



GROWNOTES

OATS

- PLANNING/PADDOCK PREPARATION
- **PRE-PLANTING**
- PLANTING
- PLANT GROWTH AND PHYSIOLOGY
- NUTRITION AND FERTILISER
- WEED CONTROL
- **INSECT CONTROL**
- NEMATODE MANAGEMENT

DISEASES

- PLANT GROWTH REGULATORS AND CANOPY MANAGEMENT
- **CROP DESICCATION AND SPRAY OUT**
- HARVEST
- STORAGE
- ENVIRONMENTAL ISSUES
- MARKETING
- CURRENT AND PAST RESEARCH



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Start here for answers to your immediate Oats crop management issues



What grass weed control options do I have in oats?

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Can I plant the same oat variety for grain, hay and grazing?



Do oats have the same nutritional requirements as other cereals?



Which diseases are oats susceptible to?



What are the best sowing rates for grain, hay and grazing production?



How can I avoid grain shedding in oats?









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Key messages

- Australia produces on average 1.3 million tonnes of oats per year, with a large proportion processed domestically and up to 20% exported as grain. However, demand for Australian oat grain and hay is increasing annually.
- Oats adaptability to tolerate acid soils, use for hay and silage, for pasture renovation, suitability for broadleaf weed control by post emergent herbicides, and usefulness for grazing out make oats a versatile crop in farming systems.
- Oats can tolerate a range of cereal diseases such as take-all, crown rot and common root rot.
- Oats are often thought of as an 'easy' crop to grow but attention to detail is required to produce high yields and quality.

A.1 Crop overview

Oats are grown for human consumption and for animal feed as grain or hay (Photo 1). This widely adapted and reliable cereal is a major winter cereal grazing crop. It also offers some rotational benefits where conditions are not suitable for broadleaf break crops. Oats can tolerate a range of cereal diseases such as take-all, crown rot and common root rot. The ease of establishment and early time of sowing are other major benefits. Its adaptability to tolerate acid soils, use for hay and silage, for pasture renovation, suitability for broadleaf weed control by post emergent herbicides, and usefulness for grazing out make oats a versatile crop in farming systems. ¹ However, its lower grain value means other dual purpose crops, such as winter wheats, will generally provide better returns than grazing oats.







Photo 1: Oats for cattle feed.

Photo: GRDC

Australia produces on average 1.3 million tonnes of oats per year, with a large proportion processed domestically and up to 20% exported as grain. Australia is the fourth largest global exporter of oats after Canada, Finland and Sweden. Western Australia is the largest oat exporting state in Australia, and oats produced in Victoria and New South Wales are predominantly processed domestically.

Oats are often thought of as an 'easy' crop to grow but attention to detail is required to produce high yields and quality. Timely harvest is important to maintain good grain quality. The option of oats for hay is becoming increasingly popular in some regions where growers have identified it as profitable and perhaps as a tool to manage herbicide resistance. ² Oats are adaptable to a wide range of soils and can tolerate some diseases that other cereals cannot. Oats can produce more forage than other cereals and have a higher winter growth rate than pastures. ³ The ability of oats to withstand waterlogged conditions better than other cereals makes them well suited to cropping systems in high rainfall regions and on flood irrigation, particularly following rice.

A.1.1 Health benefits

Oat fibre has been been shown to help reduce cholesterol and there is a growing promotion of oats as a health food—a movement that could help diversify market opportunities. For example, oats are being used in new products, including oat noodles, oat milk and oat health-care products. ⁴

There are active components in oats which lower blood lipids, regulate blood glucose and protect against tumour development in the colon. Oat bran and oatmeal supplementation studies show a more favourable effect on blood glucose and insulin responses than other cereal grains like wheat and maize. Oat soluble fibre should delay the onset of fatigue and enhance athletic performance. ⁵



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² Agriculture Victoria (2015) Growing oat, <u>http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-oat</u>

³ NSW DPI (2008) Agriculture Today. Early start with oats, <u>http://www.dpi.nsw.gov.au/content/archive/agriculture-today-stories/ag-today-archives/march-2008/early-start-with-oats</u>

⁴ J Paterson, I Wilkinson (2016) Western Australian oat industry. DAFWA, <u>https://www.agric.wa.gov.au/hay-production/western-australian-oat-industry</u>

P Guerin (2007) Development of High-Vigour Oat Varieties in Australia, <u>http://www.australianoats.com.au/oats/p-07.htm</u>



A.1.2 Hay

Oaten hay for the domestic and export livestock markets is worth an additional \$100 million per annum. Good colour, a sugary taste and aroma and a fine texture are critical for good animal performance (Photo 2).

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Oaten hay is a preferred source of fodder for dairy cows due to its high digestibility and palatability. High in water-soluble carbohydrates (around 25%), oaten hay provides dairy cows with energy that can be utilised by ruminant microflora for high milk production and sustained live weight gain. ⁶



Photo 2: Bales of oaten hay. Source: DAFWA.

A.1.3 Grain

Most milling-quality oats are exported for processing in destination markets but a significant quantity is also processed prior to export, adding significant value to this grain sector. About 50,000 tonnes of milling oats are processed domestically for export (set to increase with additional capacity coming online in 2015–16, as per estimates in Table 1), with some also used domestically in the breakfast cereal, health bar, bakery and baby food industries. Milling-quality oats attract a premium of between \$15 and \$30 per tonne compared to lower quality oats.⁷

A.1.4 Exports

The major markets for milling oats are Mexico, North Asia, South-East Asia and South Africa. Oaten hay exports to Japan, China and other Asian markets are expanding, with consistent supply of first-grade hay essential to retain this market share (Figure 1). 8



⁶ P Carmody (2015) Hay exports, DAFWA https://www.agric.wa.gov.au/grains/hay-exports

⁷ J Paterson, I Wilkinson (2016) Western Australian oat industry. DAFWA, <u>https://www.agric.wa.gov.au/hay-production/western-australian</u> oat-industry

⁸ J Paterson, I Wilkinson (2016) Western Australian oat industry. DAFWA, <u>https://www.agric.wa.gov.au/hay-production/western-australian-oat-industry</u>



Figure 1: Areas of oat production.

increasing production

Source: Australian Export Grains Innovation Centre.

 Table 1: Oat crop estimates by district for South Australia in 2015–2016.

		Western Eyre Peninsula	Lower Eyre Peninsula	Eastern Eyre Peninsula	Yorke Peninsula	Upper North	Mid North	Lower North	Kangaroo Island
Oats	ha	16,500	3,200	6,000	4,000	4,800	5,500	1,500	3,300
	t	17,500	6,700	7,000	9,000	6,200	11,500	3,300	8,000
		Central Hills & Fleurieu	Lower Murray	Nth Murray Mallee	Sth Murray Mallee	Upper South East	Lower South East		State total
Oats	ha	1,800	3,000	2,200	4,100	19,500	5,200		80,600
	t	4,100	4,500	2,600	5,300	41,000	12,500		139,200

Source: PIRSA 9

A.2 Brief history

Oats was not an important crop for humans as early as wheat or barley were. Oats probably persisted as a weed-like plant in other cereals for centuries prior to being cultivated. The history of oats is clouded because there are so many different species and subspecies, making identification of old remains difficult. One theory is that modern cultivated oats developed from a mutation in wild oats. Probably the oldest known oat grains were found in Egypt around 2,000 B.C. These probably were weeds and not actually cultivated by the Egyptians. The oldest known cultivated oats were found in caves in Switzerland that are believed to belong to the Bronze Age. ¹⁰

Wheat is Australia's largest grain crop and came to Australia with European settlement in 1788. Other grains produced by Australia have come to Australia at



TAS

⁹ Rural Solutions SA (2016) Crop and pasture report: South Australia. PIRSA, <u>http://pir.sa.gov.au/__data/assets/pdf_file/0005/279122/</u> <u>PIRSA_Crop_and_Pasture_Report_July_2016.pdf</u>

¹⁰ L Gibson, G Benson. (Revised January 2002) Origin, history, and uses of Oat (Avena sativa) and Wheat (Triticum aestivum), lowa State University, Department of Agronomy, <u>http://agron-www.agron.iastate.edu/Courses/agron212/Readings/Oat_wheat_history.htm</u>



different times since European settlement. The expansion of grain production in Australia can be attributed to plant breeding, engineering and farming research. $^{\rm 11}$

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A.2.1 Grains in southern Australia

The Grain Industry Association of Victoria was formed in 1917 as the Melbourne Corn Exchange. Activities were centred on the west end of the city, close to the railhead, the Melbourne ports and Flinders Lane, where the oats for horse transport were traded. Significant changes swept through the grain trade in the 1930s, including the demand for oats decreasing as motor transport replaced heavy horses. The Australian Wheat Board (AWB) was established in 1939 under war-time emergency powers. With the establishment of the AWB and later the Australian Barley Board the activities of the corn exchange were greatly reduced. In practical terms commodity trading was reduced to oats and corn sacks. ¹²



Photo 3: William Tyner's Grain and Produce Store in High St Malvern, c. 1900. This store distributed animal feeds including oat hay and grain to the local horse owners and dairy farmers in the outer suburbs. Animal feed stores in Malvern and Armadale were essential support to the transport system which was mainly horse-drawn cart.



¹¹ PWC (2011) The Australian Grain Industry – The Basics, PricewaterhouseCoopers, <u>http://www.pwc.com.au/industry/agribusiness/assets/</u> australian-grains-industry-nov11.pdf

¹² Grain Industry Assoc. of Victoria (2015) <u>http://giav.com.au/history/</u>





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Key messages

- Oats have the reputation of tolerating poorer soils than wheat but the higher yielding crops are grown on more fertile soils.
- Control grasses prior to the oat crop through pasture manipulation or spraytopping in the previous pasture. Control in the preceding grain legume is essential to reduce root disease and allow early sowing.
- A good rotation for grain oats is following canola—this provides an opportunity to reduce grass weeds and minimise cereal diseases.
- Conduct soil testing using PreDicta® B to establish disease and nematode status which will inform decision making.





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Oats are sensitive to triazine residues—significant damage can occur on soil treated with 2.24 kg/ha of triazine in the preceding year. Soil tests prior to sowing can confirm if the residues will harm the crop.

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• Oats seed needs good soil contact for germination. This can be assisted with press wheels, coil packers or rollers.

1.1 Paddock selection

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

Successful crop establishment is the key to maximising crop yield potential. Focus on paddock selection, the use of good quality seed, optimising seeding rate, depth and spacing, and matching varieties to seeding date and length of growing season.

Select soils with at least 50 cm of suitable root-zone (freely drained, without hardpans or surface crusting). Oats have the reputation of tolerating poorer soils than wheat but the best crops are grown on more fertile soils (Photo 1). Oats are considered less suited to heavier clay soils than wheat or barley but the application of gypsum in such situations can improve yields. Waterlogging will severely reduce yield and quality so these areas should be sown earlier to reduce the detrimental effects. Oats can be grown in frost-risk areas with yield losses being much lower than wheat.²



Photo 1: Oat seedlings in healthy soil eight days after planting. Source: <u>B&D Lilies</u>.

Identify paddocks with the most potential to produce high yields with minimum cost. Knowledge of paddock history, soil type and occurrence of weeds, diseases and rotation, as well as use of management tools such as nutrient testing prior to sowing, will enable better identification of paddocks suitable for oat production. Select the best cropping paddock in terms of uniform soil type, soil fertility and crop rotation.

Avoid paddocks prone to long periods of waterlogging. Oats tolerate waterlogging better than wheat and barley but long periods of perched water within 30 cm of the soil surface will reduce their yield potential.

There are limited herbicide options for grass weed control in oats—choose paddocks with minimal weed burden, undergoing an integrated weed management strategy



¹ Agriculture Victoria (2012) Growing wheat. DEDJTR Victoria, <u>http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-wheat</u>

² G Troup (2016) Oats: essentials. DAFWA, <u>https://www.agric.wa.gov.au/hay-production/oats-essentials</u>



and capable of a double knockdown before seeding. Avoid ARGT susceptible paddocks for the production of export oaten hay. However the production of export oaten can be a tool for growers to control herbicide resistant ryegrass.

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Avoid paddocks with soil constraints such as high acidity soils. Although oats are more tolerant of acidic soils than wheat or barley, paddocks with surface soil pH (calcium chloride) below 5.3 can impair plant growth.

Nutritional imbalances should be addressed prior to sowing or monitored through the season and micronutrient deficiencies (particularly manganese) treated with fertiliser or foliar applications.³

1.1.1 Topography

Topographical characteristics can determine crop and pasture options. Crops and varieties prone to lodging should be avoided in uneven paddocks. Waterlogged conditions also reduce root growth and can predispose the plant to root rots. The topographic variations typical of large agricultural paddocks can have a substantial impact on dynamics of soil mineral N as well as on performance of crops. spatial variations in soil organic matter, soil microbial biomass, natural drainage, plant growth, and water and nutrient redistribution caused by topography are the main factors controlling the dynamics of soil mineral N. Along with weather, landscape topographic patterns accounted for most of the variations in plant available N.

There are potential environmental and economic benefits of site-specific topographydriven crop management. Management decisions regarding where to plant crops can vary depending on the management goals and complexity of the terrain. ⁴

1.1.2 Paddock preparation

Control grasses prior to the oat crop through pasture manipulation or spray-topping in the previous pasture. Control in the preceding grain legume is essential to reduce root disease and allow early sowing.

There is a requirement by customers of export hay markets that hay be free of any contamination. Paddock preparation is a major part of management for export hay and requires:

- removal of old crop residues (burning) or managing harvest the year before to minimise residues (i.e. harvesting low at 15 cms or fallow management of stubbles)
- removal of sticks, tree branches, stones, carcasses, wire, etc.
- in some cases, rolling of paddocks.

For no-till systems before seeding, follow standard paddock preparation protocols such as knocking down the weeds. $^{\rm 5}$

1.1.3 Soil type

Soil characteristics (surface and subsurface) such as soil pH, sodicity, salinity, acidity, texture, drainage characteristics and compaction will affect variety selection.

Oats have the reputation of being considered a low-input crop, requiring less nutrients and therefore suited to marginal soils. As a result, soil management and maintenance are often overlooked but research has shown that healthy soils with good fertility and physical conditions always give better yields particularly when growing dwarf varieties. Soil characteristics (surface and subsurface) such as soil pH, sodicity, salinity, acidity, texture, drainage characteristics and compaction will affect variety selection.

- 3 G Troup (2016) Oats: paddock selection. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-paddock-selection</u>
- 4 Ladoni, M., Kravchenko, A. N., & Robertson, G. P. (2015). Topography Mediates the Influence of Cover Crops on Soil Nitrate Levels in Row Crop Agricultural Systems. PloS one, 10(11), e0143358.
- 5 DAFWA (2016) Oats: seeding and establishment, Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/</u> oats/oats-seeding-and-establishment





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Oat crops are generally less sensitive to soil acidity and waterlogging, but good quality soils are required for profitable yields. Acidity, waterlogging and salt problems can adversely affect yield and quality.

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Deep well-drained soils are ideal as they maximise the opportunity to store subsoil moisture and allow the crop to explore the maximum available range of moisture and nutrients. Ideally, select soils with at least 50 cm of suitable root-zone (freely drained, without hardpans or surface crusting). On poorly drained soils, yield may be unprofitable.

Medium textured soils are preferred to sandy soils because of their greater waterholding capacity but research has shown that oats can be successfully grown on sandy soils provided they are supplied with adequate nutrients and moisture.

Soil pH

Soils with low pH often have high levels of aluminium in the soil solution. Oats can tolerate soil pH as low as 5.3 and although they are considered more tolerant of acidity and aluminium toxicity than other cereals, significant yield losses can occur under extremely acidic conditions with high levels of exchangeable aluminium. Paddocks with low soil pH should still be subject to a liming program even if being sown to oat grain and oat hay crops. ⁶

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

Hydrogen ion concentration in the soil is called pH and is influenced by chemical reactions between soil components and water. Soil pH is affected by the varied combinations of positively charged ions (sodium, potassium, magnesium, calcium, aluminum, manganese and iron) and negatively charged ions (sulfate, chloride, bicarbonate and carbonate). Soil pH directly affects the concentration of major nutrients and the forms of microelements available for plant uptake and can result in deficiencies or toxicities (Figure 1).



Figure 1: Classification of soils on the basis of pH (1:5 soil:water) the implications for plant growth and some management options.

Source: <u>Soilquality.org</u>

- 6 G Troup (2016) Oats: paddock selection. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-paddock-selection?page=0%2C1</u>
- 7 Soilquality.org. Soil pH—South Australia, <u>http://www.soilquality.org.au/factsheets/soil-ph-south-australia</u>





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What influences location of acid and alkaline soils in Southern Australia?

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

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

Measurement of soil pH

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

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

Managing soil pH

Alkaline soils:

Treating alkaline soils through the addition of acidifying agents is not generally a feasible option due to the large buffering capacity of soils and uneconomic amounts of acidifying agent (e.g. sulfuric acid, elemental sulfur or pyrites) required.

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

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

Acid soils:

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

Soils prone to becoming acidic will need liming every few years. Seek advice on an appropriate liming regime from your local agricultural adviser. $^{\rm 8}$

Liming

Oats are relatively tolerant of acid soil, being more tolerant than wheat or barley. Growth will be adversely affected when soil pH is below 5.3. $^{\rm 9}$

The signs of soil acidity are more subtle than the clearly visible symptoms of salinity and soil erosion. Cereal growers may predict that their soil is acidic when acid sensitive crops fail to establish, or crop production is lower than expected, particularly in dry years. In pasture paddocks poor establishment or lack of persistence of acid sensitive pastures such as lucerne, and to a lesser degree phalaris, is an indication that the soil may be acidic.

More definitive indications of acidic soil are:

- stunted or shallow root growth in crops and pastures;
- 8 Soilquality.org. Soil pH—South Australia, <u>http://www.soilquality.org.au/factsheets/soil-ph-south-australia</u>
- 9 Pacific Seeds (2006/07) Pacific Seeds Yearbook 2006/2007 Oats Agronomy Guide, <u>https://www.yumpu.com/en/document/view/31552601/pacific-seeds-oats-agronomy-guide-2006-07-direct-router/2</u>





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- poor nodulation in legumes or ineffective nodules; and
- manganese toxicity symptoms in susceptible plants.

A soil test is the most reliable way to assess if soils are acidic. Where soils are at risk of becoming acidic the future impact of soil acidity can be reduced, but not eliminated, by slowing the rate of acidification.

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To slow the rate of acidification:

- minimise leaching of nitrate nitrogen
- use less acidifying fertilisers
- reduce the effect of removal of product
- prevent erosion of the surface soil

Application of finely-crushed limestone, or other liming material, is the only practical way to neutralise soil acidity. Limestone is most effective if sufficient is applied to raise the pHCa to 5.5 and it is well incorporated into the soil. Where acidity occurs deeper than the plough layer, the limestone will only neutralise subsurface soil acidity if the pHCa of the surface soil is maintained above 5.5.¹⁰

The economic benefits of lime

The benefits of lime prove to be not only economically significant but the consequence of improved soil quality and increased nutrient uptake makes cropping more sustainable. However, a liming scheme does not result in overnight success. The amelioration of acidified soils is a lengthy process but it is worthwhile in the retention of a healthy, vibrant and sustainable soil. The longer the beneficial effects of lime persist, the more the investment in liming becomes economically favourable. Subsoil constraints such as acidity result in decreased rates of root elongation and limit the plant's ability to access water and nutrients. Subsoil acidity is caused by the excess application of acidic substances such as ammonium fertilisers. Surface liming is a common practice for ameliorating topsoil acidity in the relatively short-term, but is generally slow in ameliorating subsoil acidity. When acidity is increased, important nutrients such as nitrogen (N) and phosphorus (P) are less available to plants, while nutrients only needed in trace amounts such as aluminium (AI) and manganese (Mn) are increased. This can lead to Al and Mn toxicity resulting in a dramatic decline of plant growth. Lime substantially reduces the level of exchangeable AI and exchangeable Mn while raising soil pH by about 1.0 unit. Liming soils can remove the toxicities of AI and Mn and, dependent on the extent of acidity and species, plants may differ in their response to soil amelioration with lime. ¹¹ A pH level of 5.5 is often seen as the optimum value for the growth of the plants.

Liming schemes are an appropriate solution to this problem and ensure the longevity of soils that may be succumbing to acidity. The long-term residual benefits of limestone have been shown to extend for beyond 8–10 years and indicate that liming should be profitable in the long term. ¹²

Soil salinity

Excessive soil salts can reduce the performance of oats. Although they are considered a moderately salt tolerant crop, oats are more sensitive than other cereals. In saline environments oats show decreased seed germination and stunted plant growth, turning dull, bluish yellow green and many tillers die, ultimately affecting yield (Photo 2). Caution should be taken when combining waterlogging and salinity. Under these conditions, low oxygen concentrations around the roots limit energy available to the plants and they are not able to exclude salts from their tissues.¹³

11 D Brooke, DR Coventry, TG Reeves, DK Jarvis (1989) Plant and Soil, 115, 1–6

13 G Troup (2016) Oats: paddock selection. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-paddock-selection?page=0%2C1</u>



VIDEOS

WATCH : GCTV8: Liming Acids Soils.

Western Australia Wheat Belt

¹⁰ B Upjohn, G Fenton, M Conyers (2005) Soil acidity and liming. Agfact AC. 19. 3rd edition. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/167209/soil-acidity-liming.pdf</u>

¹² M Quin (2015) Central West Farming Systems Inc., <u>http://cwfs.org.au/2015/12/08/the-economic-benefits-of-lime/</u>



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Photo 2: Water stressed oat plant in saline patch. Source: DAFWA.

For more information, see Section 14: Environmental issues.

Subsoil moisture

Low levels of soil moisture at sowing can significantly increase financial risks. Paddocks with ground cover can retain moisture for longer, extending the time for planting after small rainfall events. Levels of starting soil water should also affect variety choice. Varieties with greater canopy size, such as late-maturing and/or very vegetative varieties, will generally require higher soil moisture levels to perform well.

Paddock nutrition

Fertiliser is a major cost. Fertiliser rates to meet crop requirements may be modified if residual fertiliser from the last season remains. Paddock history, past crop performance, fertiliser test strips and soil tests can help to determine the most appropriate decision. It is not uncommon for paddocks to have multiple nutrition deficiencies, or variations in nutritional requirements, even with a similar cropping history.

See Section 5: Nutrition and fertiliser, for more information.

Herbicide history

Part of the management of herbicide resistance includes rotation of herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonyl urea, triazines, etc.) may be an issue in some paddocks and particularly low rainfall years. Remember that plant-back periods begin after rainfall occurs.





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Weed burden

Identify your 'cleanest' paddocks and consider the use of pre-emergent herbicides. Risk may be reduced through the combination of presowing weed knockdown, latesown (early-maturing) crops/varieties and pre-harvest desiccation in crops where registration is current. Weed management involves strategic herbicide applications in combination with other, non-chemical management options. Weed management in year one will affect the crop in year two.

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See Section 6: Weed control for more information.

Disease carryover

Crop sequencing is an important component of long-term farming systems and contributes to the management of soil nitrogen (N) status, weeds, pests and diseases. Broad-scale decisions on the sequence of crops include commodity prices, the shortand medium-term weather outlook, and the level of acceptable risk. In the paddock, considerations include soil moisture levels before planting, current and desired stubble cover, history of herbicide use, history of diseases, and the population level(s) of root-lesion nematodes. Crop sequences also affect the incidence and severity of major diseases of summer crops, especially those diseases that have several summer, and in some instances winter, crop hosts.

Crop sequencing is only a part of the integrated management of disease. Other practices include maintaining sufficient distance from last year's paddock of the same crop or from a paddock with residue infected with a pathogen of the intended crop, the use of high quality, fungicide-treated seed, planting within the planting window, variety selection, and in-crop fungicide treatments.¹⁴

The previous crop and susceptibility will influence levels of both soil- and residueborne diseases. Transmission from neighbouring paddocks and volunteers are key concerns with some diseases. Controlling the 'green bridge' of over-summering cereals and weeds is an important strategy.

Pests

Pests such as redlegged earth mites, blue oat mites, nematodes and, in some seasons, cutworms, aphids and armyworm may pose a risk in some paddocks. Aphids may also be vectors for transmission of diseases such as BYDV, particularly in higher rainfall environments. Risk should be assessed based on paddock history (including recent control) and crop susceptibility. Controlling weeds in summer fallows and around paddocks can also minimise some of these pests. ¹⁵

See Section 7: Insect control for more information.

1.2 Paddock rotation and history

Rotation is important for disease management, potential weed burden, risk of herbicide residues and for increasing soil health. Grain oats are not received on the basis of protein level so the previous crop is not as critical as with wheat and barley.

