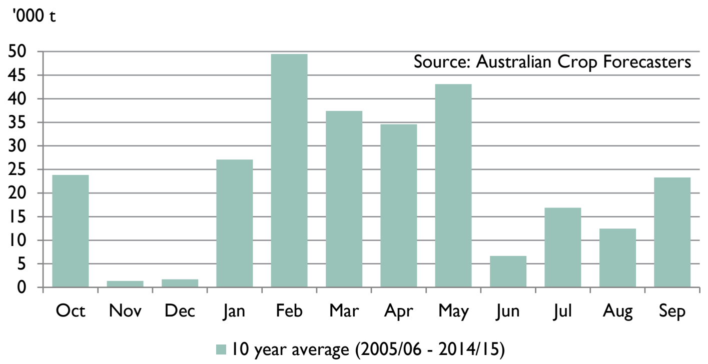
Due to the inelastic nature of durum demand, consumers and exporters traditionally focus their accumulation programs on the period immediately leading up to, during and after harvest when supply is the most certain. Hence appetite for durum tends to be strongest from October to January each marketing year.

Over 95 per cent of durum exports are executed via bulk export vessels rather than container exports. Hence the bulk handling system is an effective means for durum destined for the export market.

Being a specialty crop, there are fewer buyers of durum wheat than other grades of wheat. This means liquidity risk is a particularly important consideration for durum growers. Liquidity risk is the risk that buyers reach their accumulation requirements and step out of the market, the price may fall sharply as a result, or buyer appetite could dry up altogether.

The timing of the Australian export program is also an important consideration for ensuring market access for northern durum. With the export program typically focused in the first half of the marketing year, it is critical sellers take this in to consideration when making decisions around the timing of sales.

Holding durum later in the post-harvest period may result in a scenario where by there is no buyer appetite for that grain. Hence holding durum wheat grades later in the post-harvest period should be considered higher risk in most seasons, compared with holding other grades of wheat or commodities.



Note to figure: Australian durum exports are typically strongest between January and May in each marketing year.

Figure 24: Australian durum export pace.

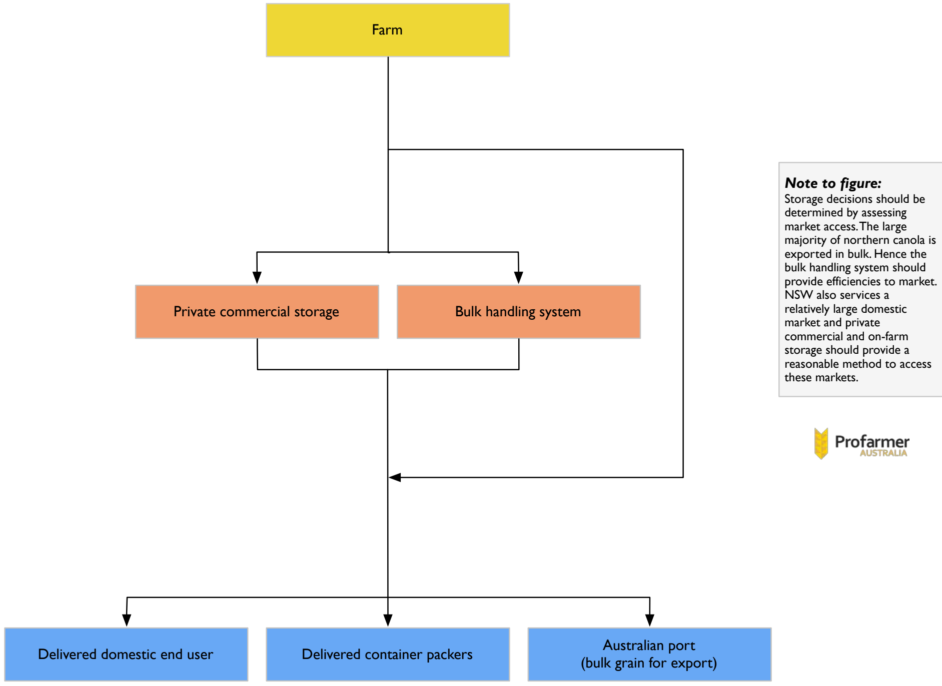


Figure 25: Australian supply chain flow.