- A good rotation for grain oats is following canola or other broadleaf crops this provides an opportunity to reduce grass weeds and minimise cereal contamination and diseases.
- Oats are sensitive to triazine residues—significant damage can occur on soil treated with 2.24 kg/ha of triazine in the preceding year. Soil tests prior to sowing can confirm if the residues will harm the crop. Soil type may have significant effect on amount of damage due to herbicide application, e.g. triazines last longer on lighter alkaline soils



¹⁴ M Ryley (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Papers 13 September 2011, <u>http://elibrary.grdc.com.au/ark%21%2133517/vhnf54t/a9ft5hf</u>

¹⁵ N Border, K Hertel, P Parker (2007) Paddock selection after drought. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/126100/paddock-selection-after-drought.pdf</u>



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The suitability of oats after a legume pasture or crop depends on whether you are growing for grain or hay, and the straw strength of the variety you wish to grow. Dwarf oats are more suited to rotations with good nitrogen supply. Hay crops grown after legume crops may be less suitable for the export hay industry as they may be prone to low water soluble carbohydrates, high crude protein and increased fibre levels.¹⁶

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Ensure the previous year's crop has had good grass weed management, as there are few grass weed control options available in an oat crop. This control can be via pasture manipulation or spray-topping in the previous pasture, diligent grass control in-crop in previous years or weed seed capture at harvest in a cropping situation to reduce weed seed numbers for the coming seasons crop. Grass control in the preceding grain legume or oilseed crop is essential to reduce diseases that may use grass weeds as hosts. Crop sequencing is a key part of a long-term farming system's approach to tackling weed, disease and moisture challenges. Nitrogenfixing pulses are gaining popularity as cereal breaks. Paddock history should record chemicals applied to a paddock each year so appropriate withholding periods can be observed, fertilisers applied and a weed and disease audit conducted each year. Soil constraints of the paddock should also be considered when deciding on crop and variety options.



¹⁶ DAFWA (2016) Oats: paddock selection. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-paddock-selection</u>



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Limited option in grass weed

weed control chemicals.

rot, CCN, take-all, etc.

A smaller range of in-crop broadleaf

Still a cereal, so offers little disease

Lower yields than wheat and barley.

occurred due to the limited volumes

traded relative to wheat and barley.

break to diseases such as crown

Inconsistent grain prices have

control

1.3 Oats as a rotation crop

 Table 1: Advantages and disadvantages of Oats as a rotation crop.

Advantages of Oats as a rotation crop Disadvantages of Oats as a rotation crop

- Early sowing options—as less prone to frost damage and helps spread out the work load at a busy time.
- Long coleoptile length—enables deeper sowing when moisture is not close to the surface.
- Dual purpose nature—can graze or cut for hay.
- Selection of CCN resistant oat varieties offers a disease break for other cereals.
- Frost mitigation—sow into more frost prone paddocks as a more robust market for oaten hay if hit by severe frost. For example, in 2013, oats once again showed their tolerance to frost, compared with other cereals in some regions of Victoria and southern NSW.
- Oat mills offer forward contracts that can guarantee a market and price prior to planting.

1.4 Fallow weed control

Paddocks with well-managed fallow periods and brown manuring significantly lower the risk of poor crop and financial performance. The best form of weed control is rotation and careful selection of paddocks largely free from winter weeds, for example, vetch that has been brown manured.

Controlling fallow weeds prior to sowing oats is important for retaining soil moisture and nitrogen levels and facilitates early sowing. Fallow weed control also removes the 'green bridge', reducing the survival of aphids and the risk of aphid transmitted viruses. The green bridge is not associated with BYDV, however there may be a correlation with early sowing. Paddocks with well-managed fallow periods significantly lower the risk of poor crop and financial performance (Photo 3). Timely weed control reduces moisture losses and weed seed set. Maintaining ground cover increases moisture conservation. Absence (or restriction) of grazing periods maintains soil friability and ground cover. Prolonged grazing periods may create crop emergence problems through induced surface compaction. The green bridge provides a 'between-season' host for insects and diseases (particularly rusts); these pose a serious threat to future crops.

Paddocks generally have multiple weed species present at the same time, making weed control decisions more difficult and often involving a compromise after assessment of the prevalence of key weed species. Knowing your paddock and controlling weeds as early as possible is important for good control. Information is included for the most common problem weeds; however, for advice on individual paddocks you should contact your agronomist.



¹⁷ T Bray (2014) Irrigated milling oats set to roll. IREC Farmers' Newsletter – Large Area No. 190: Autumn 2014, <u>http://irec.org.au/wp-content/uploads/FN%20190.pdf</u>



FEEDBACK



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VIDEOS

WATCH: GCTV5: <u>Managing summer</u> fallow.



Photo 3: Fallow paddock. Source: Farmers Weekly Photo: Tim Scrivener

Benefits of fallow weed control are significant:

- Conservation of summer rain and fallow moisture (this can include moisture stored from last winter or the summer before in a long fallow) is integral to winter cropping, particularly so as the climate moves towards summer-dominant rainfall.
- Modelling studies show that the highest return on investment in summer weed control is for lighter soils or in situations where soil water that would support continued weed growth is present. ¹⁸

1.4.1 Management strategies

- Outright kill of the weeds and volunteers is the only certain way to avoid them hosting diseases and insects.
- Diseases and insects can quickly spread from the green bridge or summer weeds, jeopardising crops and current control methods, including the effectiveness of chemicals and genetic breeding for resistance.
- Effective control of pest and disease risks requires neighbours to work together to simultaneously eradicate weeds and crop volunteers.
- Weed growth during summer and autumn also depletes soil moisture and nutrients that would otherwise be available to following crops and can have an allelopathic effect.¹⁹

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

Practices such as controlled traffic farming and long-term no-till seek to change the very nature of soil structure to improve infiltration rates and improve plant access to stored water by removal of compaction zones.

Shorter-term management decisions can have an equal or even greater impact on how much plant available water (PAW) is stored at sowing. These include decisions such as crop sequence/rotation that dictate the length of the fallow and amount of stubble cover, how effectively fallow weeds are managed, stubble management and decisions to till/not to till at critical times.



¹⁸ GRDC (2012) Summer fallow—make summer weed control a priority. GRDC Fact Sheet January 2012.

¹⁹ GRDC (2009) Green bridge—the essential crop management tool. GRDC Fact Sheet, <u>http://www.grdc.com.au/uploads/documents/</u> <u>GRDC_GreenBridge_FS_6pp.pdf</u>



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i) MORE INFORMATION

FEEDBACK

Section 6: Weed control

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

VIDEOS

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



While many factors influence how much plant available water is stored in a fallow period, good weed management consistently has the greatest impact. $^{\rm 20}$

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1.4.2 Stubble retention

Key points

- Retaining stubble has several advantages to soil fertility and productivity.
- Retaining stubble can decrease erosion and increase soil water content.
- Benefits of stubble retention are enhanced by reduced tillage and leguminous crop rotations.

Historically, stubble has been burnt in southern Australia because it creates easier passage for seeding equipment, enhances seedling establishment of crops, and improves control of some stubble-borne diseases and herbicide resistant weeds. However, the practice of burning stubble has recently declined due to concerns about soil erosion, loss of soil organic matter and air pollution. Stubble is increasingly being retained, which has several advantages of soil fertility and productivity (Photo 4). Summer rainfall and warmer conditions promote decomposition of stubble.



Photo 4: Cereal sown into stubble. Source: Kaspar T in MCCC.

Reducing erosion risk

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

Increasing soil water content

A major advantage of retaining stubble is that it increases soil water content by decreasing runoff and increasing infiltration. The actual benefits depend on the timing and intensity of rainfall as well as the quantity and orientation of stubble. Late summer–early autumn rains have more chance of improving the germination and establishment of the next crop. In addition, increased infiltration of water over summer can result in greater nitrogen mineralisation and availability for the subsequent crop.

Increasing soil carbon

Retaining stubble increases the input of carbon to soil. Stubble is approximately 45% carbon by weight and represents a significant input of carbon to soil. It can take decades for retaining stubble to increase the amount of soil organic carbon. After 10

20 GRDC (2014) Summer fallow weed management, <u>https://grdc.com.au/Resources/Publications/2014/05/Summer-fallow-weed-management</u>





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i) MORE INFORMATION

Developments in stubble retention.

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



WATCH : Managing Stubble.



WATCH : Stubble height part 1 and part 2.



years, stubble retention generated 2 t/ha more soil organic carbon than stubble burnt plots to a depth of 10 cm in a red chromosol during cropping trials with ley pasture rotations at Wagga Wagga. After 25 years the inclusion of a clover pasture in the rotation in the same trial had a greater effect on soil organic carbon increases even with tillage compared to stubble retention. Retaining stubble may only increase soil carbon where it is coupled with cultivation but not with direct drilling. Latest findings indicate that soil carbon increases are extremely difficult to achieve and maybe related more to annual rainfall than to any surface treatment. ²¹

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

Other benefits of stubble retention

Retaining stubble returns nutrients to the soil, but the amounts depend on the quality and quantity of stubble. Wheaten stubble from a high yielding crop may return up to 25 kg of available N/h to the soil. The addition of organic matter with retained stubbles supports soil life, and can improve soil structure, infiltration, biological activity, and water holding capacity. These benefits are greater when integrated with no-till practices. ²²

Management practices affecting stubble cover

Stubble burning, grazing and cultivation are the main management practices with the potential to reduce stubble cover. A single tillage operation using a chisel plough, for example, can reduce stubble coverage by 30–40% (Table 2).

It is recommended that stubble cover be maintained as long as possible in the fallow, and that planting and fertilising machinery be adapted to minimise disturbance. Where cultivation is required in order to control herbicide resistant weeds, this should be carried out as a one off operation. ²³

Table 2: Estimated reduction in wheat or barley stubble cover from differenttillage operations. (Reproduced from Measuring stubble cover: Photo standards forwinter cereals.)

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

Source: Soilquality

23 Soilquality.org. Benefits of retaining Stubble—Queensland, http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble-in-gld



²¹ Sonogan R. (2016). Personal communication.

²² Soilquality.org. Benefits of retaining stubble—NSW, <u>http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble-nsw</u>









1.5 Fallow chemical plant-back effects

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of a subsequent crop (Table 3). Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods, (e.g. sulfonylureas (chlorsulfuron)). Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the 'Protection of crops etc.' heading in the 'General Instructions' section of the label.²⁴

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 Table 3: Residual persistence of common pre-emergent herbicides used across a range of crops in broadacre agriculture, and noted residual persistence in broad acre trials and paddock experiences. ²⁵

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high pH soils. Weed control commonly drops off within 6 weeks.
Glean® (chlorsulfuron)	28–42	High. Persists longer in high pH soils. Weed control longer than Logran®.
Diuron	90 (range 1 month to 1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Has had observed long lasting activity on grass weeds such as black/stink grass (<i>Eragrostis spp.</i>) and to a lesser extent broadleaf weeds such as fleabane.
Atrazine	60–100, up to 1 year if dry	High. Has had observed long lasting (>3 months) activity on broadleaf weeds such as fleabane.
Simazine	60 (range 28–149)	Med/high. 1 year residual in high pH soils. Has had observed long lasting (>3 months) activity on broadleaf weeds such as fleabane.
Terbyne® (terbulthylazine)	6.5–139	High. Has had observed long lasting (>6 months) activity on broadleaf weeds such as fleabane and sow thistle.
Triflur® X (trifluralin)	57–126	High. 6–8 months' residual. Higher rates longer. Has had observed long lasting activity on grass weeds such as black/stink grass (<i>Eragrostis spp</i> .).
Stomp [®] (pendimethalin)	40	Medium. 3–4 months' residual.
Avadex® Xtra (triallate)	56–77	Medium. 3–4 months' residual.
Balance® (isoxaflutole)	1.3 (metabolite 11.5)	High. Reactivates after each rainfall event. Has had observed long lasting (>6 months) activity on broadleaf weeds such as fleabane and sow thistle.

24 B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/_____data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf</u>

25 B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf</u>





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Conditions required for breakdown

Warm, moist soils are required to breakdown most herbicides through the processes of microbial activity. For the soil microbes to be most active they need good moisture and an optimum soil temperature range of 18°C to 30°C. Extreme temperatures above or below this range can adversely affect soil microbial activity and slow herbicide breakdown. Very dry soil also reduces breakdown. To make matters worse, where the soil profile is very dry it requires a lot of rain to maintain topsoil moisture for the microbes to be active for any length of time.

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

If dry areas do get rain and the temperatures become milder, then they are likely to need substantial rain (more than the label requirement) to wet the sub-soil, so the topsoil can remain moist for a week or more. This allows the microbes to be active in the topsoil where most of the herbicide residues will be found. ²⁶

Plant-back periods for fallow herbicides in the Southern region

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

When treating fallow weeds, especially in late summer or autumn, consideration must be given to the planned crop or pasture for the coming year. In some cases, the crop or pasture for the following year may also have an influence on herbicide choice.

Most herbicide residues are broken down by microbial activity in the soil. The soil microbes require warm, moist soil to survive and "feed" on the chemical. Degradation of chemical residue is slower when soils are dry or cold. Soil type and pH also have an influence on the rate at which chemicals degrade.

The following points are especially relevant:

- Phenoxy herbicides such as 2,4D Ester, 2,4D Amine and Dicamba, require 15 mm of rainfall to commence the plant-back period when applied to dry soil.
- Group B herbicides such as Ally, Logran and Glean break down more slowly as soil pH increases. Recently applied lime can increase the soil surface pH to a point where the plant-back period is significantly extended.
- Lontrel, Grazon and Tordon products break down very slowly under cold or dry conditions, which can significantly extend the plant-back period.

Keeping accurate records of all herbicide treatments and planning crop sequences well in advance can reduce the chance of crop damage resulting from herbicide residues (Table 4). ²⁷

- 26 Dow AgroSciences. Rotational crop plant-back intervals for southern Australia, <u>http://msdssearch.dow.com/PublishedLiteratureDAS/</u> <u>dh_0931/0901b80380931d5a.pdf?filepath=au&fromPage=GetDoc</u>
- 27 RMS (2016) Plant-back periods for fallow herbicides in Southern-NSW, <u>http://www.rmsag.com.au/2016/plant-back-periods-for-fallow-herbicides-in-southern-nsw/</u>





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Table 4: The below table provides indicative plant-back intervals for a selection of relevant herbicides.

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Product	Rate	Plant-back period	Wheat	Barley	Oats	Canola	Legume Pasture	Pulse Crops
2,4-D 680*	0—510 ml/ha	(days)	1	1	1	14	7	7
	510—1,150 ml/ha		3	3	3	21	7	14
	1,150—1,590 ml/ha		7	7	7	28	10	21
Amicide Advance 700*	0 – 500 ml/ha	(days)	1	1	1	14	7	7
	500 - 980 ml/ha		3	3	3	21	7	14
	980–1500 ml/ha		7	7	7	28	10	21
Kamba*	200 ml/ha	(days)	1	1	1	7	7	7
	280 ml/ha		7	7	7	10	14	14
	560 ml/ha		14	14	14	14	21	21
Hammer 400 EC					No	Residual	Effects	
Nail 240 EC					No	Residual	Effects	
Goal					No	Residual	Effects	
Striker					No	Residual	Effects	
Sharpen	26 g/ha	(weeks)	-	-	-	16	-	-
Lontrel	300 ml/ha	(weeks)	1	1	1	1	36	36
Garlon 600		(weeks)	1	1	NS	NS	NS	NS
Ally**		(weeks)	2	6	36	36	36	36
Logran #		(months)	-	-	-	12	12	12
Glean**		(months)	-	9	6	12	12	12
Grazon Extra /Grazon DS		(months)	9	9	NS	9	24	24
Tordon 75D, Tordon 242		(months)	2	2	NS	4	9	6
Tordon Fallow Boss		(months)	9	9	NS	12	20	20

Table key:

15 mm rainfall required to commence plant-back period Period may extend where soil pH is greater than 7 Assumes 300 mm rainfall between chemical application and sowing

NS Not Specified

Source: <u>RMS</u>

1.5.1 Herbicide residues in soil—an Australia wide study

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

In addition, little is known about how herbicides affect soil biological processes and what this means for crop production. This is especially the case for repeated applications over multiple cropping seasons. In Australia, herbicides undergo a rigorous assessment by the Australian Pesticides and Veterinary Medicines Association (APMVA) before they can be registered for use in agriculture. However, relatively little attention is given to the on farm soil biology—partly because we are only now beginning to grasp its complexity and importance to sustainable agriculture.





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Although a few tests are mandatory, such as earthworm toxicity tests and effects on soil respiration, functional services provided by soil organisms such as organic matter turnover, nitrogen cycling, phosphorus solubilisation and disease suppression are usually overlooked.

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GRDC recently co-funded a five-year project (DAN00180) to better understand the potential impacts of increased herbicide use on key soil biological processes. This national project, coordinated by the NSW Department of Primary Industries with partners in Western Australia, South Australia, Victoria and Queensland, is focused on the effect of at least six different herbicide classes on the biology and function of five key soil types across all three grain growing regions.

Below are the results of a field survey of herbicide residues in 40 cropping soils prior to sowing and pre-emergent herbicide application in 2015 (Table 5).

Table 5: Residue loads (average and maximum) of herbicide active ingredients (active ingredient) in the 0–30 cm soil profile of paddocks by region.

Estimated average load across all sites (kg a.i./ha)*			Estimated maximum load detected (kg a.i./ha)*			
NSW-Qld	SA	WA	NSW-Qld	SA	WA	
0.91	0.95	0.92	1.92	1.97	2.21	
0.56	0.48	0.79	2.05	1.05	1.75	
0.08	0.11	0.53	0.14	0.26	1.34	
0.01	0.03	0.04	0.02	0.05	0.09	
0.14	0.05	0.17	0.16	0.05	0.29	
0.20	0.02	0.01	1.00	0.05	0.02	
0	0	0	0	0	0	
0.02	0.03	0.02	0.03	0.05	0.02	
0	0.04	0	0	0.05	0	
0.03	0	0	0.03	0	0	
0	0	0	0	0	0	
0	0.04	0.01	0	0.07	0.01	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
	Estimated NSW-QId 0.91 0.08 0.08 0.01 0.01 0.02 0.02 0.02 0.02 0.03 0 0.03 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Estimated stress (kg at a stres	Batimated sets (kg strike sets)NSW-QidSAWANSW-Qid0.950.920.910.950.920.560.480.790.080.110.530.010.030.040.140.050.170.140.050.170.140.050.170.140.050.170.140.020.170.140.020.170.150.020.170.020.030.020.030.030.020.040.010.140.030.040.140.040.010.140.050.040.140.040.040.140.050.140.14 <trr><t< td=""><td>Estimated werage with solution of the section of the</td><td>Stimmated Series (kg series</td></t<></trr>	Estimated werage with solution of the section of the	Stimmated Series (kg series	

MORE INFORMATION

Herbicide residues in soils – are they an issue?

Weed control in winter crops.

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

Conclusions

- Glyphosate, trifluralin and diflufenican are routinely applied in grain cropping systems and their residues, plus the glyphosate metabolite AMPA, are frequently detected at agronomically significant levels at the commencement of the winter cropping season.
- Given the frequency of glyphosate application, and the persistence of trifluralin and diflufenican, further research is needed to define critical thresholds for these chemicals to avoid potential negative impacts to soil function and crop production. 28

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

M Rose, L Van Zwieten, P Zhang, D Nguyen, C Scanlan, T Rose, G McGrath, T Vancov, T Cavagnaro, N Seymour, S Kimber, A Jenkins, A Claassens, I Kennedy I (2016) GRDC Update Paper: Herbicide residues in soils—are they an issue? <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Herbicide-residues-in-soils-are-they-an-issue</u> 28





1.6 Seedbed requirements

Oats seed needs good soil contact for germination. This can be assisted with press wheels, coil packers or rollers. Soil type determines the implement that produces the ideal seedbed. Between 70 and 90% of seeds sown produce a plant if vigour and germination are high. Depth of sowing, disease, crusting, moisture and other stress in the seedbed all reduce the number of plants establishing. Field establishment is unlikely to be more than 90% and may be as low as 60% if seedbed conditions are unfavourable. Seedbed preparation is also important to emergence. A cloddy seedbed may reduce emergence, as the clods allow light to penetrate below the soil surface. The coleoptile senses the light and stops growing while still below the surface.²⁹ For successful crop establishment, seed needs to be placed into soil with enough seedbed moisture for germination to occur, or into dry soil with the anticipation of rainfall to increase soil moisture levels such that germination may occur. Oats are ideally suited to 'moisture seeking' as they generally have a longer coleoptile length than wheat and barley. The practice of 'moisture seeking', where seed is placed deeper in the soil than is generally recommended, aims to promote timely crop establishment. This practice generally involves the use of tines to open a furrow to a depth of >7.5 cm, into which the seed is then placed, followed by a press wheel to close moist soil around the seed.

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A good seedbed should be weed, disease and insect free. It should provide good seed/soil contact and be moist and warm. To aid in erosion control use implements that will preserve the previous crop residue. Substituting herbicides for cultivation and seeding without pre-seeding tillage (minimum to zero till) are other practical considerations. Under dry or firm soil conditions, seed with seeding implements that minimize soil disturbance, such as air drills with disc or narrow openers, to prevent soil drying.

When shallow seeding, the previous crop's residue will have a greater tendency to interfere with good seed-to-soil contact. Even spreading of the previous crop residue is essential for quick emergence. Make sure seed-to-soil contact occurs. When seeding on summer fallow, take extra care to obtain a firm seedbed to facilitate shallow seed placement into moist soil and to prevent soil erosion by wind.

If irrigating, pre-irrigation is favoured over "irrigating up" after sowing, as seeds can swell and burst. Sowing after pre-irrigation should be as soon as soil conditions allow. For an April 1st pre-irrigation, this delay may range from one week on light soils to 3–4 weeks on some heavy clay soils.

Following the initial irrigation, subsequent irrigations should be at a cumulative evaporation less rainfall interval (E-R) of 75 mm on grey soils and 50 mm on red soils.

Pre-irrigation completed by April 1st is a safe option in most years. Later irrigations can cause problems by making the ground too wet for both sowing and grazing.

If not pre-irrigated, then the crop should be sown following sufficient rainfall to wet the soil to 100 mm depth. $^{\rm 30}$

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

The seedbed lays the foundations for crop establishment. However, there are different techniques that can be used to create a seedbed. The technique used depends on many different factors, e.g. harvest residues, the equipment available, soil type, climate, labour requirement, etc (Figure 2).



²⁹ District Agronomists (2008) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries 2007, <u>http://</u> www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

³⁰ Agriculture Victoria. Managing winter cereals, <u>http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/irrigated-pastures/</u> managing-winter-cereals



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Figure 2: Diagram demonstrating the results of different seedbed preparation techniques.

Source: Vaderstad

The seedbed and sowing using different techniques:

- 1. <u>Conventional technique</u>: ploughing in of straw, cultivation to sowing depth with a tyne/disc cultivator, conventional drilling, fertiliser spreading.
- 2. <u>Mouldboard ploughing:</u> Ploughing in of straw.
- 3. <u>Minimal tillage</u>: tillage of straw by cultivator.
- 4. <u>Shallow tillage</u>: shallow burial of straw at the surface.
- 5. <u>Direct drilling:</u> The straw remains on the surface.

Ploughing warms up the soil and buries plant residues so that they do not obstruct sowing. However, ploughing disrupts the soil structure and increases oxidation of the organic material. Without ploughing, the organic material and the soil structure are retained, but the straw can cause problems with sowing and can transmit diseases.³¹

1.6.1 Seedbed soil structure decline

Key Points

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

Background

Surface soil structure decline generally results in one of two things: hard-setting or crusting (Photo 5). A surface crust is typically less than 10 mm thick and when dry can normally be lifted off the loose soil below. Crusting forces the seedling to exert more energy to break through to the surface thus weakening it. A surface crust can also form a barrier, reducing water infiltration.

Soil structure breakdown caused by rapid wetting can lead to hard-setting. Once wet, the unstable soil structure, collapses, and then shrinks as it dries. This leads to a "massive" soil layer with little or no cracks and greatly reduced pore space. This hard-set "massive" structure is associated with poor infiltration, low water holding capacity







and a high soil strength. In many instances, this causes patchy establishment and poor crop and pasture growth.



Photo 5: Soil crusting (left) and cloddy seedbed (right) associated with high concentrations of exchangeable sodium.

Source: Soilquality.org

Management to improve seedbed soil structure

To decrease the level of crusting or hard-setting in soils, it is necessary to stabilise soil structure. For example, amelioration of a hard-setting grey clay was found to be most effective using management practices that increased soil organic matter and reduced trafficking, thereby improving soil structure. Removing or reducing stock when the soil is saturated also helps avoid compaction, smearing and "pugging" of the soil surface.

Another option for stabilising soil structure in soils prone to hard-setting or crusting is through the addition of gypsum on dispersive soils. This effectively displaces sodium, and causes clay particles to bind together, helping to create stable soil aggregates. A resulting reduction in the exchangeable sodium percentage (ESP) and increase in the calcium/magnesium ratio may be observed. Addition of lime also adds calcium to the soil, but is generally only used for soils with a low pH. ³²

1.7 Soil moisture

Forage oats will grow on most soils but will not provide good recovery on strongly acidic soils or wet soils that develop aluminium and manganese toxicities.

1.7.1 Dryland

The practice of using soil moisture probes has had limited use in the dryland cropping industry and as such many farmers are unable to utilise this technology.

The Department of Environment and Primary Industries will provide live deep soil moisture data to help dryland croppers, farmers, and advisors/managers validate the technology, as well as conducting training to interpret the data for crop decision making. E-Communication includes monthly broadcasts of 'The Break', soil moisture products, and piloting new technology formats to expand reach and impact.

Eleven sites across Victoria are being monitored using 'capacitance probes' that take hourly measurements of soil water content through the soil profile. Sensors on the capacitance probes measure zones every 10 cm, from a depth of 30 cm down to 1 m. A total of eight measurements from eight probes are taken at each site, with the







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data collected sent via the mobile phone network to a server which stores the data to allow interpretation through graphing software. ³³

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Measuring soil moisture will help provide an indication of:

- yield potential based on plant-available water
- crop water use
- sub soil moisture base and reserves
- rainfall required to refill soil profile
- water infiltration
- water logging
- water use of different crops.

Access to this data enables growers and advisers to:

- measure moisture at one representative point in the paddock for a farm in the region
- use live soil moisture data that is collected from a representative site for a
 particular rainfall region and soil type
- monitor localised weather (rain, wind and temperature/humidity) and have the ability to download historical data from an archive list for farm management records
- increase production and efficiencies
- help farmers to adapt to climate variability
- make informed input decisions such as minimising input in low decile years with a low soil moisture base and maximising yield potential in more favourable conditions based on current soil moisture levels and incorporating seasonal forecasts probabilities
- determine if measurements obtained through the life of the project could be relevant at whole farm or even district level. ³⁴

Table 6: Examples of options you may choose for your paddocks depending on the soil moisture results obtained. Being able to accurately measure soil moisture when required provides opportunities to aid management decisions at various stages in the production cycle. As more information is collected over a wider range of seasons, confidence levels will increase as comparisons can be used to different years.

Production stage	Moisture level	Management action
Sowing	High	Early sow long season varieties, canopy management to maximise yields. Up front N.
Sowing	Middle	Reduce upfront input costs, seed rate, fertiliser, and herbicides. Canopy management for average yields.
Sowing	Low	Reduce upfront costs, and seed rate. Consider decreasing area sown, target lower risk crops and more productive paddocks.
Early/late tillering	High	High confidence in N application, weed and disease management.
Early/late tillering	Middle	Lower confidence level. Reduce rates of N application.
Early/late tillering	Low	Low confidence level. Reduce costs, consider grazing or hay later in the season.

33 Agriculture Victoria (2014) Soil Moisture Monitoring in Dryland Cropping Areas. Risk management through soil moisture monitoring project. Agriculture Victoria, May 2014, <u>http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/soil-moisture-monitoring-in-dryland-cropping-areas</u>

34 Agriculture Victoria (2014) Soil Molsture Monitoring in Dryland Cropping Areas. Risk management through soil moisture monitoring project. Agriculture Victoria, May 2014. <u>http://agriculture/ic.gov.au/agriculture/grains-and-other-crops/crop-production/soil-moisture-monitoring-in-dryland-cropping-areas</u>





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Production stage	Moisture level	Management action
Stem elongation	High	High confidence. Apply late N, fungicides and pesticides.
Stem elongation	Middle	Lower confidence. Reduce rates of N.
Stem elongation	Low	Low confidence. No N. No forward selling. Consider grazing and hay production.
Flowering	High	High confidence. Consider forward selling options if favourable. Head counts to determine potential yield.
Flowering	Middle	Lower confidence. Reduce forward selling quantities. Head counts to determine potential yield.
Flowering	Low	Low confidence. No N. No forward selling, consider grazing and hay production.
Pre-harvest	High/ middle/ low	Determine potential yields. Adjust insurance estimates.

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 $Source: \ \ \ http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/soil-moisture-monitoring-in-dryland-cropping-areas and the second second$

Devices for soil monitoring

In-situ devices that have relatively small zones of measurement and rely on good soil-sensor contact to measure soil water are at a disadvantage in shrink-swell soils where soil movement and cracking are typical. This is more important in dryland than irrigated systems as seasonal soil water levels vary from above field capacity through to wilting point or lower. Consequently, the potentially high levels of error associated with cracking and soil movement and high levels of inherent soil variability mean that increased device replication would be necessary to achieve confidence in results. This comes at an increased capital cost. Some devices (capacitance; time domain reflectometry (TDR)) also have an upper measurement limit over which they are unable to accurately measure soil water. This may be a problem on high clay soils where moisture content at drained upper limit is likely to be >50% volumetric, the common limit for these devices. By comparison, the use of a portable electromagnetic induction (EMI) device to measure bulk electrical conductivity and calculate soil water has a number of advantages. The EMI is guick, allowing for greater replication, measures the soil moisture of a large volume of soil (to 150 cm depth), is not affected by cracking or soil movement, and does not require installation of an access tube, thus making it available for use on multiple paddocks. However, it is unsuitable for use in saline soils and does not assign soil water to particular layers within the soil profile. $^{\rm 35}$

New thoughts on soil moisture monitoring

Despite there being an extensive range of monitoring instruments now available, measuring paddock soil moisture is still a considerable challenge. Among the suite of instruments currently on offer, one that is increasingly being used by researchers and agronomists is the EM38 (Geonics Ltd, Ontario, Canada). This electromagnetic induction instrument is proving to have significant application potential for determining soil properties useful in precision agriculture and environmental monitoring. It is now commonly used to provide rapid and reliable information on properties such as soil salinity and soil management zones, both of which relate well to crop yield. It is also used widely in agronomic and environmental applications to monitor soil water within the root-zone. It provides an efficient means to monitor crop water use and plant-available water (PAW) in the soil profile throughout the growing season so that informed management decisions can be made (e.g. the application, timing and conservation of irrigation water and fertiliser). EM38 datasets



³⁵ N Dalgliesh, N Huth (2013) New technology for measuring and advising on soil water. GRDC Update Papers Goondiwindi March 2013, http://www.ardc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-onsoil-water.



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have also proved valuable to test and validate water-balance models that are used to extrapolate to other seasons, management scenarios and locations. The EM38 is an easy-to-use, geophysical surveying instrument that provides a rapid measure of soil electrical conductivity. Soil calibrations or qualitative assessments can be used to convert this to estimates of soil water in the root-zone. This information is vital to farm management decisions based on accurate knowledge of soil PAW. ³⁶

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Calibration of monitoring devices

Electronic monitoring tools require calibration to convert the device output signal into information easily understood by the user (e.g. millivolts to volumetric soil water or PAW). This process requires the development of a relationship between sensor output and physically measured soil moisture content at moisture levels from dry to wet. The resulting calibration is then used to convert device output signal to gravimetric or volumetric water content.

Modelling of soil water

Simulation of the water balance should be considered as an alternative to field-based soil water monitoring. Considering the error surrounding in-field measurement and issues with installation of sensing devices, there is a reasonable argument that the modelling of the water balance, when initialised with accurate plant-available water capacity (PAWC) and daily climate information, is likely to be as accurate as direct measurement. APSIM and Yield Prophet successfully predict soil water and they should be considered for both fallow and cropping situations. CliMate is a logical choice for managing fallow water. ³⁷

Effect of strategic tillage

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

Research has shown that one-time tillage with chisel or offset disc in long-term, notillage systems helped to control winter weeds, and slightly improved grain yields and profitability, while retaining many of the soil quality benefits of no-till farming systems (Photo 6).



Photo 6: The impact of tillage varies with the tillage implement used: inversion tillage using a mouldboard plough, as pictured here, results in greater impacts than using a chisel or disc plough.

Source: https://grdc.com.au/Resources/Factsheets/2014/07/Strategic-tillage



Foley (2013) A 'how to' for getting soil water from your EM38 field measurements. GRDC Update Papers Goondiwindi March 2013, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/A-how-to-for-getting-soil-water-from-your-EM38-field-measurements</u>

³⁷ N Dalgliesh, N Huth (2013) New technology for measuring and advising on soil water. GRDC Update Papers Goondiwindi March 2013, http://www.ardc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-onsoil-water


SECTION 1 OATS



i) MORE INFORMATION

<u>GRDC Strategic Tillage Tips and</u> <u>Tactics fact sheet</u>



WATCH : <u>Strategic tillage, does no-till</u> mean never till?



WATCH : <u>Over the Fence South:</u> Andrew Simpson – Strategic tillage.



WATCH : Adoption of NoTill SA Mallee.



In this research, tillage reduced soil moisture at most sites; however, this decrease in soil moisture did not adversely affect productivity. This could be due to good rainfall received after tillage and prior to seeding and during the crop of that year. The occurrence of rain between the tillage and sowing or immediately after sowing is necessary to replenish soil water lost from the seedzone. This suggests the importance of tillage and of considering the seasonal forecast. Future research will determine the best timing for strategic tillage in no-till systems (Photo 7). ³⁸ Note that these results are from one season and research is ongoing, so any impacts are likely to vary with subsequent seasonal conditions and fallowing itself is not common practice in the Southern region.

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Photo 7: Strategic tillage can provide control for herbicide-resistant weeds and those that continue to shed seed throughout the year. Here it has been used for control of barnyard grass in fallow.

Source: <u>GRDC</u>

Tillage can, however, also result in increased soil erosion and surface water eutrophication. During the past 30 years, much progress has been made in reducing tillage. No-tillage crop production has increased 2.5-fold from about 45 million ha worldwide in 1999 to 111 million ha in 2009. One downside of this trend is increased use of herbicides for weed suppression. ³⁹

In general, pre-plant tillage to prepare the seedbed, control weeds, and disrupt insect and disease life cycles improves crop establishment. However, with cereal rye or other small grains, no-till establishment is an effective option that allows maintenance of the no-till system. Conventional seedbeds are prepared by ploughing, discing, and harrowing the soil prior to seeding. Seeding depth depends upon the species being sown. ⁴⁰

- 38 Y Dang, V Rincon-Florez, C Ng, S Argent, M Bell, R Dalal, P Moody, P Schenk (2013) Tillage impact in long term no-till. GRDC Update Papers February 2013, <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Tillage-impact-in-long-term-no-till</u>
- 39 MR Ryan, SB Mirsky, DA Mortensen, JR Teasdale, WS Curran (2011) Potential synergistic effects of cereal rye biomass and soybean planting density on weed suppression. Weed science, 59(2), 238–246.
- 40 Cover crops for conservation-tillage systems, <u>http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/cover-crops-for-conservation-tillage-systems</u>







Irrigation is the controlled application of water to land for the purpose of agricultural production. Effective irrigation will influence the entire growth process from seedbed preparation, germination, root growth, nutrient utilisation, plant growth and regrowth, yield and quality.

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The ability of oats to withstand waterlogged conditions better than other cereals makes them well suited to cropping systems in high rainfall regions and on flood irrigation, particularly following rice. Oats provide an excellent rotation option for irrigators in southern NSW, though irrigation is not often practiced in the Southern region. Oats withstand waterlogged conditions better and generally grow well with less inputs than other winter crops. Oats can utilise more water than any other cereal (excluding rice). The security of irrigated oat production and the high quality of oats produced is attracting premiums and great interest from processors. The National Oat Breeding Program has supported the expansion of oats onto irrigation with the first National Variety Trial (NVT) irrigated oat evaluation at Yanco NSW in 2013 (Figure 3). While oat yields may not be comparable to wheat, cost inputs for fertiliser are usually less.⁴¹



Figure 3: Yield results of an oat variety trial under irrigated conditions conducted at Yanco in 2013.

Source: NVT

The future of irrigation

Climate change is likely to lead to reductions in rainfall. These reductions in rainfall will be amplified such that proportional reductions in runoff are likely to be two to four times larger. That is, a 10% rainfall reduction will lead to a 20–40% reduction in runoff. The runoff reductions will be larger in drier catchments, making the water supply systems with drier source catchments more vulnerable. The experience of the Millennium Drought has shown that reductions in runoff under persistent climate changes (~10 year drought) are larger than reductions that occur for short droughts with similar rainfall reductions in many catchments. ⁴²



Agriculture Victoria: About Irrigation

<u>GRDC Update Paper: The Future of</u> <u>irrigation, what's in store.</u>



⁴¹ T Bray (2014) Irrigated milling oats set to roll. IREC Farmers' Newsletter – Large Area No. 190: Autumn 2014, <u>http://irec.org.au/wp-content/uploads/FN%20190.pdf</u>

⁴² A Western, M Saft M, M Peel (2016) GRDC Update Papers: The future of irrigation—what's in store? <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/The-future-of-irrigation-whats-in-store</u>



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1.8 Yield and targets

Yield potential (as opposed to achieved yield) is determined in the growth phase before anthesis during the formation and growth of the ear. Yield potential can best be thought of in terms of the number of grains per unit area and the size (weight) of each grain. There are several critical times during crop development where grain number and size are determined. The first step in establishing yield potential is that of crop establishment; i.e. how many plants per square metre, as this directly effects the number of heads per metre squared a crop can produce.⁴³

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

Yield potential in the southern region depends on seasonal rainfall, especially in autumn and spring, and there is less dependence on stored soil moisture than in the northern region.

In the Southern grain-growing region, the most significant yield constraints are high soil density, sodicity and acidity. $^{\rm 44}$

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

- Do a simple calculation to see how much water you need to achieve this yield.
- Know how much soil water you have (treat this water like money in the bank).
- Think about how much risk your farm can take.
- Consider how this crop fits into your cropping plan, will the longer-term benefits to the system outweigh any short-term losses?
- Avoiding a failed crop saves money now and saves stored water for future crops.⁴⁵

Estimating crop yields

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

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

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

Estimation methods

There are many methods available for farmers and others to estimate yield of various crops. Some are straightforward, whereas others are more complicated. The method presented here is one that can be undertaken relatively quickly and easily. Steps are as follows:

- Select an area that is representative of the paddock. Using some type of measuring rod/tape, measure out an area 1 m² and count the number of heads/pods.
- 2. Do this five times to get an average of the crop.

- 44 Soilquality.org. Biological inputs—Southern Australia, <u>http://www.soilquality.org.au/factsheets/biological-inputs-southern-grain-growing-region</u>
- 45 J Whish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Papers 23 July 2013, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/impact-of-stored-water-on-risk-and-sowing-decisions-inwestern-NSW</u>



⁴³ N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC, https://grdc.com.au/CanopyManagementGuide



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- 3. Count the number of grains in at least 20 heads/pods and average.
- 4. Determine the grain weight for the crop concerned and follow through the calculation outlined below (Table 7). Oats 100 grain weight = 4 g. ⁴⁶

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Table 7: Methodology for estimating yield. 47

Number of heads/pods per square meter	(A)	Example	220
Average number of grains per head/pod	(B)	Example	24
Number of grains per square metre = AxB	(C)	Example	= 220 x 24 = 5280
Yield per square meter = C/100 x 3.4gms	(D)	Example	= 5280/100 x 3.4 = 179.52gms
Yield in t/ha = $D/100$		Example	= 179.52/100 = 1.79t/ha

The same method can be used for any other grain crop as long as you choose the correct seed weight. The basis behind this method for estimating yields is the counting of heads or pods per square meter.

Accuracy of yield estimates depends upon an adequate number of counts being taken so as to get a representative average of the paddock. The yield estimate determined will only be a guide and assumptions made from the estimates contain a degree of uncertainty.

This type of yield estimation is one of the easiest and quickest to complete and should be able to be used in a number of situations on a grain growing property. Grain losses both before and during harvest can be significant and an allowance for 5-10% loss should be included in your final calculations. ⁴⁸

Yield Prophet®

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

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

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

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

The simulations provide a framework for farmers and advisers to:

- forecast yield
- manage climate and soil water risk
- make informed decisions about N and irrigation applications
- match inputs with the yield potential of their crop

- 47 Agriculture Victoria. Estimating crop yields; a brief guide. <u>http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/estimating-crop-yields-a-brief-guide</u>
- 48 Agriculture Victoria. Estimating crop yields; a brief guide, <u>http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/estimating-crop-yields-a-brief-guide</u>



⁴⁶ Agriculture Victoria. Estimating crop yields; a brief guide. <u>http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/estimating-crop-yields-a-brief-guide</u>



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assess the possible effects of climate change

Farmers and consultants use Yield Prophet to match crop inputs with potential yield in a given season. This is achieved primarily by conducting scenario analyses in which the effects of alternative management options on crop yield and potential profitability can be assessed and applied, and can thereby influence decision making.

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How does it work?

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

- a soil test sampled prior to planting
- a soil classification selected from the Yield Prophet library of №1000 soils, chosen as representative of the production area
- historical and active climate data taken from the nearest Bureau of Meteorology (BOM) weather station
- paddock-specific rainfall data recorded by the user (optional)
- individual crop details
- fertiliser and irrigation applications during the growing season

1.8.1 Seasonal outlook

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

Mobile applications (apps) are providing tools for ground-truthing precision agriculture data. Apps and mobile devices are making it easier to collect and record data on-farm. The app market for agriculture is evolving rapidly, with new apps becoming available on a regular basis.⁴⁹

Australian CliMate

Australian CliMate is a suite of climate analysis tools delivered on the web, iPhone, iPad and iPod Touch devices. CliMate allows you to interrogate climate records to ask questions relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, as well as El Nino Southern Oscillation status. It is designed for decision makers such as farmers whose businesses rely on the weather. Download from the <u>Apple iTunes store</u> or <u>Australia ClMate</u>.

One of the CliMate tools, 'Season's progress?', uses long-term (1949–present) weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years. It explores the readily available weather data, compares the current season with the long-term average, and graphically presents the spread of experience from previous seasons. Crop progress and expectations are influenced by rainfall, temperature and radiation since planting. Season's progress? provides an objective assessment based on long-term records:

- How is the crop developing compared to previous seasons, based on heat sum?
- Is there any reason why my crop is not doing as well as usual because of below average rainfall or radiation?
- Based on the Season's progress? (and starting conditions from How wet? N?), should I adjust inputs?

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



Yield Prophet



GRDC Update paper: Managing data

on the modern farm



⁴⁹ R Heath (2013) Managing data on the modern farm. GRDC Update Papers 25 February 2013, <u>http://www.grdc.com.au/Research-and-</u> <u>Development/GRDC-Update-Papers/2013/02/Managing-data-on-the-modern-farm</u>



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presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. The Bureau of Meteorology has recently moved from a statistics-based to a physics-based (dynamical) model for its seasonal climate outlooks. The new system has better overall skill, is reliable, allows for incremental improvements in skill over time, and provides a framework for new outlook services including multi-week/monthly outlooks and the forecasting of additional climate variables. 50

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CropMate

Growers and advisers now have a readily available online tool. CropMate was developed by NSW Department of Primary Industries and can be used in pre-season planning to analyse average temperature, rainfall and evaporation. It provides seasonal forecasts and information about influences on climate, such as the impact of Southern Oscillation Index (SOI) on rainfall. The CropMate decision tool provides estimates of soil-water and N, frost and heat risk, as well as gross margin analyses of the various cropping options.

Download CropMate from the App Store on iTunes.

1.8.2 Fallow moisture

For a growing crop there are two sources of water: first, the water stored in the soil during the fallow, and second, the water that falls as rain while the crop is growing. As a farmer, you have some control over the stored soil water; you can measure how much you have before planting the crop. Long-range forecasts and tools such as the Southern Oscillation Index (SOI) can indicate the likelihood of the season being wet or dry; however, they cannot guarantee that rain will fall when you need it. ⁵¹

How wet?

How wet? is a program that uses records from a nearby weather station to estimate how much PAW has accumulated in the soil and the amount of organic N that has been converted to an available nitrate during a fallow. How wet? tracks soil moisture, evaporation, runoff and drainage on a daily time-step. Accumulation of available N in the soil is calculated based on surface soil moisture, temperature and soil organic carbon. How wet?:

- estimates how much rain has been stored as plant-available soil water during the most recent fallow period;
- estimates the N mineralised as nitrate-N in soil; and
- provides a comparison with previous seasons.

This information aids in the decision about what crop to plant and how much N fertiliser to apply.

Questions this tool answers:

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

Inputs:

- A selected soil type and weather station.
- J Sabburg, G Allen (2013) Seasonal climate outlook improvements changes from historical to real time data. GRDC Update Papers 18 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Seasonal-climate-outlook--changes-from-historical-to-real-time-data
- J Whish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Papers 23 July 2013, <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-update-source-autor-auto</u> <u>NSW</u>





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- An estimate of soil cover and starting soil moisture.
- Rainfall data input by the user for the stand-alone version of How often?.

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Outputs:

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

Reliability

How wet? uses standard water-balance algorithms from *How leaky*? and a simplified nitrate mineralisation based on the original version of *How wet*? Further calibration is needed before accepting with confidence absolute value estimates. Soil descriptions are based on generic soil types with standard organic carbon (C) and C/N ratios, and as such should be regarded as indicative only and best used as a measure of relative water accumulation and nitrate mineralisation.

1.8.3 Water Use Efficiency

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

Water Use Efficiency relies on:

- the soil's ability to capture and store water;
- the crop's ability to access water stored in the soil and rainfall during the season;
- the crop's ability to convert water into biomass; and
- the crop's ability to convert biomass into grain (harvest index).

Water is the principal limiting factor in rain-fed cropping systems in northern Australia. The objective of rain-fed cropping systems is to maximise the proportion of rainfall that crops use, and minimise water lost through runoff, drainage and evaporation from the soil surface and to weeds. Rainfall is highly variable and can range, during each cropping season, from little or no rain to major rain events that result in waterlogging or flooding.

Fallow efficiency: the efficiency with which rainfall during a fallow period is stored for use by the following crop.

Fallow efficiency (%) = <u>change in plant available water during the fallow x 100</u> fallow rainfall (mm)

Crop water use efficiency (WUE): the efficiency with which an individual crop converts water transpired (or used) to grain.

Crop WUE (kg/ha/mm) = grain yield (kg/ha) crop water supply (mm) – soil evaporation

Systems water use efficiency (SWUE): the efficiency with which rainfall is converted to grain over multiple crop and fallow phases.

SWUE (kg grain/mm rainfall) = total grain yield (kg) total rainfall (mm)

Increasing yield through Water Use Efficiency:

- 1. Increase the amount of water available to a crop (e.g. good summer weed control, stubble retention, long fallow, sowing early to increase rooting depth).
- Increase the proportion of water that is transpired by crops rather than lost to evaporation or weeds (e.g. early sowing, early N, vigorous crops and varieties, narrow row spacing, high plant densities, stubble retention, good weed management).





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i) MORE INFORMATION

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

Making the most of available water in wheat production.



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



WATCH : GCTV10: <u>Grazing stubbles</u> and Water Use Efficiency.



- 3. Increase the efficiency with which crops exchange water for carbon dioxide to grow dry matter, i.e. transpiration efficiency (e.g. early sowing, good nutrition, high transpiration efficiency varieties).
- Increase the total proportion of dry matter that is grain, i.e. improve harvest index (e.g. early-flowering varieties, delayed N, wider row spacing, low plant densities, minimising losses to disease, high harvest index varieties). ⁵²

The French-Schultz approach

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

Potential yield (kg/ha) = WUE (kg/ha × mm) x [crop water supply (mm) – estimate of soil evaporation (mm)]

Where crop water supply is an estimate of water available to the crop; i.e. soil water at planting plus in-crop rainfall minus soil water remaining at harvest. In the highly variable rainfall environment in the northern region, it is difficult to estimate in-crop rainfall, soil evaporation and soil water remaining at harvest. However, this model may still provide a guide to crop yield potential. The French-Schultz model has been useful in giving growers performance benchmarks where yields fall well below these benchmarks, it may indicate something wrong with the crop's agronomy or a major limitation in the environment. There could be hidden problems in the soil such as root diseases, or soil constraints affecting yields. Alternatively, apparent underperformance could be simply due to seasonal rainfall distribution patterns, which are beyond the grower's control. ³⁰

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

A practical WUE equation for farmers to use developed by James Hunt (CSIRO) is: WUE = (yield \times 1000) / available rainfall Where avail rain = (25% Nov-Mar rain) + (GSR) – 60 mm evap



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

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

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

Researchers have analysed some of the consequences of the shift from winter to summer rainfall between southern and northern regions in terms of implications for management and breeding. They advise caution on the use of simple rules of thumb (French–Schultz) for benchmarking WUE, and discuss the importance of more integrative and dynamic modelling approaches to explore alternatives to increase WUE at the single-crop and whole-farming-systems level, i.e. \$/ha.mm.⁵³



⁵² GRDC (2009) Water Use Efficiency—converting rainfall to grain. GRDC Fact Sheet Northern Region, <u>http://www.grdc.com.au/"/</u> media/607AD22DC6934BE79DEAA05DFBE00999.pdf

⁵³ Rodriguez (2008) Farming systems design and Water Use Efficiency (WUE). Challenging the French & Schultz WUE model. GRDC Update Papers, 13 June 2008, <u>https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/Farming-systemsdesign-and-water-use-efficiency-WUE-Challenging-the-French-Schultz-Wue-model</u>



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The fundamentals of increasing

nitrogen use efficiency.