15.2.3 Executing tonnes into cash for Northern durum

Growers of durum have a number of avenues to convert tonnes in to cash.

In the forward market an area program, allows producers to commit to planting a certain area of durum and the buyer may take on some or all of the production risk. These contracts are normally offered either directly by domestic users or their agents. Area contracts can take a number of different forms so it is important when comparing these contracts the seller considers the following risks in particular;

- Production risk – is the buyer taking on all of the production risk or does the contract include minimum and/or maximum volume commitments.

- Quality risk – what premiums and discounts are being offered for protein, screenings and other quality parameters? Are quality discounts based on a sliding scale based on the quality produced or set based on the bin grade delivered?

Forward durum multi grade contracts for fixed tonnages are also available. An important consideration of any forward contract is what quality is deliverable against the contract. There are a large number of receival grades for durum from DR1 down to DRF it is important to consider which grade you may end up delivering and whether or not this is deliverable against your contract.

Pricing in the durum market is not always transparent, with few buyers and a number of transactions taking place outside the public indicative bid; it can be difficult to gauge fair market value. In periods of short supply durum can trade above the indicative public bid. Hence placing a firm offer to the market above the public indicative bid can be an effective means of achieving fair value for your durum.

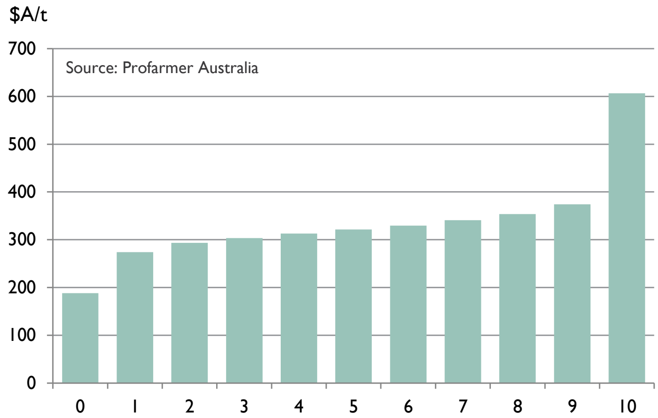


Figure 26: Newcastle DRI durum decile.

Note to figure:
Decile charts such as the one to the left provide us an indication of how current values are performing relative to historical values. For example, a decile of 8 or above indicates current values are in the top 20% of historical price observations.

SECTION 16

Current research

16.1 Searching GRDC projects

Each year the GRDC supports several hundred research and development, and capacity-building projects.

In the interests of improving awareness of these investments among growers, advisers and other stakeholders, the GRDC has assembled summaries of projects on its website.

These summaries are written by GRDC's research partners as part of the Project Specification for each project, and are intended to communicate a useful summary of the research activities for each project investment.

The review expands existing communication products where we summarise the R&D portfolio in publications such as the Five-year Strategic Research and Development Plan, the Annual Operating Plan, the Annual Report and the Growers Report.

GRDC's project portfolio is dynamic with projects concluding and new projects commencing on a regular basis.

The GRDC values the input and feedback it receives from its stakeholders and so would welcome your feedback on this website search engine.

Visit http://projects.grdc.com.au/search.php

SECTION 17

Key contacts

GRDC Northern Regional Panelists

John Minogue - Chair

John Minogue runs a mixed broadacre farming business and an agricultural consultancy, Agriculture and General Consulting, at Barmedman in south-west NSW. John is chair of the local branch of the NSW Farmers' Association, has formerly sat on the grains committee of the NSW Farmers' Association and is a winner of the Central West Conservation Farmer of the Year award. John has also been involved in the biodiversity area as a board member of the Lachlan Catchment Management Authority. His vast agricultural experience in central west NSW has given him a valuable insight into the long-term grains industry challenges.
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Penny Heuston - Deputy Chair