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1.8.4 Nitrogen use efficiency

Key points

- Improving nitrogen use efficiency (NUE) begins with identifying and measuring meaningful NUE indices and comparing them with known benchmarks, and contrasting N management tactics.
- Potential causes of inefficiency can be grouped into six general categories. Identification of the most likely groups is useful in directing more targeted measurement and helping identify possible strategies for improvement.
- As a result of seasonal effects, NUE improvement is an iterative process. Therefore, consistency in investigation strategy and good record keeping is essential. ⁵⁴

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

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

A balance of nutrients is essential for profitable yields. Fertiliser is commonly needed to add the essential nutrients P and N. Lack of other essential plant nutrients may also limit production in some situations. Knowledge of the nutrient demand of crops is essential in determining nutrient requirements. Soil testing and nutrient audits assist in matching nutrient supply to crop demand.⁵⁵

Optimising nitrogen use efficiency

Nitrogen fertilisers are a significant expense for broadacre farmers. Optimising use of fertiliser inputs can reduce this cost. There are four main sources of nitrogen available to crops: stable organic nitrogen, rotational nitrogen, ammonium and nitrate. To optimise plants' ability to use soil nitrogen, growers should first be aware of how much of each source there is. The best method of measuring these nitrogen sources is soil testing. ⁵⁶

1.8.5 Double crop options

Double cropping is growing a winter and summer crop following one another. Successful double cropping relies on careful planning of rotations, herbicide use and minimal hold-ups between harvesting and sowing. There has been little adoption of double cropping in northern Victoria because issues such as stubble management, conflict of harvest and sowing times between winter and summer crops, and difficulty in determining the best rotation of winter and summer crop options have been identified as barriers to adoption. Double cropping in northern Victoria provides irrigation farmers with an opportunity to capitalise on their investment in irrigation infrastructure and improve their profitability and Water Use Efficiency.⁵⁷

- 54 C Dowling C (2014) The fundamentals of increasing nitrogen use efficiency. <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/The-fundamentals-of-increasing-nitrogen-use-efficiency-NUE</u>
- G Schwenke, P Grace, M Bell (2013) Nitrogen use efficiency. GRDC Update Papers 16 July 2013, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Nitrogen-use-efficiency</u>
- Soilquality.org. Optimising soil nutrition, <u>http://www.soilquality.org.au/factsheets/optimising-soil-nutrition</u>
- 57 D Boyd (2009) Double cropping in Northern Victoria. GRDC, August 2009, <u>http://www.dairyfertility.com.au/hgf/110405%20-%20</u> Double%20Cropping%20in%20Northern%20Victoria.pdf





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A best practice management guide outlines nine key checks that must be undertaken to maximise the results of double cropping in northern Victoria. ⁵⁸ These are:

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- 1. Field layout, water delivery and drainage: double cropping layouts need to be irrigated quickly and drained without delay. Use as a priority the paddocks with efficient channel delivery systems and reuse systems that allow drainage and eliminate farm runoff.
- Weed, pest and disease control: use fallow, hay/silage and break crops to control weeds, pests and diseases. Determine weed densities and use integrated weed management to reduce the likelihood of herbicide resistance and limit yield loss.
- Opportunity cost of water: determine the production costs of growing the crop. In low water allocation years, compare the market price of temporary trade water with the return on potential crop production. Use the opportunity cost v commodity price matrix to determine best gross margin return for 1 mL of water.
- 4. Sowing Time: a double cropping program can commence in either the summer or winter crop phase. The critical issue with crop sowing is timeliness—sowing on time to maximise yield potential, and to ensure harvest is complete before the optimal sowing window of the next crop phase.
- 5. Soil moisture at sowing: ensure there is adequate soil moisture for crop establishment and crop growth during the season. Determine subsoil moisture levels after the previous crop and pre-irrigate if required.
- 6. Crop establishment: achieve a uniform plant population using equipment necessary for good plant establishment. Some summer crops require the use of a precision planter. It is critical to the desired plant density for summer crops otherwise the economics of irrigation can be poor.
- 7. Nutrition: determine the soil nutrient status of paddocks by soil testing. Apply nutrients to the crop according to potential yield and product nutrient requirements.
- 8. Irrigation: double cropping is limited by water availability so efficient application is critical. Use soil moisture monitoring equipment to assist in determining root-zone moisture levels. Use crop growth stage and weather patterns in conjunction with soil moisture levels to schedule irrigation.
- 9. Timeliness of operations: if necessary, use contractors with appropriate equipment to sow into potentially heavy stubble loads and for precision sowing to achieve optimum plant density. Contractors may also be required to harvest the crop in a timely manner so the next crop can be sown. ⁵⁹

The GRDC Correct Crop Sequencing project will investigate rotations and techniques to provide results that will allow irrigators to be confident in investing their time and resources into double cropping. Research into double cropping funded by GRDC commenced with the winter 2014 season. It is a joint project between the Irrigated Cropping Council (ICC) and NSW Department of Primary Industries (DPI). Each organisation has a different focus, with NSW DPI looking at rotations and ICC examining herbicide residues and techniques to reduce the intervals between the summer and winter crops.

1.9 Disease status of paddock

Disease management of paddocks is essential for maximising yield. SARDI-GRDC research is combining DNA technology with PA zoning techniques to provide grain growers with better risk assessment of soil-borne diseases before sowing crops.

The main findings so far are:

- soil-borne pathogen levels usually vary between PA zones within a paddock, even when zones are created using simple PA layers (for example, EM38 maps, elevation maps); and
- 58 D Boyd (2009) Double cropping in Northern Victoria. GRDC, August 2009, <u>http://www.dairyfertility.com.au/hqf/110405%20-%20</u> Double%20Cropping%20in%20Northern%20Victoria.pdf
- 59 D Boyd (2009) Double cropping in Northern Victoria. GRDC, August 2009, <u>http://www.dairyfertility.com.au/hgf/110405%20-%20</u> Double%20Cropping%20in%20Northern%20Victoria.pdf





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robust sampling methods for soil tests are critical: our current recommendation is to collect 45 cores targeted where practical along the rows of the previous cereal crop. Target sampling within PA zones gives more useful information than samples taken across the whole paddock. ⁶⁰

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1.9.1 Soil testing for disease

PreDicta[®] B (B = broadacre) is a DNA-based soil testing service to identify which soilborne pathogens pose a significant risk to broadacre crops prior to seeding (Photo 8).

It has been developed for cropping regions in Australia and includes tests for:

- cereal cyst nematode (CCN)
- take-all (Gaeumannomyces graminis var. tritici (Ggt) and G. graminis var. avenae (Gga))
- rhizoctonia barepatch (Rhizoctonia solani AG8)
- crown rot (Fusarium pseudograminearum) *Note that oats are not very susceptible to crown rot—but do host it
- root-lesion nematode (Pratylenchus neglectus and P. thornei)
- stem nematode (Ditylenchus dipsaci)





Source: <u>GRDC</u>

PreDicta[®] B samples are processed weekly from February to mid-May (prior to crops being sown) to assist with planning the cropping program. PreDicta[®] B is not intended for in-crop diagnosis. That is best achieved by sending samples of affected plants to your local plant pathology laboratory.

Monitoring stubble for crown rot

Oat crops are considered 'symptomless hosts' of crown rot that may contribute to the maintenance of inoculum of the disease. Some of the current strategies for management of crown rot are to control grass hosts prior to cropping, rotate susceptible cereals with non-host break crops, inter-row sowing, and grow tolerant varieties. It is therefore very important for crown rot testing to be carried out on a paddock, so that growers and consultants can determine whether crown rot is present and if so, its severity. An informed decision can then be made regarding crop choice and farming system. Testing involves a visual assessment on stubble followed by a precise plating test (Photo 9). This is the only way to accurately test for the disease. Results are provided to the grower and consultant within ~4 weeks of receiving the sample. Check your cereal crops for crown rot between grainfill and harvest. Collect plant samples from deep within the paddock by walking in a large 'W' pattern, collecting five plants at 10 different locations. Examine each plant for basal browning, record the percentage of plants showing the symptom and then put in place appropriate measures for next year. To see the honey/dark brown colour more easily, the leaf sheaths should be pulled back. This symptom may not appear on all stems of an infected plant and is difficult to see in oats.

As a general rule, the risk for a cereal in the next season will be:

- low, if <10% of plants infected
- 60 J Heap, A McKay (2007) Spotlight on diseases. GRDC Ground Cover Issue 58. Precision agriculture supplement 08 Aug 2007, <u>https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-58-Precision-Agriculture-Supplement/Spotlight-on-diseases</u>



PIR SA PreDicta B- website





medium, if 10–25% of plants infected high, if >25% of plants are infected. ⁶¹



Photo 9: Paddock Stubble.

1.9.2 Cropping history effects

Continuous cereal cropping increases the risk of diseases including crown rot and tan spot. All winter cereals and many grassy weeds host crown rot, and it can survive for many years in infected plant residues. Infection can occur when plants come in close contact with those residues. 62

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Transmission from neighbouring paddocks and volunteers are key concerns with some diseases. Controlling the "green bridge" of over-summering cereals and weeds is an important strategy.

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

Crop sequencing is only a part of the integrated management of diseases. Other practices include maintaining sufficient distance from last year's paddock of the same crop or from a paddock with residue infected with a pathogen of the intended crop, the use of high-quality, fungicide-treated seed, planting within the planting window, variety selection, and in-crop fungicide treatments. ⁶³

Pathogen/ Nematode	Common name	Sorghum	Maize	Sunflower	Summer pulses	Cotton	Winter cereals	Winter pulses
Pratylenchus thornei	root-lesion nematode	-	-	-	√√ m,s	-	$\checkmark\checkmark$	✓✓ c,f
Pratylenchus neglectus	root-lesion nematode	$\checkmark\checkmark$				nt	$\checkmark\checkmark$	√ √ C
Fusarium graminearum	head blight	\checkmark	$\checkmark\checkmark$	-	-	-	$\checkmark\checkmark$	-
Macrophomina phaseolina	charcoal rot	$\checkmark\checkmark$	$\checkmark\checkmark$	$\checkmark\checkmark$	√√ m,s,g	\checkmark	-	\checkmark
Sclerotinia sclerotiorum, S. minor	sclerotinia rot	-	-	$\checkmark\checkmark$	√√ s,m,g	-	-	√√ c,f,p

 Table 8: Significant pathogens shared by different crops in the southern region. 64

61 GRDC (2009) Crown rot in cereals Fact Sheet. GRDC May 2009, <u>http://www.grdc.com.au/uploads/documents/GRDC_CrownRot_North.</u> pdf

62 GRDC (2012) Crown rot—about the crown rot disease. GRDC Hot Topics 10 July 2012, <u>http://www.grdc.com.au/Media-Centre/Hot-Topics/Crown-Rot</u>

63 M Ryley (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Papers 13 September 2011, <u>http://</u> <u>elibrary.grdc.com.au/arkl!33517/vhnf54t/a9ft5hf</u>

64 M Ryley (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Papers 13 September 2011, <u>http://</u> elibrary.grdc.com.au/arkl/33517/vhnf54t/a9ft5hf





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Pathogen/ Nematode	Common name	Sorghum	Maize	Sunflower	Summer pulses	Cotton	Winter cereals	Winter pulses
Sclerotium rolfsii	basal rot	\checkmark	\checkmark	\checkmark	√√ s,g	\checkmark	-	-
Fusarium verticillioides	fusarium stalk and cob rot	\checkmark	$\checkmark\checkmark$	-	-	-	-	-
Fusarium semitectum	fusarium head blight and stalk rot	$\checkmark\checkmark$	\checkmark	-	-	-	-	-

Table key:

Two ticks = major disease, one tick = recorded but generally a minor disease, c = chickpea, f = fababean, g = peanut, m = mungbean, p = field pea, s = soybean, nt = not tested.

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1.10 Nematode status of paddock

1.10.1 Nematode testing of soil

Cereal cyst nematode (CCN) and stem nematode (SN) are major soil-borne diseases limiting the yield of oats in certain areas of southern Australia. Due to the significant effect of CCN and SN on varietal performance, soil testing is recommended to assess if either of these nematodes will be a significant problem. The PreDicta[®] B Root Disease Testing Service (RDTS) provides a diagnostic service to assess the levels of both nematodes prior to sowing (see PreDicta B information above). ⁶⁵

1.10.2 Effects of cropping history on nematode status

They must survive in the soil between crops and different tillage practices will affect their survival rates. Findings in research have shown that nematode numbers may build up rapidly in wheat crops and decline slowly during fallow periods. When the soil is dry and no living roots are available, nematodes become dormant and may survive in the root tissue of old crops. ⁶⁶

See Section 8: Nematode Control for more information.

1.11 Insect status of paddock

Deciding the best way to sample for a particular pest depends on where in the crop the pest feeds and shelters, and the effects of weather on its behaviour. The stage of crop development and the insect being monitored, will determine which sampling method is most suitable. For example, pests in seedling crops generally cannot be collected by sweeping because the crop is too short.

Pest outbreaks occur often in response to natural conditions, but sometimes in response to management practices. Minimum tillage and stubble retention have resulted in greater diversity of invertebrate species seen in crops. Cultural control methods such as burning, rolling or cultivating stubbles are sometimes needed to complement chemical and biological controls. ⁶⁷

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

Soil insects include:

- cockroaches
- crickets
- earwigs

- 6 Understanding root lesion nematodes—A hidden problem. NSW Department of Primary Industries
- 67 P Bowden, P Umina, G McDonald (2014) Emerging insect pests. GRDC Update Papers 29 July 2014, <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Emerging-insect-pests</u>



⁶⁵ P Zwer, S Hoppo, P McCormack, M Hill, P Wheeler, KL McMurray, M Williams (2015) Oat variety sowing guide. SARDI, <u>http://aexco.com.</u> <u>au/wp-content/uploads/2014/03/SARDI-2015-Oats-Sowing-Guide.pdf</u>



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- black scarab beetles
- cutworms
- false wireworm
- true wireworm.

Different soil insects occur under different cultivation systems and farm management can directly influence the type and number of these pests:

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- Weedy fallows and volunteer crops encourage soil insect build-up.
 - Insect numbers decline during a clean long fallow due to lack of food.
- Summer cereals followed by volunteer winter crops promote the build-up of earwigs and crickets.
- High levels of stubble on the soil surface can promote some soil insects due to a food source, but this can also mean that pests continue feeding on the stubble instead of germinating crops.
- No-tillage encourages beneficial predatory insects and earthworms.
- Incorporating stubble promotes black field earwig populations.
- False wireworms are found under all intensities of cultivation but numbers decline if stubble levels are very low.

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

1.11.1 Insect sampling of soil

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

The majority of crop monitoring for insect pests is done with a sweep net, or visually. Using a shake/beating tray is another technique. Sampling pastures mostly relies on visual assessment of the sward or the soil below it. The sweep net is the most convenient sampling technique for many insects. The net should be about 38 cm in diameter, and swept in a 180° arc from one side of the sweeper's body to the other. The net should pass through the crop on such an angle that it is tilted so that the lower lip travels through the crop marginally before the upper lip. The standard sample is 10 sweeps, taken over 10 paces. This sampling 'set' should be repeated as many times as practicable across the crop, and at no less than five locations. After completing the sets of sweeps, counts should be averaged to give an overall estimate of abundance. Sweep nets tend to under-estimate the size of the pest population. Sweep net efficiency is significantly affected by temperature, relative humidity, crop height, wind speed, plant density and the operator's vigour. ⁶⁸

Soil sampling by spade

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

Germinating-seed bait technique

Immediately following planting rain:

Soak insecticide-free crop seed in water for at least 2 hours to initiate germination.



⁶⁸ DEPI Victoria (2000) Sampling methods for insects and mice. The State of Victoria, Department of Natural Resources & Environment, <u>http://ipmquidelinesforgrains.com.au/insectopedia/introduction/sampling.htm</u>



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• Bury a dessertspoon of the seed under 1 cm of soil at each corner of a 5 by 5 m square at 5 widely spaced sites per 100 ha.

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- Mark the position of the seed baits, as large populations of soil insects can destroy the baits.
- One day after seedling emergence, dig up the plants and count the insects.

Trials have shown no difference in the type of seed used for attracting soil-dwelling insects. However, use of the type of seed to be sown as a crop is likely to indicate the species of pests that could damage that crop. The major disadvantage of the germinating-grain bait method is the delay between the seed placement and assessment.⁶⁹

The South Australian Research and Development Institute (SARDI) Entomology Unit provides an insect identification and advisory service. The unit identifies insects to the highest taxonomic level for species where this is possible and can also give farmers biological information and guidelines for control.⁷⁰



The Ute Guide The Insect ID Ute Guide is a comprehensive reference guide for insect pests commonly affecting broadacre crops and growers across Australia, and includes the beneficial insects that may help to control them. Photos have been provided for multiple lifecycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored and other pests that they may be

confused with. Use of this app should result in better management of pests, increased farm profitability and improved chemical usage. ⁷¹

App features:

- Region selection.
- Predictive search by common and scientific names.
- Compare photos of insects side by side with insects in the app.
- Identify beneficial predators and parasites of insect pests.
- Opt to download content updates in-app to ensure you are aware of the latest pests affecting crops for each region.
- Ensure awareness of international bio-security pests.

Insect ID: The Ute Guide is available on iPhone and Android.

See Section 7: Insect control for more information

1.11.2 Effect of cropping history

It is important to consider paddock history when planning for pest management. Resident pests can be easier to predict by using paddock history, and agronomic and weather data to determine the likely presence (and numbers) of certain pests

- 69 DAFF (2011) How to recognise and monitor soil insects. Queensland Department of Agriculture, Fisheries and Forestry, <u>https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects</u>
- 70 PIR SA (2015) Insect diagnostic service. Primary Industries & Regions SA, 26 Jun 2015, <u>http://pir.sa.gov.au/research/research_specialties/sustainable_systems/entomology/insect_diagnostic_service</u>
- 71 GRDC, https://grdc.com.au/Resources/Apps



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within a paddock. This will point towards the likely pest issues and allow growers to implement preventive options. ⁷² Reduced tillage and increased stubble retention have changed the cropping landscape with respect to soil moisture-retention, groundcover and soil biology and this has also affected the abundance and types of invertebrate species being seen in crops. These systems increase invertebrate biodiversity but also create more favourable conditions for many pests such as slugs, earwigs, weevils, beetles and many caterpillars. In turn they have also influenced beneficial species such as carabid and lady beetles, hoverflies and parasitic wasps. ⁷³

See Section 7: Insect control for more information.



⁷² R Jennings (2015) Growers chase pest-control answers. GRDC Ground Cover Issue 117: July–August 2015, <u>https://qrdc.com.au/Media-Cover/Ground-Cover/Ground-Cover/Super-117-July-August-2015/Growers-chase-pest-control-answers</u>

⁷³ P Bowden, P Umina, G McDonald (2014) Emerging insect pests. GRDC Update Papers 29 July 2014, <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Emerging-insect-pests</u>



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Key messages:

- Oats are often thought of as an 'easy' crop to grow but attention to detail is required to produce high yields and quality.
- Variety selection should be based on agronomic traits, potential grain quality and marketing or end use options e.g. grain or hay.
- Grain quality traits for the milling industry include high groat percent, high betaglucan, low screenings, and high hectolitre weight.
- Grain quality traits for improved animal feed include low hull lignin, high groat percentage, and high oil content, resulting in high grain digestibility.
- Important hay quality traits are high digestibility, high water soluble carbohydrates, low fibre and high protein.







Oats are often thought of as an 'easy' crop to grow but attention to detail is required to produce high yields and quality (Photo 1). 1

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Photo 1: Milling oat grain prior to ripening. Photo: Nicole Baxter, Source: <u>GRDC</u>

Variety selection should be based on agronomic traits, potential grain quality and marketing or end use options.

When selecting a variety there are a number of considerations: What is the crop being used for?

- Grazing only
- Dual-purpose grazing and grain
- Hay (export or domestic)
- Silage
- Grain (milling or stock feed).

Once an end use has been determined, a suitable variety can be selected. This variety needs to match the following criteria for an individual's farm:

- high/low rainfall zone
- pests/diseases present in the paddock
- moisture status of the paddock
- nematode status
- proximity to previous year's oat paddock
- if the crop is to be sown into last year's oat stubble or not. Sowing after wheat or barley can also affect variety choice as disease carryover may be a factor.
- soil type (e.g. acid soils)
- sowing date
- proximity of markets if a specialty grain is to be grown
- when is feed most important—in early or late winter?²

Grain quality traits for the milling industry include high groat percent, high betaglucan, low screenings, and high hectolitre weight. Grain quality traits for improved

1 Agriculture Victoria (2015) Growing oat. DEDJTR Victoria, <u>http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-oat</u>

2 P. Heuston (2016) Personal comms





WATCH: Over the Fence: QA system for oaten hay: a cut above the rest





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animal feed include low hull lignin, high groat percentage, and high oil content, resulting in high grain digestibility. Important hay quality traits are high digestibility, high water soluble carbohydrates, low fibre and high protein.

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Yield will be the main determinant of returns but grain quality has now become an important consideration. Choose a range of two or more varieties to suit likely sowing opportunities in your area and consider producing a high value, manufacturing variety if these varieties suit your rainfall, soil type and rotation. In the higher rainfall areas dwarf oats are high yielding, more responsive to nitrogen fertilisers than non-dwarf oats, and are likely to be a good option for on-farm feed crops. Assess risk factors of varieties such as disease susceptibilities, herbicide sensitivities, dockages for downgraded samples, susceptibility to weather damage, coleoptile length, tolerance to acid soil and boron toxicity.

The decision to grow oats for milling, feed or hay depends on the following factors:

- the relative yields/gross margins of milling grade, feed grade and hay oat varieties
- the likelihood that the grain will be accepted for milling grade and the premium paid for that grade
- the quality parameters for a high yielding dual-purpose or a high quality hay variety for the export market
- agronomic and disease constraints of the different varieties ³

Consult your local agronomist, most recent <u>oat sowing guide</u> and the tables below to help inform your choice of oat variety.

Table 1: Seven year (2007–2013)	average grain yield (t/ha) of oat varieties tested in
grain trials in Southern Australia.	

	Lower eP	upper eP	Yorke Peninsula	Mid north	South east	Murray Mallee	Overall			
Semi-dwarf (husked)										
Bannister	4.2	2.0	4.9	3.5	4.3	1.6	3.6			
Mitika	3.9	1.9	4.6	3.3	4.0	1.4	3.4			
Possum	3.9	1.9	4.6	3.2	3.9	1.4	3.4			
Potoroo	3.9	1.9	4.9	3.2	4.0	1.6	3.4			
Wombat	3.8	1.9	4.7	3.2	4.0	1.5	3.4			
Semi-dwar	f (naked)									
Numbat	2.9	1.2	3.4	1.9	2.5	0.5	2.1			
Tall (huske	d)									
Williams	4.4	1.9	4.5	3.5	4.4	1.4	3.6			
Yallara	3.2	1.7	3.9	3.0	3.6	1.4	3.0			
no. trials	7	8	7	27	20	5	74			

Source: National Oat Breeding Program





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 Table 2: Nine year (2005–2013) average hay and grain production of oat varieties tested in hay trials.

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	<375 mm	Hay yield (t/r Rainfall zon 375– 500 mm	na) e >500 mm	G <375 mm	rain yield (t/ Rainfall zon 375– 500 mm	ha) e >500 mm
Tall (husked	l) - early to	mid season	maturity			
Brusher	6.6	9.0	12.9	1.7	2.7	2.9
Mulgara	6.7	8.9	13.1	1.8	2.8	3.0
Wallaroo	6.7	8.9	12.4	1.7	2.7	2.8
Wintaroo	7.3	9.1	13.6	1.9	2.8	3.0
Yallara	6.8	9.0	12.5	2.0	3.0	3.3
Tall (husked	l) - mid late	e to very late	maturity			
Forester	na	7.4	13.7	1.2	1.8	1.8
Glider	na	8.2	12.8	1.4	2.1	2.2
Kangaroo	na	8.7	13.3	1.8	2.6	2.9
Tammar	na	8.6	13.6	1.8	2.6	3.1
Tungoo	na	8.6	13.7	1.5	2.5	2.7
no. trials	9	25	7	10	23	12

Source: National Oat Breeding Program

Table 3: Agronomic features of oat varieties.

Variety	early vigour	Plant height	Heading	Maturity	Shattering resistance	Standing ability					
Semi-dwarf	(husked)										
Bannister	G	D	EM	EM	R	R					
Echidna	G	D	EM	EM	R	R					
Mitika	G	D	E	E	R	R					
Possum	G	D	EM	EM	R	R					
Potoroo	G	TD	E	E	MR	MR					
Wombat	G	D	М	М	R	R					
Semi-dwarf (naked)											
Numbat	MG	D	EM	EM	MR	R					
Tall (husked)											
Brusher	MG	Т	E	EM	MS	MR					
Forester	VG	MT	VL	VL	R	R					
Glider	Р	MT	L	L	MS	MR					
Kangaroo	MG	MT	ML	ML	MS	R					
Mulgara	MG	Т	EM	EM	MR	MR					
Tammar	Μ	MT	LM	LM	MS	R					
Tungoo	MP	MT	ML	ML	MS	MS					
Wallaroo	G	MT	E	E	MS	MS					
Williams	G	ST	EM	EM	R	R					
Wintaroo	М	Т	М	EM	MS	MR-MS					
Yallara	VG	MT	EM	EM	MR	R					

Value for trait: Early vigour: VG=very good, G=good, MG = moderately good, M=moderate, P=poor, MP = moderately poor





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Plant height: D = dwarf, TD = tall dwarf, T = tall, ST = short tall, MT = moderate tall

Heading and maturity: E = early, EM = early mid, M= mid season, ML = mid late season, LM = late mid season, L = late, VL=very late Shattering and standing ability: R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, Source: <u>National Oat Breeding Program</u>

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Table 4: Grain quality comparisons.

Variety	Hectolitre Weight (kg/hl)	Screening <2 mm	1000 Grain weight (g)	kernel (%)	Probability of reaching milling grade	Protein (%)	Oil(fat) (%)	Hull lignin content
Semi-dwarf (husked)							
Bannister	MH	ML	MH	MH	Н	М	М	Н
Echidna	Μ	MH	Μ	ML	L	М	М	MH
Mitika	Н	L	Н	ΜΗ	Н	MH	М	L
Possum	MH	L	MH	MH	Н	MH	М	Н
Potoroo	L	MH	Μ	ML	-	М	MH	Н
Wombat	Н	М	MH	Н	Н	MH	М	Н
Semi-dwarf (naked)							
Numbat	VH	Н	L	-	-	Н	VH	-
Tall (husked)								
Brusher	Μ	Μ	MH	Μ	-	MH	Μ	L
Forester	L	М	L	L	-	М	Μ	Н
Glider	L	М	Μ	ML	-	MH	ML	L
Kangaroo	Μ	ML	MH	ML	-	М	М	Н
Mulgara	Μ	М	MH	MH	-	MH	М	Н
Tammar	L	Н	L	ML	-	MH	М	SEG
Tungoo	L	Н	L	ML	-	MH	М	L
Wallaroo	Μ	М	Μ	ΜΗ	-	М	MH	L
Williams	MH	М	М	Μ	MH	М	Μ	MH
Wintaroo	Μ	М	MH	MH	-	М	М	L
Yallara	Н	L	Н	Н	VH	MH	L	Н

Value for trait: L = low, ML = moderately low, M = medium, MH = moderately high, H = high, VH = very high, - not applicable Source: <u>National Oat Breeding Program</u>





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i) MORE INFORMATION

Oats variety sowing guide 2015

National Oat Breeding Program Newsletter 2016

Cereal Variety Disease Guide 2016

Table 5: Hay quality comparisons.

Variety	Digestible dry matter (%dm)	Crude protein (%dm basis)	neutral detergent fibre (%dm basis)	Water soluble carbohydrate (%dm basis)	Stem diameter
Tall (husked)				
Brusher	MH	Μ	Μ	MH	Μ
Forester	MH	Μ	ML	MH	MH
Kangaroo	ML	MH	MH	ML	ML
Mulgara	Μ	Μ	Μ	Μ	Μ
Tammar	Μ	MH	Μ	Μ	ML
Tungoo	Μ	MH	M-MH	Μ	Μ
Wallaroo	Μ	Μ	Μ	Μ	L
Wintaroo	Μ	Μ	Μ	Μ	Μ
Yallara	MH	Μ	ML	Н	ML

Value for trait: L = low, ML = moderately low, M = medium, MH = moderately high, H = high.

Source: National Oat Breeding Program

Table 6: Oat variety agronomic guide to disease reactions. (Oat disease reactions provided by Pamela Zwer, SARDI).

	End	Height	Maturity	Hectolitre	Stem	Leaf	С	CN	BYDV	Septoria	Bacterial	Red
	use			weight	Rust	Rust	Res	Tol			blight	Leather Leaf
Milling Oats												
Bannister	Μ	TD	М	Н	S	R	VS	T	MS	S	S	MS
Dunnart	М	TD	М	Н	S	MR	R	MT	MR	MS	S	MS
Mitika	М	D	Е	Н	S	S	VS	T	S	S	MR	S
Possum*	М	D	EM	Н	-	-	-	-	-	-	-	-
Williams	М	MT	E	Н	S	R	S	I	MS	MS	R	MS
Wombat	М	D	EM	Н	S	MS	R	Т	MR	MS	MS	MS
Yallara	М	MT	EM	Н	S	MS	R	I	MS	MS	MS	MS
Feed Oats												
Echidna*	M/F	D	EM	Μ	-	-	-	-	-	-	-	-
Quoll*	F	TD	EM	ML	-	-	-	-	-	-	-	-
Hay/Grazing	/Feed											
Brusher	H/G/F	Т	EM	М	S	S	R	MI	MS	MS	MS	MS
Forester	Н	MT	VL	L	S	MS	MS	MI	S	MR	S	RMR
Kangaroo	Н	MT	ML	М	S	S	R	MT	S	MS	MS	MS
Mulgara	Н	Т	EM	М	MS	MS	R	MT	MS	MS	MR	MSS
Tammar	Н	MT	LM	L	S	MS	MR	MT	MS	MR	MR	R-MS
Tungoo	Н	MT	ML	L	S	MS	R	MT	MS	MR	MR	R
Wintaroo	H/G	Т	EM	М	S	S	R	MT	MRMS	MS	MS	MS

 $\mathsf{End} \; \mathsf{use:} \; \mathsf{M} = \mathsf{milling}, \; \mathsf{F} = \mathsf{feed} \; \mathsf{grain}, \; \mathsf{G} = \mathsf{grazing}, \; \mathsf{H} = \mathsf{hay} \qquad \mathsf{Hectolitre} \; \mathsf{weight:} \; \mathsf{H} = \mathsf{heavy}, \; \mathsf{M} = \mathsf{medium}, \; \mathsf{L} = \mathsf{light}$

Plant height: D = dwarf, TD = tall dwarf, T = tall, ST = short tall, MT = moderate tall

Maturity: E = early, EM = early mid, M = mid-season, ML = mid-late season, LM = late mid-season, L = late, VL = very late mid-season, VL = very late mid-season, LM = very late mid-s

Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS.

p = provisional ratings - treat with caution. R = resistant, M = moderately, S = susceptible, V = very.

Disease tolerance: T = tolerant, MT = moderately tolerant, MI = moderately intolerant, I = intolerant * Disease ratings on these older varieties are not current and have not been included.

Source: National Oat Breeding Program







2.2 Varietal characteristics

The National Oat Breeding Program breeds oats for southern Australia under a partnership between the South Australian Research and Development Institute (SARDI), the Department of Agriculture and Food Western Australia (DAFWA), GRDC and RIRDC.

2.2.1 Milling oats

Durack()

Durack was launched in September 2016 as a candidate milling variety with potential for use in oaten hay production. Durack has been released to partner the varieties Bannister and Williams as the benchmark milling quality oat varieties for Australian production. Durack is expected to enhance on-farm oat profitability.

Agronomic characteristics

Durack is the earliest maturing oat variety of any current milling or hay variety. As a short season type it is suited for conventional sowing windows in medium-low rainfall areas or for delayed sowing opportunities in traditional (medium-high rainfall) oat areas.

Durack is moderately tall, standing at between 80 and 90 cm. Its grain yield is similar to other tall varieties Carrolup and Yallara assessed in yield trails across four states. While yields associated with tall oat varieties may not surpass dwarf oats, the yield is competitive and grain quality characteristics of Durack indicate it will provide robust performance when compared to other varieties in medium-lower rainfall areas. ⁴

Bannister()

A dwarf milling variety with wide adaption. Compared to Mitika() it is about 13 cm taller and flowers 3–4 days later. Similar to Mitika() for groat percentage. R to leaf rust moderately resistant to bacterial blight. Very susceptible and intolerant to CCN. Bannister() has slightly lower hectolitre weight and slightly higher screenings compared to Mitika(). Bred by the National Oat Breeding Program. Released in eastern Australia in 2013 via Seednet. EPR \$2.30.

Mitika()

An early maturing dwarf variety with some resistance to common rusts. Suited to high rainfall areas, it has around 73% groat yield and provides excellent feed value. It is not suited to areas where CCN is a problem. Released 2005 and marketed by Heritage Seeds. EPR \$2.

Mitika() is a dwarf milling oat released in 2005. It is earlier maturing than Possum() and Echidna() and this trait favours Mitika() in a dry finish. Mitika() was R to stem rust until 2010 when a new pathotype of stem rust was identified, rendering it MS to leaf rust. Mitika() has improved resistance to bacterial blight and is superior to Echidna() for septoria resistance. Mitika() is S to BYDV, septoria and red leather leaf disease. It is very susceptible and intolerant of CCN and moderately intolerant of stem nematode and is not recommended in areas where either of these nematodes are a problem. Mitika() has high hectolitre weight, low screenings and high groat percentage compared to Echidna(). Mitika() also has improved feed quality with low husk lignin and high grain digestibility.

One of the National Oat Breeding Program's most successful varieties, Mitika(b), now comprises more than 80% of the oats used by Uncle Tobys Australia in popular porridge and muesli bar snacks. Mitika(b) has high grain yield potential, improved disease resistance—as well as increased levels of β -glucan (beta-glucan) compared to other oat varieties.



⁴ DAFWA. (2016). Durack: A short season oat with milling grade potential or dual purpose for hay production <u>https://www.agric.wa.gov.au/</u> <u>durack-oat?nopaging=1</u>



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Possum(1)

A dwarf variety to replace Echidna() for milling in medium to high rainfall regions with improved grain quality. Late sowing may result in yield penalty. Bred by SARDI, released 2002 and marketed by Seednet. EPR \$1.70.

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Possum(*b* is a dwarf milling grain variety. It is a replacement for Echidna(*b* in medium and high rainfall areas. Possum(*b* has a similar yield to Echidna(*b* in high rainfall zones and slightly lower yield in medium rainfall zones. Possum(*b* also has a high husk lignin content like Echidna(*b*. It has better milling quality than Echidna(*b* and has similar hectolitre weight and fewer screenings than Euro(*b*. It is an improvement compared to Echidna(*b* for stem rust, leaf rust and septoria resistance. Like Echidna(*b*, Possum(*b* is S to bacterial blight and BYDV and VS and intolerant to CCN. is not recommended for areas where CCN or stem nematode is a problem. Possum(*b* is S to red leather leaf and intolerant of stem nematode. Developed by SARDI, released in 2003. Seednet.

Williams(D

A medium to tall milling oat suited to medium to high rainfall zones (Photo 2). It is 15 cm taller than Mitika(), 5 cm taller than Bannister() and 15 cm shorter than Yallara(). A higher yielding variety, similar to Bannister() but with slightly inferior grain quality. Produces high screenings when grown in low rainfall areas. S to stem rust, but R to leaf rust and S and intolerant to CCN. MS to septoria. Bred by the National Oat Breeding Program (WA2332). Released 2015. Marketed by Heritage Seeds. EPR \$2.30.

Williams(*b*) has a high grain yield potential. Williams(*b*) is an early to mid-season variety similar to Yallara(*b*), but three to seven days later than Mitika(*b*. Taller than Mitika(*b*) by 15 cm, 5 cm taller than Bannister(*b*), and 15 cm shorter than Yallara(*b*). Williams(*b*) is R to leaf rust and depending on the stem rust pathotype present can range from moderately R to S. It is S and intolerant to CCN. Williams(*b*) is R to bacterial blight and MR to MS to BYDV. Williams(*b*) is not recommended for low rainfall areas due to higher screenings.



Photo 2: The foreground shows a trial plot of Williams() oats at early panicle emergence.





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Wombat∕⊕

A dwarf mid-season variety that flowers about six days later than Mitika(). It is the first dwarf milling variety with CCN resistance and tolerance. Intended to replace Mitika() and Possum() where CCN and stem nematode are limiting yield, but may have higher screenings. Bred by SARDI (SV97181-12) released 2011 and marketed by Seednet. EPR \$2.

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A dwarf milling variety, which is similar in height to Possum() and slightly taller than Mitika(). It is a mid-season variety flowering about six days later than Mitika(). Wombat() was the first dwarf milling variety with CCN resistance and tolerance. It is also moderately tolerant to stem nematode. Wombat() has high hectolitre weight and low screenings compared to the feed variety Potoroo(), which was the first dwarf variety with CCN resistance and tolerance. It also has a high groat percentage, slightly higher than Mitika().

Yallara(D

Medium to tall similar to Euro(), which it is intended to replace. S to stem rust, MS to leaf rust and MS to septoria. Resistant but intolerant to CCN. Suited to drier areas. Bred by SARDI, released in 2009 and marketed by Seednet. EPR \$2.

A medium to tall, early to mid-season variety similar to Euro() for flowering and maturity. Yallara() was released in 2009. Yallara() is a Euro() lookalike milling line with slightly better grain quality, but not as susceptible to stem rust. It is resistant but intolerant to CCN. It is moderately susceptible to BYDV and septoria. Yallara() is susceptible and intolerant to stem nematode and moderately susceptible to red leather leaf disease. Yallara() has excellent grain quality. It has a high hectolitre weight, low screenings and a high groat percentage. Yallara() has bright, plump grain suitable for the milling industry and specialised feed end-uses like the horse racing industry as well as human consumption. Yallara() was evaluated for hay production and although the hay yield is lower than popular hay varieties it has excellent hay quality.

Mortlock()

Medium height, strong strawed grain oat. Can be leniently grazed. It has a consistently high test weight, protein content and lower screening losses with light coloured grain, but discolours easily. Low yielding compared to Mitika() and Possum(). Released by Agriculture Western Australia in 1983.

2.2.2 Feed grain, hay and grazing varieties

Intermediate and late-maturing varieties remain vegetative until late in the season and provide a longer duration of grazing for livestock.

Echidna() – Feed oat

A widely adapted, high yielding, semi-dwarf variety for milling and feed. Echidna() is outclassed by Possum() and Mitika() for milling quality. Released 1984 by SARDI.

Mulgara(D – Hay/feed oat

A mid-season tall oat targeted as a replacement for Wintaroo() but with better resistance to leaf rust and lodging. Has excellent hay colour with quality similar to Wintaroo(). Bred by SARDI, released 2009 and marketed by AEXCO. EPR \$2.

Tall mid-season hay oat similar in heading time and height to Wintaroo() with CCN and stem nematode resistance and tolerance. Mulgara() is an improvement compared to Wintaroo() for resistance to stem rust and bacterial blight, lodging and shattering resistance and early vigour. Hay yield is an improvement compared to Brusher() but slightly lower than Wintaroo(). Hay quality is similar to Wintaroo(). Mulgara() has excellent hay colour and resists brown leaf at hay cutting. Grain yield and quality is similar to Wintaroo() with lower screenings, higher protein and groat percentage. Mulgara() has high husk lignin. Released by SARDI in 2009. AEXCO





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Late season tall hay oat variety for medium and high rainfall zones which provides a slightly later cutting time than Tungoo() and Kangaroo(). S to stem rust, MS to leaf rust, and MR & MT to CCN. Bred by SARDI, released 2010 and marketed by AEXCO. EPR \$2.

OUTHERN

AUGUST 2017

Brusher(D – Hay/grazing/feed oat

Early to mid-season tall oat, well suited to low rainfall areas. Low husk lignin with improved hay digestibility. S to stem and leaf rust. Resistant but moderately intolerant to CCN and MRMS to *P. neglectus* nematodes. Bred by SARDI, released 2002 and marketed by AEXCO. EPR \$2.

Wintaroo() - Hay/grazing/feed oat

Tall, mid-season variety for all rainfall zones. Susceptible to leaf and stem rust. Resistant and moderately tolerant to CCN and MRMS to *P. neglectus* nematodes. Bred by SARDI, released 2001 and marketed by AEXCO. EPR \$2.

Forester() – Hay oat

A medium height late hay variety adapted to high rainfall and irrigated cropping regions. It has excellent lodging and shattering resistance. S to stem rust and MS to leaf rust. It has excellent hay qualities, but is MS & MI to CCN. Bred by SARDI, released 2011 and marketed by AGF Seeds. EPR \$2. It is three days later than Riel and three weeks later than Wintaroo(). Forester() has excellent early vigour, lodging and shattering resistance. Good foliar disease resistance spectrum. Good hay colour, but like all late hay varieties may not resist hot dry winds as well as earlier varieties. Forester() has excellent hay quality.

Kangaroo(D – Hay oat

A mid to late season moderately tall oat, a later flowering time makes it less suited to low rainfall environments. S to rusts. Resistant and moderately tolerant to CCN. High husk lignin. Released 2003. Bred by SARDI, marketed by AEXCO. EPR \$2.

Tungoo() – Hay oat

A medium to tall variety. S to stem rust and MS to leaf rust. Resistant and moderately tolerant to CCN and stem nematode. Hay yield similar to Kangaroo() but grain yield poor. Released 2008. Bred by SARDI, marketed by AEXCO. EPR \$2.

2.2.3 Feeding oat digestibility

The GRDC-supported Premium Grains for Livestock Program project demonstrated large differences between varieties in whole grain digestibility. Cattle feeding trials have subsequently demonstrated these differences translate into large differences in grain digestibility. Most of the difference in whole grain digestibility is caused by varietal differences in the lignin content of the oat husk. Where varieties have a high husk lignin content, digestion of both the husk and the underlying grain is poor. Husk lignin ratings of a range of oat varieties is presented in the following table (Table 7). While other seasonal factors affect whole grain digestibility, varieties with a high husk lignin rating will inherently have low whole grain digestibility. NIR tests have been developed to measure the feeding value of grains. ⁵

Research from 2003, as part of the GRDC-supported Premium Grains for Livestock Program, shows great variations in the digestibility and suitability of common oat varieties as cost-effective feed grains. The research revealed more than a 20% variation in digestibility among eight oats tested in a cattle production trial. Both variety and environment (growing conditions) influence digestibility. The varietal effect



⁵ NSW DPI (2015) Winter crop variety growing guide 2016. New South Wales Department of Primary Industries, <u>http://www.dpi.nsw.gov.</u> au/content/agriculture/broadacre/guides/winter-crop-variety-sowing-guide



is correlated with lignin (an indigestible carbohydrate) levels in the hulls of the grain—high lignin content results in low digestibility. $^{\rm 6}$

OUTHERN

While not often used as a grain in feedlot rations, the performance of cattle that are fed oats is equivalent to the performance when cattle are fed other more commonly used grains. Oats have a slightly lower energy range than most other grains. They have a high fibre content, and are considered a safer grain to feed than either wheat or barley. When trialled experimentally, oats-fed cattle consumed similar amounts of grain to barley-fed cattle.⁷

2.2.4 Oat grain for feed

While not often used as a grain in feedlot rations, the performance of cattle that are fed oats is equivalent to the performance when cattle are fed other more commonly used grains. Oats have a slightly lower energy range than most other grains (Table 8). They have a high fibre content, and are considered a safer grain to feed than either wheat or barley. When trialled experimentally, oats-fed cattle consumed similar amounts of grain to barley-fed cattle. ⁸

Table 7: Feed properties of various grains.

Foodstuff	Dry matter (DM) (%)	Starch (%)	Metabolis (ME) (MJ/I	ed energy (g DM)	Crude protein (CP) (% DM)		
			Average	Tested range	Average	Tested range	
Oats	90	50	10.5	8.5–12.5	10.5	8–12	
Barley	90	59–61	13	12.5–13	11	10–12	
Wheat	90	60–76	13	12.5–13.5	12	11–13	
Sorghum	90	75	13	12.5–13	9	5–11	
Maize	90	76	13.5	13–14	9.5	9–10	

Table 8: Hull lignin rating of a range of oat varieties—low hull lignin is better for ruminant feed value.

Low	Medium	Medium-high	High
Bass, Bimbil, Brusher, Carbeen, Cooba, Eurabbie, Graza 68, Mannus, Mitika, Mulgara, Nile, Tungoo, Wintaroo, Yarran, Yiddah	Blackbutt (variable), Graza 80, Quoll	Euro, Potaroo, Wandering	Bannister, Carrolup, Coolabah, Dawson, Drover, Dunnart, Echidna, Forester, Genie, Graza 50, Kangaroo, Mortlock, Nugene, Possum, Taipan, Williams, Womba, Yallara

2.2.5 Seed size

Seed grading is an effective way to separate good quality seed of uniform size from small or damaged seeds and other impurities, such as weed seeds. Seed size is also important—the larger the seed, the greater the endosperm and starch reserves. While size does not alter germination, bigger seeds have faster seedling growth, a higher number of fertile tillers per plant and potentially higher grain yield.



⁶ SARDI (2016) National Oat Breeding Program Newsletter 2016 http://pirsa.gov.au/case_studies/case_study/sardi/sustainable_systems/ national_oat_breeding_program

⁷ A Rayner (2007) Using oats as an alternative grain in opportunity feedlot rations. Primefacts No. 381. New South Wales Department of Primary Industries.<u>https://www.scribd.com/document/237517323/Using-Oats-as-an-Alternative-Grain-in-Opportunity-Feedlot-Rations</u>

⁸ B. Granzin (2003) Energy supplements for dairy cows. New South Wales Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/</u> agriculture/livestock/dairy-cattle/feed/research/energy



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Seed size is usually measured by weighing 1,000 grains, known as the 1000-grain weight. Sowing rate needs to vary according to the 1000-grain weight for each variety, in each season, in order to achieve desired plant densities. ⁹

OUTHERN

To measure 1000-grain weights, count out 10 lots of 100 seeds, then weigh. When purchasing seed, remember to request the seed analysis certificate, which includes germination percentage, and the seed weight of each batch where available.

The coleoptile is the pointed, protective sheath that encases the emerging shoot as it grows from the seed to the soil surface (Photo 3). Coleoptile length is an important characteristic to consider when planting an oat crop, especially in drier seasons when sowing deep to reach soil moisture.



Photo 3: The coleoptile is the pointed, protective sheath that encases the emerging shoot as it grows from the seed to the soil surface.

Photo: David L. Hansen, University of Minnesota

For a seed to emerge successfully from the soil, the seed should never be planted deeper than the coleoptile length. Sowing varieties with short coleoptile lengths too deep can cause poor establishment, because the shoot will emerge from the coleoptile underground and it may never reach the soil surface.¹⁰

Small seeds contain less starch reserves than larger seeds. Starch is a form of energy for seeds, so less starch means less energy to get the seedling out of the ground. It also means less energy to fight off seedling stresses such as disease, waterlogging or false breaks.

Small seed—for example, 1,000 seed weight of less than 30 g—should not be sown deep, and should only be sown where there is ideal moisture. Increase sowing rates by 10–15% to compensate for potentially low vigour. ¹¹

Coleoptile length is influenced by several factors, including variety, seed size, temperature, low soil water and certain seed dressings, such as those with the active ingredient triadimenol or flutriafol. Trifluralin and several Group B pre-emergent

- 9 NSW DPI District Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/odf_file/0008/516i85/Procrop-wheat-growth-and-development.pdf</u>
- 10 J Pumpa, P Martin, F McCrae, N Coombes (2013) Coleoptile length of wheat varieties. NSW Department of Primary Industries, February 2013, <u>http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat_barley-and-other-winter-creals/coleoptile-length</u>
- 11 K Condon K (2003) Targeting optimum plant numbers. NSW Agriculture, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf</u> file/0007/168523/targeting-optimum-plant-numbers.pdf





chemicals can also affect coleoptile length. Growers should read the label when using any seed-dressing fungicide, in order to see what affect it may have on coleoptile length. ¹²

2.2.6 Seed germination and vigour

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

- 1. Water absorption (imbibition)
- 2. Activation
- 3. Visible germination.