Penny Heuston is an agronomist based in Warren, NSW. She is passionate about the survival of the family farm and its role in the health of local economies. Penny is dedicated to ensuring research is practical, farm-ready and based on sound science and rigor. She sees 'two-way communication' as one of the panellists' primary roles and is committed to bringing issues from the paddock to 'the lab' and conversely, the science to the paddock.
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Loretta Serafin

Loretta Serafin has extensive experience as an agronomist in northwest NSW and works with the NSW Department of Primary Industries in Tamworth. As the leader northern dryland cropping systems, she provides expertise and support to growers, industry and agronomists in the production of summer crops. Loretta is a member of numerous industry bodies and has a passion for helping growers improve farm efficiency. She sees her role as a conduit between advisers, growers and the GRDC to ensure growers' research needs are being met.
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Jules Dixon

Jules Dixon has an extensive background in agronomy and an established network spanning eastern Australia and WA including researchers, leading growers and agronomy consultants through to the multinational privatesector. Based in Sydney, Jules operates a private consultancy specialising in agronomy, strategy development and business review.
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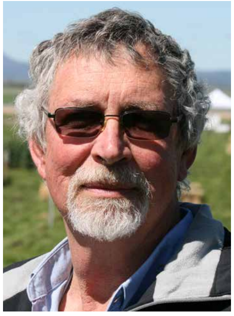
Neil Fettell



Neil Fettell is a part-time senior research adviser with Central West Farming Systems and runs a small irrigation farm near Condobolin, NSW. Neil has a research agronomy background, conducting field research in variety improvement, crop physiology and nutrition, water use efficiency and farming systems. He is a passionate supporter of research that delivers productivity gains to growers, and of grower participation in setting research goals.
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Andrew McFadyen

Andrew McFadyen is an agronomist and manager with Paspaley Pastoral Company near Coolah, NSW, with more than 15years' agronomy and practical farm management experience. He is an active member of the grains industry with former roles on the Central East Research Advisory Committee, NSW Farmers Coolah branch and planning committees for GRDC Updates. He is also a board member and the chair of Grain Orana Alliance.
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Jack Williamson

Jack Williamson is a private agricultural consultant and helps run a family broadacre farm near Goondiwindi, Queensland. Six years of retail agronomy and three years of chemical sales management have given Jack extensive farming systems knowledge, and diverse crop management and field work experience. He is a member of the Northern Grower Alliance local consultative committee and Crop Consultants Australia.
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Arthur Gearon

Arthur Gearon is a grain, cotton and beef producer located near Chinchilla, Queensland. He has a business degree from the Queensland University of Technology in international business and management and has completed the Australian Institute of Company Directors course. He is vice-president of AgForce Grains and has an extensive industry network throughout Queensland. Arthur believes technology and the ability to apply it across industry will be the key driver for economic growth in the grains industry.
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Dr Tony Hamilton

Tony Hamilton is a grower from Forbes, NSW, and managing director of an integrated cropping and livestock business. He is a member of GRDC's Regional Cropping Solutions Network – Irrigation panel and a director of the Rural Industries Research and Development Corporation. He has worked as an agricultural consultant in WA and southern NSW. With a Bachelor of Agricultural Science and a PhD in agronomy, Tony advocates agricultural RD&E and evidence-based agriculture.
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Brondwen MacLean

Brondwen MacLean was appointed to the Northern Panel in August 2015 and is the GRDC executive manager for research programs. She has primary accountability for managing all aspects of the GRDC's nationally coordinated R&D investment portfolio and aims to ensure that these investments generate the best possible return for Australian grain growers. Prior to her current appointment, Brondwen was senior manager, breeding programs, and theme coordinator for Theme 6, Building Skills and Capacity.
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David Lord - Panel Support Officer

David Lord operates Lord Ag Consulting, an agricultural consultancy service. Previously, David worked as a project officer for Independent Consultants Australia Network, which gave him a good understanding of the issues growers are facing in the northern grains region. David is the Northern Panel and Regional Grower Services support officer.
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