Seed vigour affects the level of activity and performance of the seed or seed lot during germination and seedling emergence. Loss of seed vigour is related to a reduction in the ability of the seeds to carry out all of the physiological functions that allow them to perform.

This process, called physiological ageing (or deterioration), starts before harvest and continues during harvest, processing and storage. It progressively reduces performance capabilities due to changes in cell membrane integrity, enzyme activity and protein synthesis. These biochemical changes can occur very quickly (a few days) or more slowly (years), depending on genetic, production and environmental factors not yet fully understood. The end point of this deterioration is death of the seed (i.e. complete loss of germination). However, seeds lose vigour before they lose the ability to germinate. That is why seed lots that have similar, high germination values can differ in their physiological age (the extent of deterioration) and so differ in seed vigour and therefore the ability to perform. ¹³

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

Request a copy of the germination and vigour analysis certificate from your supplier for purchased seed. For seed stored on-farm, you can send a sample to a laboratory for analysis, see <u>Australia Seeds Authority Ltd</u>.

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

- Use a flat, shallow, seeding tray (about 5 cm deep). Place a sheet of newspaper on the base to cover drainage holes, and fill with clean sand, potting mix or freely draining soil. Ideally, the test should be done indoors at a temperature of ~20°C or lower.
- Alternatively, lay a well-rinsed plastic milk container on its side and cut a window in it, place unbleached paper towels or cotton wool in the container, and lay out the seeds. Moisten and place on a window-sill. Keep moist, and count the seeds as outlined below.
- Randomly count out 100 seeds, do not discard damaged ones, and sow 10 rows
 of 10 seeds at the correct seeding depth. This can be achieved by placing the
 seed on the smoothed soil surface and pushing in with a pencil marked to the
 required depth (Photo 4). Cover with a little more sand/soil and water gently.
- Keep soil moist but not wet, as overwatering will result in fungal growth and possible rotting.
- After 7–10 days, the majority of viable seeds will have emerged.
- Count only normal, healthy seedlings. If you count 78 normal vigorous seedlings, the germination percentage is 78%.
- Germination of 80% is considered acceptable for cereals.
- 12 J Pumpa, P Martin, F McCrae, N Coombes (2013) Coleoptile length of wheat varieties. NSW Department of Primary Industries, February 2013, <u>http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat-barley-and-other-winter-creals/coleoptile-length</u>
- 13 ISTA (1995) Understanding seed vigour. International Seed Testing Association, <u>http://www.seedtest.org/upload/pri/product/</u> <u>UnderstandingSeedVigourPamphlet.pdf</u>





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(i) MORE INFORMATION

Germination testing and seed rate

calculation

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The results from a laboratory seed-germination test should be used for calculating seeding rates. ¹⁴

OUTHERN

Grain retained for seed from a wet harvest is more likely to be infected with seedborne disease. It is also more likely to suffer physical damage during handling, increasing the potential for disease. Seed-borne disease generally cannot be identified from visual inspection, so requires laboratory testing.¹⁵



Photo 4: Use a pencil or straw to poke holes in a testing tray. Source: <u>NSW DPI</u>.

Seed purity

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

With the dramatic increase in herbicide resistance in the region, growers need to take seed purity into account when deciding on paddock selection for seed. Ryegrass and black oats frequently appear in harvested grain samples and have the potential to infest otherwise clean paddocks.¹⁶

- 14 GRDC (2011) Retaining seed. Saving weather damaged grain for seed, northern and southern regions. GRDC Fact Sheet Jan. 2011, http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC_FS_RetainingSeed2.pdf
- 15 GRDC (2011) Retaining seed. Saving weather damaged grain for seed, northern and southern regions. GRDC Fact Sheet Jan. 2011, http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC_FS_RetainingSeed2.pdf
- 16 S Simpfendorfer, A Martin, M Sutherland (2012) Seed impurity undermines stripe rust resistance. 16th Australian Agronomy Conference. Australian Society of Agronomy/the Regional Institute Ltd, <u>http://www.regional.org.au/au/asa/2012/disease/8325_simpfendorfer.</u> <u>htm#TopOfPage</u>





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VIDEOS

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



2.2.7 Seed storage

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

UTHERN

- Temperature <15°C. High temperatures can quickly reduce seed germination and quality. This is why germination and vigour testing prior to planting are so important.
- Moisture control. Temperature changes cause air movements inside the silo, carrying moisture to the coolest parts of the seed. Moisture is carried upwards by convection currents in the air; these are created by the temperature difference between the warm seed in the centre of the silo and the cool silo walls, or vice versa. Moisture carried into the silo head space may condense and fall back as free water, causing a ring of seed to germinate against the silo wall.
- Aeration slows the rate of deterioration of seed with 12.5–14% moisture. Aeration markedly reduces grain temperature and evens out temperature differences that cause moisture movement.
- No pests. Temperature <15°C stops all major grain insect pests from breeding, slowing down their activity and causing less damage.¹⁷

For more information, see Section 13: Storage.

2.2.8 Safe rates of fertiliser sown with the seed

Crop species differ in tolerance to N fertiliser when applied with the seed at sowing. Recent research work funded by Incitec Pivot Fertilisers has shown that the tolerance of crop species to ammonium fertilisers placed with the seed at sowing is related to the fertiliser product (ammonia potential and osmotic potential), the application rate, row spacing and equipment used (such as a disc or tyne), and soil characteristics such as moisture content and texture.

The safest application method for high rates of high ammonium content fertilisers is to place them away from the seed by physical separation (combined N-phosphorus products) or by pre- or post-plant application (straight N products). For the lower ammonium content fertilisers (e.g. mono-ammonium phosphate (MAP)) close adherence to the safe rate limits set for the crop species and the soil type is advised. High rates of N fertiliser applied at planting in contact with, or close to, the seed may severely reduce seedling emergence. If a high rate of N is required, then it should be applied pre-planting or applied at planting but not in contact with the seed (i.e. banded between and below sowing rows). Rates should be reduced by 50% for very sandy soil and increased by 30% for heavy-textured soils or if soil moisture conditions at planting are excellent. ¹⁸

Nitrogen rates should be significantly reduced when using narrow points and press wheels or disc seeders (Table 9). When moisture conditions are marginal for germination, growers need to reduce N rates if fertiliser is to be placed with, or close to, the seed.

Table 9: Suggested safe rates (kg/ha) of some nitrogen fertiliser products sown with oat seed at planting.

Row spacing		Max.	Urea	DAP	MAP
cm	in	N rate			
18	7	30	65	158	230
36	14	15	33	79	115

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



¹⁷ GRDC (2011) Retaining seed. Saving weather damaged grain for seed, northern and southern regions. GRDC Fact Sheet Jan. 2011, <u>http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC_FS_RetainingSeed2.pdf</u>

¹⁸ BigN (2014) Nitrogen fertiliser placement and crop establishment. Incitec Pivot Ltd, <u>http://bign.com.au/Big%20N%20Benefits/</u> <u>Nitrogen%20Fertiliser%20Placement%20and%20Crop%20Establishment</u>



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Key messages

- Use plump good quality seed from paddocks with a good fertiliser history, uniform in size, not cracked or broken, stored in dark cool dry conditions (preferably not more than one year old) and free from pests and disease.
- Seed should have a high germination percentage, free from weed seeds and inert rubbish.
- Ensure good soil-seed contact and sufficient soil moisture for quick germination.
- Ensure no weeds are present at sowing.¹

3.1 Seed treatments

Seed treatments are applied to seed to control diseases such as smuts, bunts or rust, and insects. When applying seed treatments, always read the chemical label and calibrate the applicator. Seed treatments are best used in conjunction with other disease-management options such as crop and paddock rotation, clean seed, and resistant varieties.

Seed dressing and in-furrow fungicides contain active ingredients for the control or suppression of seed-borne diseases, some fungal root rots and insect pests in cereal crops. At seeding, fungicides can be applied to seed (seed dressing) or applied in soil (coated on compound fertiliser or mixed with liquid fertiliser and applied in-furrow) to be taken up by cereal seedlings. Some seed dressing and/or in-furrow products suppress early foliar diseases such as rusts, while others can provide either control or suppression of insect pests such as aphids and mites. When choosing seed dressing or in-furrow fungicides, consider the range of diseases that threaten your crop. Consult product labels for registrations, the Australian Public Chemical Registration Information System (PubCRIS) at the Australian Pesticides and Veterinary Medicines Authority (APVMA) or InfoPest. Reassess your disease risk before seeding by looking at seasonal forecasts, green-bridge updates and crop disease forecasts for your local



DAFWA (2014) Oats: seeding and establishment. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/</u> oats/oats-seeding-and-establishment?page=0%2C0



area. Paddock and farm history is also an important consideration when determining disease risks. Consult the most recent Winter crop variety sowing guide for more information.

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

- slowing the rate of germination, or
- shortening the length of the coleoptile, the first leaf and the sub-crown internode.

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



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

Source: based on P Cornish 1986.

Product registrations change over time and may differ between states and between products containing the same active ingredient. The registration status for the intended use pattern in your state must be checked on the current product label prior to use.²

Caution in fungicide seed dressings

Read and follow directions on fungicide labels carefully. In some situations, certain fungicide seed dressings (e.g. triazoles) may reduce coleoptile length, which could result in leaves growing under the soil surface and not emerging, particularly if short-coleoptile varieties and/or deep sowing are used. Check chemical labels for this information. Coleoptile shortening may also result from use of dinitroaniline herbicides (trifluralin, pendimethalin, oryzalin). Take care where coleoptile-shortening seed dressings are used together with these herbicides, particularly if it is difficult to obtain good depth control of herbicide incorporation and seed placement, such as in sandy soils. ³ Take into consideration variation in coleoptile length between varieties if deep sowing and triazole seed dressings are to be used.





Cereal seed treatments 2016.

² NSW DPI District Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0008/516185/Procrop-wheat-growth-and-development.pdf</u>

³ K Jayasena, C Beard, GJ Thomas, A Hills (2016) Seed dressing and in-furrow fungicides for cereals in Western Australia. Department of Agriculture and Food WA <u>https://www.agric.wa.gov.au/barley/seed-dressing-and-furrow-fungicides-cereals-western-australia</u>



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<u>GRDC Targeted nutrition at sowing</u> <u>Factsheet.</u>

3.1.1 Fertiliser at seeding

The amount of nitrogen safely placed with the seed will vary depending on soil texture, amount of seedbed utilisation and moisture conditions. Higher amounts of nitrogen can be safely applied with the seed if it is a polymerised form of urea where the nitrogen is released over the period of several weeks. If soil moisture is marginal for germination, high rates of fertiliser should not be placed with the seed. Both nitrogen and phosphorous can be banded prior to seeding, but take care to avoid loss of seedbed moisture and protective crop residue. Place phosphorous with or near the seed at seeding time or band prior to seeding.⁴

3.2 Time of sowing

Sowing time for grain crops is a balance between having the crop flowering soon after the last heavy frost, and being early enough to allow adequate grainfill before the onset of moisture and heat stress in spring. For grazing crops, management is different. The crop needs to be producing biomass as quickly as possible to fill potential autumn gaps in feed supply, and then locked up to get maximum grain recovery. Sufficiently cool soil temperature at sowing, and adequate moisture, are usually the limitations to sowing time for grazing crops. If varieties are sown within the optimum sowing period, they can produce their highest yields, but the best sowing date varies with topography and variety. Locally, sowing dates may need to be extended (earlier or later) depending upon climatic conditions, paddock topography and soil types (Table 1).

Seed at the optimum sowing date for growing season length and variety maturity to maximise yield and reduce the risk of downgrading the quality of both grain and hay. Flowering too early will mean maximum growth and yield will not be achieved and risk of frost damage and weather staining is increased. Flowering too late increases the risk of running out of soil moisture and filling grain at higher than optimum temperatures leading to lower yields and higher screenings. ⁵



⁴ Alberta Agriculture and Forestry (2016) Fall Rye Production. Alberta Government, <u>http://wwwl.agric.gov.ab.ca/\$department/deptdocs.</u> nst/all/agdext269/\$file/117_20-1.pdf

⁵ DAFWA (2014) Oats: seeding and establishment. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-seeding-and-establishment?page=0%2C3</u>



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MALLEE	April			May		June				July				
Milling: Bannister, Echidna, Mitika, Yallara, Wombat, Durack			>	Х	Х	Х	Х	Х	Х	<	<			
eed: Quoll			>	Х	Х	Х	Х	Х	Х	<	<			
Hay: Kangaroo, Mulgara, Wintaroo, Forester			>	Х	Х	Х	Х	Х	Х	<	<			
Grazing: Wintaroo			>	Х	Х	Х	Х	Х	Х	<	<			
WIMMERA	April			May			June			July				
Milling: Bannister, Echidna, Mitika, Possum, Yallara, Wombat, Williams, Durack				>	>	Х	Х	Х	Х	Х	<	<	<	
⁼ eed: Mulgara, Quoll				>	>	Х	Х	Х	Х	Х	<	<	<	
Hay: Brusher, Kangaroo, Mulgara, Wintaroo, Forester			>	>	Х	Х	Х	Х	Х	Х	Х	<	<	<
Grazing: Wintaroo			>	>	Х	Х	Х	Х	Х	Х	Х	<	<	<
NORTH CENTRAL	April			Ma	ay			June				July		
Villing: Bannister, Echidna, Mitika, Possum, Yallara, Wombat , Durack				>	>	Х	Х	Х	Х	Х	<	<	<	
[–] eed: Mulgara, Quoll				>	>	Х	Х	Х	Х	Х	<	<	<	
Hay: Kangaroo, Mulgara, Wintaroo, Forester			>	Х	Х	Х	Х	Х	Х	Х	Х	<	<	<
NORTH EAST	April			Ma	ay			June			July			
Milling: Bannister, Echidna, Possum, Yallara, Wombat, Williams, Durack				>	>	Х	Х	Х	Х	<	<			
Feed: Mulgara, Quoll, Tammar				>	>	Х	Х	Х	Х	<	<			
Hay: Mulgara, Tammar, Tungo, Wintaroo, Forester			>	Х	Х	Х	Х	Х	<					
Grazing: Tungoo		>	Х	Х	Х	<	<							
SOUTH WEST	April			May			June			July				
Milling: Bannister, Echidna, Mitika, Yallara, Wombat		>	Х	Х	Х	Х	Х	Х	Х	Х	<	<	<	
Possum, Williams,		>	Х	Х	Х	Х	Х	Х	Х	<				
Feed: Quoll, Tammar		>	Х	Х	Х	Х	Х	Х	Х	Х	<	<	<	
Hay: Tammar, Tungoo, Forester		>	Х	Х	Х	Х	Х	Х	Х	Х	Х	<	<	<

Varietal choice determines time to grazing or cutting for hay: > earlier than ideal, X optimum sowing time, < later than ideal but acceptable Source: Victorian Winter Crop Summary (2016)

Most cereals prefer soil temperatures of 15–25°C (average 24 hr temp) so poor emergence (10–50%) may occur if temperatures are too high. The exception to this is oats, which can be sown at comparatively higher temperatures. Some people successfully sow oats in February, but there have also been failures. A recommendation is still to be careful with sowing in February and March due to high



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soil temperatures, especially if relying on rainfall to keep crops alive until late autumn when rainfall is more reliable. $^{\rm 6}$

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3.2.1 Early sowing

Sowing as early as possible with a later maturing variety will:

- give the crop the opportunity to give the highest possible yield
- reduce grain protein content—one month delay in sowing date can increase protein by about 1%
- increase the severity of foliar diseases—choose varieties with good disease resistance ratings
- produce taller crops in good growing condition which may lodge.

Early sowing (May) results in higher hay yields compared to late (June) sowing; however, if early maturing varieties are sown there is a greater risk of rainfall on the cut hay.

3.2.2 Late sowing

Sowing late in the program with an early maturing variety will:

- give lower yields with higher protein because flower and grainfill will be later into spring when moisture is likely to be limiting and temperatures high
- result in less severe foliar diseases, lodging and shedding
- reduce hay quality.⁷

3.2.3 Sowing dates to minimise frost damage

Oats are less susceptible to frost damage than other cereals, but can still be impacted by severe frost events. Although outlying severe frosts cannot be mitigated, the risk of seasonal frosts at flowering needs to be assessed and balanced. There are two ways of doing this:

- In areas where the risk of frost is high (i.e. low-lying paddocks, regions with lower winter temperatures such as the Slopes to the east of the region), sow later than the suggested optimum sowing period. As a rule-of-thumb, three days' difference at planting makes one day's difference at heading.
- 2. Change varieties. Use maturity differences to have the crop flowering at a time when the seasonal frost risk is acceptable. With the wide range of oat varieties available, it is possible to choose a variety suitable for sowing from the beginning of autumn through to as late as early winter. Avoid early sowings of leaf-rust-susceptible varieties and varieties sensitive to very warm soils. ⁸

3.2.4 Soil temperature at sowing

Soil temperature at sowing time is an important consideration. The optimum soil temperature for the germination and establishment of oats is $15-25^{\circ}$ C. If the soil is too warm, germination will be delayed and plant establishment may be very poor. Oats can germinate at higher soil temperatures than wheat or barley. ⁹ However, at a soil temperature of 35° C, oats will not usually germinate. Varieties that can be successfully sown into soil temperatures > 25° C should be utilised under such conditions. Soil temperature will vary during the day, and for oats, the maximum soil temperature is the most useful measure. This can be established mid-to-late afternoon. Warm

- 6 Agriculture Victoria (2015) Sowing options for autumn: cereal varieties and other alternatives, <u>http://agriculture.vic.gov.au/agriculture/</u> dairu/pastures-management/forage-cereals/sowing-options-for-autumn-cereal-varities-and-other-alternatives
- DARWA (2014) Oats: seeding and establishment. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/</u> pats/pats-seeding-and-establishment?page=0%2C3
- 8 Pacific Seeds (2006) Oats agronomy guide. Yearbook 2006/2007. Pacific Seeds, <u>https://www.yumpu.com/en/document/view/31552601/</u> pacific-seeds-oats-agronomy-guide-2006–07-direct-router
- 9 B Haskins (2006) Cropping to fill the feed gap. Agriculture Today. New South Wales Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/archive/agriculture-today-stories/ag-today-archives/agriculture_today_march_2006/2006-003/cropping_to_fill_the_feed_gap.</u>



<u>GRDC Time of Sowing Factsheet –</u> <u>Southern Region.</u>




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

FAQ



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



WATCH : GCTV15: <u>Optimal flowering</u> <u>– follow up.</u>



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



soil reduces the plant's coleoptile length, ¹⁰ and warm soils dry out quicker than cooler soils, which means a need for deeper sowing. Oats generally have a longer coleoptile than other cereals, particularly wheat, and are therefore more suited to sowing into warmer soils.

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3.3 Targeted plant population

Establishment of optimum plant population is essential to achieve the maximum possible yield. The desired number of plants per square metre is mainly dependent on yield potential, purpose for which the crop is being grown (i.e. grain versus grazing) and also improving crop competitiveness against herbicide-resistant ryegrass. Use high rates where dense weed populations are expected, when conditions are likely to be wet during winter, in low pH soils, or if seed quality is substandard.

- The recommended plant density for oat grain production in the higher rainfall regions is 240 plants per square metre (m²), while in the lower rainfall region it is 160 plants/m².
- The recommended plant density for oat hay production is 240–320 plants/m², with higher density helping to compete better with weeds and to reduce stem thickness, which is a desirable in quality export hay.

Reasons to increase plant density include:

- hay production—to help plants compete against weeds and to produce finer stems as required for the export market. Target is 320 plants/m²
- dwarf varieties—plump-grained varieties can be sown at higher density
- seedling emergence and establishment are likely to be reduced
- plant tillering is expected to be low because of variety or soil fertility effects
- sowing later than ideal time
- full or partial irrigation
- soil fertility and moisture levels are high
- low subsoil moisture or a dry finish is expected
- a high risk of waterlogging during the winter, to compensate for a lack of tillering
- moderate to high grass weed densities are likely—increase competitiveness

Avoid higher plant densities where:

- Plump grain is required for milling quality.
- Lodging could be a problem—slightly lower densities can encourage thicker stem growth.
- Crops are growing on limited stored soil moisture and may risk depletion before the crop matures.¹¹

3.4 Calculating seed requirements/seeding rate

Seed size varies significantly between oat varieties and seasons; therefore, it is important to measure the 1000-grain weight of the selected variety to calculate the required seeding rate. Seeding rates (Table 2) should be used as a guide only, and growers should calculate their own seeding rates based on 1000-seed weight, target plant population and seed establishment percentage. ¹² Calculate seeding based on seed size, target plant population and calculated germination per cent.

Sowing rates can range from 70 to 155 kg/ha relative to seed size, sowing time, crop use (grain, hay, grazing) rainfall zone and so seeding rates should be adjusted

- 10 BJ Radford, AJ Key (1993) Temperature affects germination, mesocotyl length and coleoptile length of oats genotypes. Australian Journal of Agricultural Research 44, pp. 677–688, <u>http://www.publish.csiro.au/paper/AR9930677</u>
- 11 DAFWA (2014) Oats: seeding and establishment. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-seeding-and-establishment?page=0%2C1</u>
- 12 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. New South Wales Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf





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accordingly. Seed size can be determined, and an ideal sowing rate calculated, at many of the department's offices and seed suppliers.

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To determine the average grain weight, count and weigh 1,000 seeds of the graded sample. The seed rate calculation is:

Seed rate (kg/ha) = [Target plant density ($plants/m^2$) × Average grain weight (mg)] / Expected establishment per cent (%)

For example, if the desired plant population is 240 plants/m², the average grain weight is 40 milligrams (mg) and expected establishment is 80% the calculation is: $240 \times 40 / 80 = 120 \text{ kg/ha}$ (Table 2).



Average seed weight (mg)	160 plants/m ²	240 plants/m ²	320 plants/m ²
33	66	99	132
35	70	105	140
37	74	111	148
39	78	117	156

Source: DAFWA

When vetch is sown with oats for forage:

- seeding rates should be 30 kg/ha for the cereal and 30 kg/ha for the vetch
- the vetch will be very slow to establish in autumn, but can dominate the forage crop during spring.

Note that while including vetch is a good option for dryland situations, vetch is not ideal when a crop is likely to be flood irrigated at any stage due to potential disease problems. ¹³

3.5 Row spacing

In cereal crops that receive adequate moisture, narrow row spacing generally results in higher grain yields than wider rows by promoting ground cover, optimising light interception and suppressing weed growth (Photo 1). Most growers use 20 to 25 cm. Higher rainfall areas traditionally have narrower row spacings because of higher yield potentials. In most cases, growers do not have the option to change row spacings on machinery to suit individual crop needs for winter crops.

The advantages of wider rows can include:

- reduced trampling losses during grazing
- a more open crop canopy that will be less favourable to rust development
- potential to reduce sowing rate
- greater ability to sow through standing stubble.

The advantages of narrow rows can include:

- greater competition against weeds, especially in the presence of resistant weeds
- fewer issues with viruses
- higher grain yields
- thinner plant stems in a crop destined for oaten hay production.

For crops expected to yield greater than 4 tonnes per hectare (t/ha), rows should be sown no further apart than 25 cm and preferably less than 20 cm. For hay this will



¹³ Agriculture Victoria (2015) Managing winter cereals, <u>http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/irrigated-pastures/managing-winter-cereals</u>



give good ground coverage by plants so that the windrow can be held off the ground to improve air circulation and reduce staining. $^{\rm 14}$

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Photo 1: Wide row spacing (375 mm) is a hallmark of disc seeding, allowing plants to develop vigorous root systems.

3.6 Sowing depth

Sowing plump seed at the right depth is an important first step towards achieving vigorous, healthy seedlings. Planting should be deep enough to provide uniform coverage of the seed and to help maintain moist conditions for germination.

The recommended depth for most oat varieties is 3–6 centimetres (cm).

Oat seedlings emerge by elongation of the mesocotyl and coleoptile (in wheat and barley it is only through elongation of the coleoptile), so oats can safely be sown deeper than wheat and barley.

Sowing too shallow may:

- place the seed in dry soil or cause uneven emergence with limited rainfall
- cause shallow crown depth that may cause the plants to lodge when soil is very wet and in high winds
- make plants more vulnerable to pre-emergent herbicides, such as Diuron[®]
- expose the seeds to hotter soil temperatures during germination.
- Consequences of deep sowing can include:
- delayed seedling emergence
- emerging seedlings are weaker, limp and easily damaged by wind and insects
- reduced root development making plants more susceptible to root diseases
- delayed plant development and tillering
- reduced competitiveness with emerging weeds.

Coleoptile and mesocotyl length are temperature dependent, so early sowing into warmer soils will result in them being longer compared to later sowings in winter. $^{\rm 15}$



¹⁴ DAFWA (2014) Oats: seeding and establishment. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-seeding-and-establishment?page=0%2C2</u>

¹⁵ DAFWA (2014) Oats: seeding and establishment. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-seeding-and-establishment?page=0%2C2</u>



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WATCH : SFS seeder trial.



WATCH : <u>GCTV19</u>: <u>Different seeders</u> <u>different yields</u>. <u>Local R&D – valuable</u> solutions for the HRZ grain growers.



3.7 Sowing equipment

As much as 60% of the final yield potential for a crop is determined at planting. Seeding too thinly, using poor quality seed, and uneven stands result in end-ofseason yield losses that cannot usually be overcome. ¹⁶

Seeder calibration is important for precise seed placement and seeders need to be checked regularly during sowing (Photo 2).

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Most growers in the Southern Region use either a knife-point/press-wheel tyne system or a single disc. Disc seeders can handle greater quantities of stubble but experience crop damage issues with pre-emergent herbicide use. Tyne seeding systems do not have the same herbicide safety issues but usually require some form of post-harvest stubble treatment, such as mulching or burning.

Use press-wheels to compress the soil directly above the seed for even distribution during seeding. When using standard tyned seeders without press-wheels, the seed is often spread through a depth of 2–3 cm with the occasional seed left on the soil surface.

Sowing into water-repellent sands early in the season where the wet soil may be at 5 cm or more necessitates the use of press-wheels to ensure even establishment. $^{\rm 17}$



Photo 2: Seeder calibration is important for precise seed placement and seeders need to be checked regularly during sowing.
Photo: Rohan Rainbow

- 16 W Thomason (2004) Planting wheat: seeding rates and calibration. Virginia Cooperative Extension, <u>http://www.sites.extvt.edu/newsletter-archive/cses/2004–10/plantingwheat.html</u>
- 17 DAFWA (2014) Oats: seeding and establishment. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-seeding-and-establishment?page=0%2C2</u>





SECTION 4 OATS



Plant growth and physiology

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Oats are an erect, tufted, annual grass crop with hollow stems to 2 m tall (Table 1). The loosely branched inflorescence has large drooping spikelets, each with 2 or 3 florets. Oat seed is usually yellow.

Key Characters:

- Lemmas generally hairless.
- Awns if present are not twisted.
- Seed is yellow.
- Membranous ligule.
- No auricles.
- Emerging leaf rolled in the bud
- Sheath rolled and overlapping.

4.1 Germination and emergence issues

The dormancy period is generally short in oats—from a few days to several weeks.

Germination begins when the seed absorbs water and ends with the appearance of the radicle. Germination has three phases:

- water absorption (imbibition)
- activation
- visible germination

Phase 1. Water absorption (GS01*)

(*see heading 4. Plant growth stages, for detail on Zadoks Cereal Growth Stage Key)

Phase 1 starts when the seed begins to absorb moisture. Generally, a seed needs to reach a moisture content of around 35–45% of its dry weight to begin germination. Water vapour can begin the germination process as rapidly as liquid can.





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Seeds begin to germinate at a relative humidity of 97.7%. Soil so dry that roots cannot extract water still has a relative humidity of 99%, much higher than that of a dry seed. So even in dry conditions, there can be enough moisture for the seed to absorb and begin Phase 1, but it takes longer than in moist conditions.

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Phase 2. Activation (GS03)

Once the embryo has swollen, it produces hormones that stimulate enzyme activity. The enzymes break down starch and protein stored in the seed to sugars and amino acids, providing energy to the growing embryo. The larger the seed, the more starch and therefore energy it will have. If the seed dries out before the embryo starts to grow, it remains viable. Phase 2 continues until the rupture of the seed coat, the first visible sign of germination.

Phase 3. Visible germination (GS05–GS09)

In Phase 3, the embryo starts to grow visibly. The radicle emerges, followed soon after by other primary roots and the coleoptile. The enzymes produced in Phase 2 mobilise sugars and amino acids stored in the seed and enable their transfer to the growing embryo.¹

4.1.1 Emergence

Optimum planting depth varies with planting moisture, soil type, seasonal conditions, climatic conditions, and the rate at which the seedbed dries. The general rule is to plant as shallow as possible, provided the seed is placed in the moisture zone, but deep enough that the drying front will not reach the seedling roots before leaf emergence, or to separate the seed from any pre-emergent herbicides used.²

When shallow seeding, the previous crop's residue will have a greater tendency to interfere with good seed-to-soil contact. Even spreading of the previous crop residue is essential for quick emergence. Make sure seed-to-soil contact occurs. 3

Aeration of seed during storage can help to ensure high seed viability and germination rates. ⁴

As the first primary roots appear, the coleoptile bursts through the seed coat and begins pushing towards the surface. Emergence is when the coleoptile or the first leaf becomes visible above the soil surface.

The coleoptile (Photo 1) is well developed in the embryo, forming a thimble-shaped structure covering the seedling tube leaf and the shoot. Once the coleoptile emerges from the seed, it increases in length until it breaks through the soil surface. The fully elongated coleoptile is a tubular structure about 50 mm long and 2 mm in diameter. It is white, except for two strands of tissue that contain chlorophyll. The end of the coleoptile is bullet-shaped and is closed except for a small pore, 0.25 mm long, and a short distance behind the tip.



¹ NSW DPI District Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf-file/0008/516185/Procrop-wheat-growth-and-development.pdf

Alberta Government (2016) Fall Rye Production, <u>http://www1.agric.gov.ab.ca/\$department/deptdocs.nst/all/agdex1269/\$file/117_20-1.pdf</u>
 Baxter N. (2014). Ground Cover Issue113: Nov-Dec 2014 – Study finds aeration improves seed germination. <u>https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-113-Nov-Dec-2014/Study-finds-aeration-improves-seed-germination</u>





Photo 1: Germinated cereal seedlings. Source: <u>GRDC.</u>

When the coleoptile senses light it stops growing and the first true leaf pushes through the pore at the tip. Up to this point, the plant is living on reserves within the seed. ⁵ The difference between the coleoptile and the first true leaf is that the coleoptile knows which way the soil surface is. If it does not reach the surface, the first leaf may emerge under the soil and grow in any direction.

Seed size influences coleoptile length, which is sensitive to sowing depth. Sowing depth influences the rate of emergence and the percentage that emerges. Deeper seed placement slows emergence; this is equivalent to sowing later. Seedlings emerging from greater depth are also weaker, more prone to seedling diseases, and tiller poorly.

Recent research has confirmed the importance of avoiding smaller-sized seed when deep sowing.

Crop emergence is reduced with deeper sowing because the coleoptile may stop growing before it reaches the soil surface, with the first leaf emerging from the coleoptile while it is still below the soil surface (Photo 2). As it is not adapted to pushing through soil (does not know which way is up), the leaf usually buckles and crumples, failing to emerge and eventually dying. ⁶

5 NSW DPI District Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, <u>http://</u> www.dpi.nsw.gov.au/___data/assets/pdf_file/0008/516185/Procrop-wheat-growth-and-development.pdf



⁶ NSW DPI Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries 2007, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/516185/Procrop-wheat-growth-and-development.pdf</u>





Photo 2: GS11 – 1st unfolded leaf. Deep sown seedling (left) and correctly sown seedling (right).

Source: GRDC.

4.1.2 Soil moisture

Soil moisture influences the speed of germination. Germination is rapid if the soil is moist. When the soil dries to near the permanent wilting point, the speed of germination slows. Instead of 5 days at 7°C when there is adequate moisture, germination will take 10 days at 7°C when soil reaches permanent wilting point.

The germination process in a seed may stop and start in response to available moisture. Therefore, seeds that have taken up water and entered Phase 2, but not reached Phase 3, remain viable if the soil dries out. This can happen when dry sowing is followed by a small amount of rain that keeps the soil moist for a few days before drying out. When the next rain comes, the seed resumes germinating, taking up water and moving quickly through Phase 2, so that germination is rapid.

This ability to start and stop the germination process (in response to conditions) before the roots and coleoptile have emerged is an important consideration when dry sowing.

If the seedbed dries out before the coleoptile has emerged, the crop needs to be monitored to determine whether it will emerge, so the critical decision to re-sow can be made.

Soil moisture also affects emergence. Sowing into hard-setting or crusting soils that dry out after sowing may result in poor emergence. The hard soil makes it difficult for the coleoptile to push through to the surface, particularly in varieties with short coleoptiles. In some crusting soils, gypsum and/or lime may improve soil structure and assist seedling emergence.

Stubble reduces the impact of raindrops on the soil surface and helps to prevent formation of soil crusts. Stubble retention also encourages biological activity and increases the amount of organic matter, which improves the stability of the soil by binding the soil particles together.⁷



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⁷ NSW DPI District Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0008/516185/Procrop-wheat-growth-and-development.pdf</u>





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IN FOCUS

Influence of temperature and photoperiod on growth and yield components in oats (*Avena sativa*)

Two oat cultivars were grown to maturity in controlled environments under two temperature regimes with daylength held constant and under two daylengths with a constant temperature pattern. Plants were moved between environments at panicle initiation and at anthesis, dividing the growth period into three phases. Growth and development were hastened by warm temperature and by long days. Temperature treatments caused greater variation in the duration of growth phases in cultivar 1 than in cultivar 2; however cultivar 2 was affected more by daylength. Higher plant dry weights were obtained from cool temperature treatments; response to daylength was inconsistent. Grain yield was not closely associated with duration of growth phases. The effect of temperature and daylength on yield components was markedly different in the two cultivars. The greatest grain yield response in cultivar 2 resulted from cool temperature during panicle initiation to anthesis, attributable to increased fertile tiller development. Daylength had limited effect on components. In cultivar 1 the greatest yield response was from cool temperatures during anthesis to maturity, with increases in all components. Short days before anthesis increased grain size and number.⁸

4.3 Plant Growth Stages

The oat crop goes through three distinct phases as it grows from planting to harvest. They can be described as follows:

4.3.1 Foundation

The foundation phase starts from sowing and lasts through to the start of stem extension. During this time yield-bearing shoots and primary roots form as the canopy develops. The components of yield are set by the end of this stage. The speed of growth will depend on the environment with dull, cool days giving slow growth. In spring oats this phase will be rapid as the days are bright and temperatures increasing.⁹

4.3.2 Construction

The construction phase starts from the first node being detectable through to flowering. This is a critical growth period as yield delivering leaves, deep roots, fertile florets and stem reserves form. The canopy will be complete and capable of intercepting 95% of incoming Photosynthetically Active Radiation (PAR). Growth is very rapid with high daily nutrient demand from the soil. It is also referred to as the Grand Growth Phase.¹⁰



⁸ HR Klinck & SL Sim (1977) Influence of temperature and photoperiod on growth and yield components in oats (Avena sativa). Canadian Journal of Botany, 55(1), 96–106.

⁹ Yara Crop Nutrition. Oat growth and development, <u>http://www.yara.co.uk/crop-nutrition/crops/oats/key-facts/oat-growth-and-development/</u>

¹⁰ Yara Crop Nutrition. Oat growth and development, <u>http://www.yara.co.uk/crop-nutrition/crops/oats/key-facts/oat-growth-and-development/</u>





The production phase starts just past flowering, lasting through to grainfilling and ripening. During this period the critical yield components i.e. $grains/m^2$ and the grain weight will be determined. The health of the flag leaf and its nitrogen status must be maintained as it will contribute up to 70% of the carbohydrate that ends up in the grain. ¹¹

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4.3.4 Oat growth stages

After seedling emergence, oat leaves are produced at a rate of about one every 5–14 days, depending on temperature. The number of leaves produced on the main stem (from 1st leaf emerged to flag leaf) varies from about 7–14 leaves depending on variety, region and sowing date. Photo 3 shows the second leaf is at least 50% emerged on the main shoot and the third leaf is present but not fully emerged.



Photo 3: Seedling growth phase – 2 Leaf (GS12). Source: GRDC.

Tillering is an important stage as it allows the cereal plant to compensate for low plant populations or take advantage of good growing conditions (Photo 4). In moisture stressed conditions, tillers will not be produced. The cereal plant's growth stage is then determined by counting the number of leaves on the main stem. Without the tillering phase to help reference a cereal plant, less accurate identification of the true growth stage can occur as the old leaves on the main stem die and fall away from the plant. This means growth stage references GS17–19 are rarely used.



¹¹ Yara Crop Nutrition. Oat growth and development, <u>http://www.yara.co.uk/crop-nutrition/crops/oats/key-facts/oat-growth-and-development/</u>



First tiller emerging

Photo 4: *GS13 – 3 unfolded leaves with first tiller emerging from the first leaf axial.* Source: GRDC.

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At seedling growth stage three, the third leaf is at least 50% emerged on the main shoot (Photo 5). This growth stage is usually just prior to the initiation of the first tiller. The first tiller emerges from the leaf axial of the oldest leaf at GS13–14. But when assessing the correct growth stage, only count leaves on the main shoot.



Photo 5: Seedling growth phase – 3 Leaf (GS13) and start of tillering phase (GS21). Source: GRDC.

The fourth leaf is at least 50% fully expanded on the main shoot (Photo 6). This coincides with the initiation of the first (primary) tiller that emerges between a lower leaf and the main tiller. But when assessing the correct growth stage, only count leaves on the main shoot.







Photo 6: Seedling growth phase – 4 Leaf (GS14) and start of tillering phase (GS21). Source: GRDC.

The fifth leaf is at least 50% fully expanded on the main shoot (Photo 7). Tillers continue developing through this stage. All tillers have been initiated by the time the main shoot has five to seven leaves. Secondary roots develop during tillering.



Photo 7: Seedling growth phase – 5 Leaf (GS15) and tillering phase (GS22)

The tillering phase (GS23-24) is when the main stem and 3 or 4 tillers are visible (Photo 8). Tillers continue developing through this stage. All tillers have been initiated by the time the main shoot has five to seven leaves. Secondary roots develop during tillering.







Photo 8: Oat mid-tillering Source: GRDC

Stem elongation commences when tillering has finished and the first node can be detected on the main stem. The first node can be found by peeling back the leaves at the base of the main stem (Photo 9) to expose the node underneath. You will be able to feel the swelling with your fingers.

In Australian conditions, cereal plants rarely reach GS29 before the main stem starts to elongate.



Photo 9: Oat at the end of tillering and start of stem elongation (GS25-29, GS30). Source: GRDC.



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After stem elongation commences (GS30) the growth stage describes the stage of the main stem - it is not an average of all the tillers (Photo 10). This is very important for fungicide timing.

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If the cereal crop is being grazed, and to have minimum impact on the plant's grain development, stock must be removed from the crop at this time (GS30) and before the first node can be detected (GS31).

The second (GS32) and subsequent nodes are counted when the internode length (i.e. the space between the nodes) is greater than 2 cm.



Photo 10: Stem elongation (GS30-39) and development of the flag leaf (GS37-39).

The Flag leaf (last leaf to form) appears on top of the extended stem (Photo 11). The boot stage is just prior to head emergence when the flag leaf sheath encloses the growing head.







Photo 11: *Flag leaf (GS39) to booting (GS45).* Source: GRDC.

A growth stage key (Figure 1) provides farmers, advisers and researchers with a common reference for describing the crop's development. Management by growth stage is critical to optimise returns from inputs such as N, plant growth regulator, fungicides and water.



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	(¥	X			1
Growth stage	Description of stage	Growth stage	Description of stage	Growth stage	Description of stage	Growth stage	Description of stage
Seedling growth		Stem elongation		Ear emergence	First spikelet of ear just visible above flag leaf ligule	Dough development	
GS10	First leaf through coleoptile	GS30	Ear at 1 cm (pseudostem erect)	GS51	Half of ear emerged above flag leaf ligule	GS83	Early dough
GS11	First leaf unfolded (ligule visible)	GS31	First node detectable	GS55	Ear completely emerged above flag leaf ligule	GS85	Soft dough
GS13	3 leaves unfolded	GS32	Second node detectable	GS59		GS87	Hard dough (thumbnail impression held)
GS15	5 leaves unfolded	GS33	Third node detectable	Flowering		Ripening	
GS19	9 or more leaves unfolded	GS37	Flag leaf just visible	GS61	State of flowering	GS91	Grain hard (difficult to divide)
Tillering		GS39	Flag leaf blade all visible	GS65	Flowering half- way	GS92	Grain hard (not dented by thumbnail)
GS20	Main shoot only	Booting		GS69	Flowering complete	GS93	Grain loosening in daytime
GS21	Main shoot and 1 tiller	GS41	Flag leaf sheath extending	Milk development			
GS23	Main shoot and 3 tillers	GS42	Flag leaf sheath just visibly swollen	GS71	Grain watery ripe		
GS25	Main shoot and 5 tillers	GS45	Flag leaf sheath swollen	GS73	Early milk		
GS29	Main shoot and 9 or more tillers	GS47	Flag leaf sheath opening	GS75	Medium milk		
				GS77	Late milk		

Figure 1: Oat growth stages.

Source: <u>Yara</u>



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This is the most commonly used key to growth stages for cereals, in which the development of the cereal plant is divided into 10 distinct development phases covering 100 individual growth stages. Individual growth stages are denoted by the prefix GS (growth stage) or Z (Zadoks), for example, GS39 or Z39. The principal Zadoks growth stages (Figure 2) used in relation to disease control and N management are those from the start of stem elongation through to early flowering: GS30–GS61.

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Figure 2: Zadoks growth stages.

Source: Zadoks, J.C., Chang, T.T., Konzak, C.F. (1974). A decimal code for the growth stages of cereals. Weed res. 14, 415-421 12

Key points: Zadoks Growth Stage Key:

- The Zadoks Growth Stage key does not run chronologically from GS00 to GS99; for example when the crop reaches three fully unfolded leaves (GS13) it begins to tiller (GS20), before it has completed 4, 5, 6 fully unfolded leaves (GS14, GS15, GS16).
- It is easier to assess main stem and number of tillers than it is the number of leaves (due to leaf senescence) during tillering. The plant growth stage is

12 GRDC (2005) Cereal growth stages. Grains Research and Development Corporation, September 2005, <u>https://grdc.com.au/uploads/</u> documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf





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GRDC Cereal Growth Stages Guide

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determined by main stem and number of tillers per plant; for example GS22 is main stem plus two tillers up to GS29 main stem plus nine or more tillers.

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- In Australian cereal crops plants rarely reach GS29 before the main stem starts to stem elongate (GS30).
- As a consequence of growth stages overlapping it is possible to describe a plant with several growth stages at the same point in time. For example, a cereal plant at GS32 (second node on the main stem) with three tillers and seven leaves on the main stem would be at GS32, GS23 and GS17, yet practically would be regarded as GS32, since this describes the most advanced stage of development.
- Note: after stem elongation (GS30) the growth stage describes the stage of the main stem, it is not an average of all the tillers. This is particularly important with fungicide timing; for example GS39 is full-flag leaf on the main stem, meaning that not all flag leaves in the crop will be fully emerged.
- Use a ruler to measure node movement in the main stem to define early stem elongation growth stages.
- Take care not to confuse the basal node at the stem base with the first true node. Basal nodes are usually signified by a constriction of the stem below the node with an incompletely formed internode space; it is the point where the lowest leaves attach to the stem. Further, basal nodes will often grow small root tips. This is not the first node.
- Nodal growth stage can give an approximate guide to which leaf is emerging from the main stem, this can save time with leaf dissection when it comes to making decisions on fungicide application pre-flag leaf (when all leaves are emerged).
- The rate of development influences the time between growth stages—later sowings spend less time in each development phase including grainfill, and potentially have lower yield.
- Though it will vary between varieties and regions (due to temperature), stem elongation leaves emerge approximately five to 10 days apart (10 under cooler temperatures at the start of stem elongation and nearer five to seven days as the flag comes out.)
- The period of time between leaf emergences is referred to as the phyllochron and is approximately 100–120 (degree days leaf⁻¹), though it can be longer or shorter depending on variety. Barley varieties tend to have shorter phyllochrons, so leaves tend to emerge slightly quicker.¹³



¹³ N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC 7 January 2014, <u>https://grdc.com.au/Resources/</u> <u>Publications/2014/01/Advancing-the-management-of-crop-canopies</u>



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Key messages:

- Oats require adequate fertiliser at sowing.
- Growers should manage nitrogen differently for a grain crop compared to a hay crop as a hay crop requires less nitrogen.
- Oat crops, particularly oaten hay, remove significant quantities of all the major nutrients.
- Application of nutrients is required to optimise production either on an annual basis for nutrients like N and P or less frequently for the micronutrients like Cu and Zn.
 - Monitor paddocks and plants for signs of nutrient and micronutrient deficiency.

Oats has traditionally been considered a low input crop and has generally been grown on paddocks with lower soil fertility. The development of higher-yielding grain and hay varieties combined with greater emphasis on grain and hay quality from both export and domestic markets means that nutrient management now has to be more carefully considered when growing oats. Oat crops grow poorly without the addition of nutrients. The major nutrients required for healthy growth are nitrogen (N), phosphorus (P), potassium (K) and sulfur (S); and the micronutrients copper (Cu), manganese (Mn), molybdenum (Mo) and zinc (Zn) (Photo 1). ¹

It is important for growers to use both soil testing and tissue testing to ensure the crop nutrient status is adequate for plant growth. Apply fertiliser at above the normally recommended rates to crops used for grazing and grain, as they have a longer vegetative period than grain-only crops.



Photo 1: Application of nutrients is required to optimise production either on an annual basis for nutrients such as N and P or less frequently for micronutrients such as copper and zinc.

Photo: Nicole Baxter



DAFWA (2016) Oats: fertilisers and plant nutrition. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/</u> oats/oats-fertilisers-and-plant-nutrition



5.1 Crop removal rates

Oat crops, particularly oaten hay, remove significant qualities of all the major nutrients. As a general guide, a 6.0 t/ha crop will remove 15 kg/ha of phosphorus, 120 kg/ha of nitrogen, 18 kg/ha of potassium, and 24 kg/ha of sulfur (Table 1). 2

Table 1: Comparison of the average quantity of nutrients removed (kg/ha) per tonne of grain production for a range of crops. ³

Сгор	Nitrogen	Phosphorus	Potassium	Sulfur
Oats	17	2.5	4	1.5

The continued loss of nutrients from paddocks without replacement becomes particularly important when the soils are already marginal or deficient in nutrients. The continued depletion of nutrients, particularly K, from soil with adequate amounts will eventually reduce soil K supply and decrease the productivity and quality of produce. Removing nutrients from the soil may also reduce the pH of the soil. As the plant material is removed from the paddock, there is a net export of alkalinity which leaves behind residual hydrogen ions in the soil to maintain electrical balance. Over time, as this process is repeated the soil becomes acidic. ⁴

5.2 Soil testing

Soil-test information can be used to support decisions about fertiliser rate, timing and placement. Soil testing is the only quantitative nutrient information that can be used to predict yield response to nutrients. Soil samples should be taken close to sowing so summer mineralisation rates can be captured, but with enough lead time so fertilisers and other inputs can be ordered and be on-farm in time for the sowing operation. Incorporate deep sampling of N and S to determine N budgeting for the season. This may include the pre-drilling of N pre-sow and N at sowing or topdressing as the season progresses. For growers relying on topdressing to supply additional N, take a soil sample in-crop during early crop development or take plant-tissue tests (i.e. cereals during early tillering) with sufficient time to allow timely topdressing (i.e. cereals before GS31). Choose a laboratory that has Australasian Soil and Plant Analysis Council (ASPAC) certification for the tests they offer. National Association of Testing Authorities (NATA) accreditation is also desirable. Regular sampling of paddocks (e.g. every three years for most nutrients, except for N, which should be every year) allows monitoring of fertility trends over time. Sampling points should be GPS recorded, so subsequent samples are taken from exactly the same place.⁵

Appropriate soil tests for measuring soil-extractable or plant-available nutrients are:

- bicarbonate extractable P (Colwell P), to assess easily available soil P
- acid extractable P (BSES-P), to assess slower release soil P reserves and the build-up of fertiliser residues (not required annually)
- exchangeable K
- KCI-40 extractable S or MCP-S
- 2M KCI extractable mineral N, to provide measurement of nitrate-N and ammonium-N.

Other measurements that both aid the interpretation of soil tests and illustrate soil properties that may influence nutrient uptake include:

- Soil pH
- 2 T Bray (2014) Irrigated milling oats set to roll. IREC Farmers' Newsletter Large Area No. 190: Autumn 2014, <u>http://irec.org.au/wp-content/uploads/FN%20190.pdf</u>
- 3 Agriculture Victoria (2008) Establishing forage cereals, <u>http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/forage-cereals/establishing-forage-cereals</u>
- 4 DAFWA (2016) Oats: fertilisers and plant nutrition. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition</u>
- 5 GRDC (2013) Better fertiliser decisions for crop nutrition. Northern, Southern and Western Regions. Crop Nutrition Fact Sheet, GRDC, 4 November 2013, <u>https://grdc.com.au/Resources/Factsheets/2013/11/Better-fertiliser-decisions-for-crop-nutrition</u>





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soil carbon or organic matter content

- phosphorus buffering index (PBI)
- soil salinity measured as electrical conductivity
- chloride and other exchangeable cations, including aluminium
- soil sodicity
- cation exchange capacity (CEC)
- dispersion
- exchangeable sodium percentage (ESP).

The most common soil-sampling depth for nutrient analysis is 0–10 cm, for broadacre crops. This layer is chosen because nutrients, especially P, and plant roots are concentrated within this layer. ⁶ Deep soil testing is a must when sampling for N and S, due to their mobility in the soil. Depths should be to 60 cm. Some work is being conducted on the rundown of the immobile nutrient P at depth. ⁷ Soil testing every three years in the 10–30 cm band may be beneficial with this nutrient to establish a baseline.

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5.3 Plant and/or tissue testing for nutrition levels

Micronutrients (or trace elements) such as zinc, manganese and copper are an important part of total nutrient management, particularly following a rice crop. A plant-tissue test can detect any nutrient deficiencies that may need to be addressed, particularly when applying high rates of nitrogen to maximise yields. ⁸ Oat crops, particularly oaten hay, remove significant qualities of all the major nutrients. It is, therefore, important for growers to use both soil testing and tissue testing to ensure the crop nutrient status is adequate for plant growth. ⁹

Plant-tissue testing is an underutilised tool for diagnosing hidden nutritional deficiencies in crops. Growers are urged to consider tissue testing to diagnose macronutrient and micronutrient deficiencies. Unlike macronutrients such as nitrogen and phosphorus, micronutrients, or trace elements, cannot be reliably assessed using soil tests alone due to their low concentration in the soil. Because of this, tissue testing is a good tool to confirm a suspected micronutrient deficiency. The micronutrients most likely to limit production in Australian soils are zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo) and boron (B).¹⁰

The successful use of plant-tissue analysis depends on sampling the correct plant part at the appropriate growth stage, as nutrient concentration can change during the lifecycle of the oat plant. For these reasons, critical tissue concentrations should be associated specifically with defined stages of plant growth or plant part rather than growth periods (i.e. days from sowing). If the lab you are using has a guide or instructions for sample collection, follow them as the sample will be assessed against these sorts of interpretative guidelines (Table 2). ¹¹

- 6 GRDC (2014) Soil testing for crop nutrition. Northern Region. Crop Nutrition Fact Sheet, GRDC, 20 January 2014, <u>https://grdc.com.au/</u> <u>Resources/Factsheets/2014/01/Soil-testing-for-crop-nutrition-North</u>
- 7 S Jeffrey (2015) Deep P applications trialled in Central West NSW. GRDC, 29 September 2015, <u>https://grdc.com.au/Media-Centre/Media-News/North/2015/09/Deep-P-applications-trialled-in-Central-West-NSW</u>
- 8 T Bray (2014) Irrigated milling oats set to roll. IREC Farmers' Newsletter Large Area No. 190: Autumn 2014, <u>http://irec.org.au/wp-content/uploads/FN%20190.pdf</u>
- 9 DAFWA (2016) Oats: fertilisers and plant nutrition. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition</u>
- 10 R Barr (2015) Tissue testing a health check-up for micronutrients. Micronutrients Fact Sheet, GRDC, 11 June 2015, <u>https://grdc.com.au/</u> <u>Media-Centre/Media-News/South/2015/06/Tissue-testing-a-health-checkup-for-micronutrients</u>
- 11 GRDC (2010) Plant tissue testing: an under utilised tool for diagnosing hidden hunger in crops. GRDC Update Papers, 17 September 2010, <u>https://qrdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/PLANT-TISSUE-TESTING-AN-UNDER-UTILISED-TOOL-FOR-DIAGNOSING-HIDDEN-HUNGER-IN-CROPS</u>





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Back Paddock Guidelines for sampling plant tissue for annual cereal, oilseed, legume crops

Crop Guide - Sampling Oat.



<u>GRDC Targeted nutrition at sowing</u> <u>Factsheet.</u>

Table 2: Guidelines for sampling plant tissue of Oats.

Growth stage to sample	Plant Part	Number required
Seedling to early tillering (GS 14–21)	Whole tops cut off 1 cm above ground	40
Early tillering to 1st node (GS 23–31)	Whole tops cut off 1 cm above ground	25
Emergence of head from boot (GS 50–51)	Whole tops cut off 1 cm above ground	25
Early tillering to 1st node (GS 21–31)	Youngest expanded blade (YEB) plus next 2 lower blades	40

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Source: Back Paddock 2010

5.4 Nitrogen

Nitrogen application can range from 40–80 kg/ha relative to projected yield, rainfall and planned spring watering. Dwarf varieties like Mitika have a higher nitrogen requirement than other varieties and the application rate should be increased by about 20%. Plant emergence can be reduced if urea is drilled too close to the seed, generally at rates higher than 30 kg N/ha. Both nitrogen and phosphorous can be banded prior to seeding, but take care to avoid loss of seedbed moisture and protective crop residue. Place phosphorous with or near the seed at seeding time or band prior to seeding.¹²

Split nitrogen applications or all nitrogen topdressed at early to mid-tillering, prior to a rain event, is the preferred nitrogen application option. ¹³

Nitrogen (N) is largely responsible for setting up the yield potential of the crop. Nitrogen is required for tiller development and required by plants to create protein. The N for plant growth is supplied from both the soil and from N fertiliser application. Nitrogen is taken up by the oat plant when it is in an inorganic form (as either ammonium or nitrate). In the soil over 98% of the N is in an organic form which cannot be taken up by the oat plant until it is mineralised. A large proportion of the oat plants' requirement for N is supplied by the soil. Where the available N supply from the soil is inadequate for optimum yield and quality, N fertiliser is required (Figure 1). Soil testing helps estimate the amount of N already available in the soil. Soil type, cropping history, yield potential and the season are important factors to consider in N management decisions.



¹² Alberta Agriculture and Forestry (2016) Fall Rye Production. Alberta Government, <u>http://www1.agric.gov.ab.ca/\$department/deptdocs.nst/all/agdex1269/\$file/117_20-1.pdf</u>

¹³ T Bray (2014) Irrigated milling oats set to roll. IREC Farmers' Newsletter – Large Area No. 190: Autumn 2014, <u>http://irec.org.au/wp-content/uploads/FN%20190.pdf</u>





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The amount of N fertiliser required to grow a grain or oat hay can be estimated from your fertiliser decision support programs. The amount of N required will be modified by seasonal conditions and the oat variety. As dwarf varieties have a higher N requirement, it is suggested that the N application rate used be increased by about 20% above that recommended for non-dwarf varieties.

Oat hay and grain yield increases (response) to applied N depend on the soil moisture available during the season. In a dry season there is usually a poor crop response to applied N due to the reduced rate of mineralisation of granular N fertiliser and possible lack of soil-available water. Depending on the crop yield potential, applying a foliar spray of N in drier years may be a better option than granular fertilisers. Poor finishes to the season also reduce crop yield irrespective of how much N is applied.

In wet seasons, leaching of N can occur, particularly in sandy soils. In leaching situations, the N requirement for oats can be delayed and/or split to reduce the N lost by leaching. To maximise hay quality any late N should be applied between tillering (Z25) and stem elongation (Z31). Applying N too late (later than Z33) causes nitrates to accumulate in the plant dry matter reducing hay quality. For grain yield, profitable responses to N application have been found up to 10 weeks after sowing. There is generally little chance of a profitable yield increase to N fertiliser occurring if the N is applied later than 10 weeks after seeding. ¹⁴

) MORE INFORMATION

<u>Nutrition management – Nitrogen</u> guide.



¹⁴ DAFWA (2016) Oats: fertilisers and plant nutrition. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition</u>



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Nitrogen deficiency symptoms of oats appear in the early growth stages and become more severe as the plant grows. When the crop is young, stems are short and thin; leaves and stems are pale green. At flowering, N-deficient plants are stunted, have fewer tillers and smaller heads than N-adequate plants. At maturity the crop is multi-coloured with upper leaves pale green and middle leaves yellow to pale green with red tips. The oldest leaves may have died, turned brown and fallen to the soil's surface. Grain yield is reduced primarily through a reduction in kernels per head and head density. ¹⁵

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What to look for

Paddock:

- N deficiency may result in light-green to yellow-orange plants, particularly on sandy soils, or unburnt header or swathe rows.
- Double-sown areas have fewer symptoms if nitrogen fertiliser was applied at seeding.

Plant:

- Young plants may be short, thin and pale green, with fewer tillers.
- Symptoms first occur on the oldest leaf and then progressively younger leaves, with symptoms progressing to tip reddening and death, beginning at the base until the entire leaf is brown and withered.
- As deficiency becomes more severe, leaf tips become orange-red. As tissue dies it turns dark brown and leaf margins often roll upwards to form a tube.
- Stems may become red.
- N-deficient plants develop more slowly than healthy plants, but maturity is not greatly delayed.
- Reduced head size, grain yield and protein levels result.¹⁶

Red-tipping

Red-tipped leaf is an extreme form of foliar disorder in oats. It is associated with deficiency in N, P, K, Zn and S in the soil. N deficiency is the most common cause. Red-tipping is not a symptom of rust infection. The reddish colour, seen mostly on mature leaves, is caused by the presence of anthocyanin. The intensity of the redness varies with the season. Early stages of the disorder show light-yellow veins running parallel to the mid-rib of the leaf. This appears similar to herbicide damage (metsulfuron or Ally^{*}). The entire leaf surface may appear light-yellow. In the later stages the tip turns red. In cold dry winters the colour deepens to almost purple, while in mild wet winters it is a more washed-out orange-red. Affected plants are stunted and are less palatable for livestock (Photo 2). Red-tipping can be avoided by practising good crop nutrition. In paddocks with a history of this problem, conduct a N audit to ensure the N being supplied meets the demand of the crop. Topdressing can be used to correct the problem, with a good rainfall event required to incorporate the nitrogen.¹⁷



¹⁵ DAFWA (2016) Oats: fertilisers and plant nutrition. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition</u>

¹⁶ DAFWA (2015) Diagnosing nitrogen deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-oats</u>

¹⁷ QDAF (2012) Planting and nutrition of oats. Queensland Department of Agriculture and Fisheries, <u>https://www.daf.gld.gov.au/plants/</u> field-crops-and-pastures/broadacre-field-crops/oats/planting-information#Red_leaf_tipping



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Photo 2: Reddening and inward rolling of leaf tips (left). Waterlogged plants show nitrogen deficiency in the absence of salt (right). Source: <u>DAFWA</u>

Table 3: What else could it be? 18

Condition	Similarities	Differences
Diagnosing waterlogging and salinity in oats	Pale plants with oldest leaves most affected	Differences include root browning or lack of feeder roots and wet soil
Diagnosing molybdenum deficiency in cereals	Pale poorly tillered plants	Difference is that molybdenum deficiency affect the middle leaves first and cause white heads, shrivelled grain and delayed maturity

5.4.2 Nitrogen and hay

Increasing N supply:

- may increase hay yield
- increases hay greenness
- increases stem fibre levels (acid detergent fibre and neutral detergent fibre)
- decreases water soluble carbohydrates (WSC)
- may increase in-vitro digestibility and metabolisable energy slightly
- may sometimes lead to high nitrate-N levels—unacceptable in many hay markets
- interacts with variety for fibre and WSC.

Method of N application is also important. Split applications of N appear important, particularly for hay.

For hay production, do not apply excessive levels of N as it may decrease hay quality by increasing stem fibre levels and decreasing WSC. Varieties may differ in their response to amount of and method of applied nitrogen.¹⁹



¹⁸ DAFWA (2015) Diagnosing nitrogen deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-oats</u>

¹⁹ DAFWA (2016) Oats: fertilisers and plant nutrition. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition</u>





A good oat crop used for grazing and grain could be expected to use up to 100 kg/ ha of N. Both pre-emergent and post-emergent applications of N can be applied in N-deficient situations. With long-season dual-purpose cereals, split applications should be considered.²⁰

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An application of N after grazing (20–40 kg N/ha) will increase the speed of plant recovery, reduce tiller death and increase overall forage yield. This figure should be calculated on a sound N budget.

5.4.3 Interaction with seeding rates

Increasing the seeding rate will increase oat grain and hay yields irrespective of N fertiliser levels. Higher seeding rates will increase grain screenings and reduce leaf greenness in hay. However, higher N fertiliser rates will increase yields.

Research has shown the response of oat grain yields to seeding rate is independent of the N application rates. High seeding rates and high N fertiliser rates increase screenings but no other quality parameters. Hay yield response to seeding rate was independent of the level of applied N.

Leaf greenness was the only aspect of hay quality that decreased as seeding rate and N levels increased. At low levels of N there was a larger drop in upper canopy leaf greenness as the number of plants sown increased, compared to greater amount of N applied. Stem thickness of oats decreased as seed rate increased irrespective of N fertiliser.²¹

5.4.4 Interaction with potassium

Maintaining adequate amount of N and K nutrition are necessary for optimum grain and hay yields. High rates of K resulted in better grain and hay quality

Trials have shown that both N and K are important to optimise yield and quality of oat hay and grain. When soil test K levels are low (Colwell K soil test of less than 80 mg/kg) the response of oat plants to fertiliser N can be affected by K deficiency. To optimise the response to fertiliser N, adequate K fertiliser has to be applied.

Results suggested that both oat hay and grain yields were governed mainly by applied N but required at least 70 kg K/ha to achieve their optimum levels.

While N and K interact to influence hay yield, they do not interact to influence hay quality. On K-deficient soils, increasing K (regardless of N supply) reduces neutral detergent fibre and crude protein and increases WSC of the hay.

Grain yield increased as combined N and K fertiliser rates increased. The relationship suggests that it would not be economical to add K without an adequate amount of N fertiliser.

As with grain yield, N and K can also interact to influence grain quality. Grain quality is also affected by combined N and K fertilisers. Under low N supply, there is little benefit of K, but with high N supply, a lack of K can affect quality.²²



²⁰ G Hennessy, B Clements (2009) Cereals for Grazing. NSW DPI Primefact 720, June 2009, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/288191/Cereals-for-grazing.pdf</u>

²¹ DAFWA (2016) Oats: fertilisers and plant nutrition. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition</u>

²² DAFWA (2016) Oats: fertilisers and plant nutrition. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/</u> oats/oats-fertilisers-and-plant-nutrition



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Key points

 In environments where yields are consistently greater than 2.5 t/ha, N applications can be delayed until stem elongation without any loss in yield. In lower yielding environments, the chance of achieving a yield response similar to that achieved with an application at sowing is less.

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- There is no consistent difference in the response to N between different forms of N fertiliser.
- In general, increases in grain protein concentration are greater with N applications between flag leaf emergence and flowering.
- Volatilisation losses can be significant in some cases and the greatest risk is with urea and lower with UAN and ammonium sulphate.²³
- WARNING: There is a risk of volatilisation loss from urea or (ammonium sources of nitrogen on alkaline soils) when topdressed on dry soils in dewy conditions. Losses rarely exceed 3% per day.

N fertilisers are a significant expense for broadacre farmers, so optimising use of fertiliser inputs can reduce this cost. There are four main sources of N available to crops: stable organic nitrogen, rotational nitrogen, ammonium and nitrate. To optimise plants' ability to use soil N, growers should first be aware of how much of each source there is. The best method of measuring these N sources is soil testing.

Timing of application

Grain yield improvements are mainly caused by increased tiller numbers and grains per ear, both of which are determined early in the life of a wheat plant. A sufficient supply of N during crop emergence and establishment is critical. N use efficiency can be improved by delaying fertiliser application until the crop's roots system is adequately developed. This can be 3–4 weeks after germination.

Later N applications can also have yield benefits through increased tiller survival, leaf duration and photosynthetic area. Delaying application however, reduces the chance that economic response to N will be achieved. An advantage of late applications (1st node visible) is that growers have a better idea of yield potential before applying the N. ²⁴

Budgeting

The critical factor in budgeting is the target yield as crop yield potential is the major driver of N requirement. As a guide, Table 4 shows the N required for different yield and protein combinations at maturity and anthesis. The amount of fertiliser N required will depend on your estimate of fertiliser recovery, but if you work on a 50% recovery, you would need to supply 134 kg N/ha.

Clearly, predicting yield during the growing season is crucial to allow growers to make tactical decisions on N management. Recent experience in the mid-North has shown that Yield Prophet[®] can predict yields accurately in mid-August and can assist with N decisions. Other tools, such as the PIRSA-CSIRO N calculator, provide a way of calculating N budgets and estimating N requirements. ²⁵



²³ G McDonald, P Hooper P (2013) Nitrogen decision—Guidelines and rules of thumb, <u>https://grdc.com.au/Research-and-Development/</u> <u>GRDC-Update-Papers/2013/02/Nitrogen-decision-Guidelines-and-rules-of-thumb</u>

²⁴ R Quinlan, A Wherrett (2013) Nitrogen—NSW, <u>http://www.soilquality.org.au/factsheets/nitrogen-nsw</u>

²⁵ G McDonald, P Hooper P (2013) Nitrogen decision—Guidelines and rules of thumb, <u>https://grdc.com.au/Research-and-Development/</u> <u>GRDC-Update-Papers/2013/02/N-decision-Guidelines-and-rules-of-thumb</u>



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Table 4: *N* requirements for cereal crops at different combinations of yield and grain protein at maturity and the corresponding N required at anthesis. The estimates are based on the assumption that 75% of the total crop N is in the grain at maturity and that 80% of the total N is taken up by anthesis.

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			Gr	ain Protein((%)	
Grain Yield (t/ha)	Growth Stage	9	10	11	12	13
		(kgN/ha)				
1	Maturity	21	23	26	28	30
	Anthesis	17	19	21	22	24
2	Maturity	42	47	51	56	61
	Anthesis	34	37	41	45	49
3	Maturity	63	70	77	84	91
	Anthesis	51	56	62	67	73
4	Maturity	84	94	103	112	122
	Anthesis	67	75	82	90	97
5	Maturity	105	117	129	140	152
	Anthesis	84	94	103	112	122
6	Maturity	126	140	154	168	182
	Anthesis	101	112	124	135	146

Source: <u>GRDC</u>

5.5 Phosphorus

Key Points

- P is one of the most critical and limiting nutrients in agriculture in Australia.
- P cycling in soils is complex.
- Only 5–30% of P applied as fertiliser is taken up by the plant in the year of application.
- P fertiliser is best applied at seeding.
- P is the most generally used fertiliser for rye. The rate of P application varies from about 6–18 kg/ha, lighter applications being used in drier districts. ²⁶

P is essential for plant growth, but few Australian soils have enough P for sustained crop and pasture production. Complex soil processes influence the availability of P applied to the soil, with many soils able to adsorb or "fix" P, making it less available to plants (Figure 2). A soil's ability to fix P must be measured when determining requirements for crops and pastures. ²⁷



²⁶ RL Reid (Ed.) (2013) The manual of Australian agriculture. Elsevier.

²⁷ Soilquality.org. Phosphorus NSW, http://www.soilquality.org.au/factsheets/phosphorus-nsw





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Figure 2: The P cycle in a typical cropping system is particularly complex, where movement through the soil is minimal and availability to crops is severely limited

From the Fertiliser Industry Federation of Australia Inc., 2000. Source: Soilquality.org

In many soils of south-eastern Australia, P application has good residual value. However, if not applied for 5 to 10 years, even those soils with excellent fertiliser history are likely to develop a P deficiency.

In sandy soils P has a tendency to leach out of the soil. Sandy soils have been measured to lose up to 100% of applied P to leaching in the first season. Certainly 50% losses are common. Soils with sufficient levels of "reactive" iron (Fe) and aluminium (AI) will tend to resist P leaching. If you have sandy soils with low reactive levels of Fe and AI then you should test your P levels and apply less P more often, so that you don't lose your expensive P dollar to leaching. In soils with high free lime (10–20%), P will react with calcium carbonate in the soil to create insoluble calcium phosphates. Lock-up of P occurs on these soils at high pH and more sophisticated methods of applying P may be needed.

As phosphorus is often tied up in the soil ensure that adequate P is applied near the seed with the starter fertiliser. Rates up to 30 kg/ha of phosphorus in the starter fertiliser are needed. $^{\rm 28}$

Phosphorous (P) is important for oat production. Addition of P fertiliser can increase both hay and grain yield, depending on the initial soil test P level. The optimum P requirement for hay and grain appear to be different. Oat varieties may differ in their P requirements.

Phosphorus is a major nutrient for improved oaten hay and grain production. Phosphorus is a vital component of adenosine triphosphate (ATP), the 'energy unit' of plants. ATP forms during photosynthesis and is used to form the beginning of seedling growth through to the formation of grain and maturity. Deficiencies result in slow growth, decreased hay and grain yields, inferior quality and subsequently lost income.

P should be applied at crop establishment (drilled with the seed during sowing) as an adequate supply is critical during early growth for plant root development and elongation. An economic response is unlikely if the application is delayed for more than 10 days after sowing.

The oat crop response to P will be influenced by the level of Colwell P and the ability of the soil to retain P (Phosphorous Retention Index (PRI)). On low P fixing soils (PRI <2 mL/g, reactive Fe <280 mg/kg, Phosphorous Buffering Index (PBI) <15), P is held very loosely, making it more available to plant roots and potentially reducing the amount of P required for maximum economic yield. On medium and high P fixing soils (PRI 2–15 and >15 mL/g, reactive Fe 280–1,000 mg/kg and >1,000 mg/kg, respectively) P is held more tightly with a lesser amount available to plant roots. A better response to applied P is expected where soil Colwell tests are low. Soil testing is, therefore, required before deciding what rate of P to apply. ²⁹



²⁸ T Bray (2014) Irrigated milling oats set to roll. IREC Farmers' Newsletter – Large Area No. 190: Autumn 2014, <u>http://irec.org.au/wp-content/uploads/FN%20190.pdf</u>

²⁹ DAFWA (2016) Oats: fertilisers and plant nutrition Phosphorus. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C1</u>





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Phosphorus deficiency results in poor seedling establishment and root development. The deficiency symptoms usually only occur if the deficiency is severe and are more noticeable in young plants as they have a greater relative demand for P than more mature plants. The tips of the old leaves become dark orange-yellow and this colour moves towards the base, usually along the leaf edges. The affected leaves often have green bases, orange-yellow mid-sections and bright red or purple tips and the edges of the leaves are rolled inwards. In severe deficiency, affected areas die and turn red and purple.³⁰

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What to look for

Paddock:

- P deficiency reduces seedling establishment and root development. The deficiency symptoms usually occur only if the deficiency is severe and are more noticeable in young plants, as they have a greater relative demand for P than more mature plants.
- Symptoms of P deficiency in oats are usually non-specific and difficult to diagnose in the field. The most noticeable feature in oats is reduced growth and vigour. Acute P deficiency generally occurs when other factors, such as pests, root diseases or dry soil, restrict the plant's ability to access soil P.
- Stripes in the paddock may correspond with fertiliser 'misses' or blockages of the product.

Plant:

- Early signs are smaller erect plants with darker leaves and fewer tillers (Photo 3)
- More acute deficiency causes orange to purple colouration on old leaves.
- Orange to red colours, then necrosis, moves down older leaves from the tip. $^{\scriptscriptstyle 31}$
- Maturity will be delayed.



Photo 3: Oat plants with delayed maturity and lack of tillers (left) due to zero Phosphorus versus adequate Phosphorus nutrition in the same crop (right). Photo: P. Heuston

30 DAFWA (2016) Oats: fertilisers and plant nutrition Phosphorus. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C1</u>

31 DAFWA (2016) Diagnosing phosphorus deficiency in oats, Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-oats</u>





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 Table 5: What else could it be? 32

Condition	Similarities	Differences
Dry soil can induce phosphorus deficiency in young plants	Darker leaves and fewer tillers	Symptoms disappear when the soil rewets
Diagnosing barley yellow dwarf virus	Progressive reddening and death of older leaves	Barley yellow dwarf virus is associated with streaks and occurs in patches

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5.5.2 Managing phosphorus

Key points

- After decades of consistent P application, many soils now have adequate P status.
- Before deciding on a fertiliser strategy, use soil testing to gain a thorough understanding of the nutrient status across the farm.
- If the soil P status is sufficient, there may be an opportunity for growers to save money on P fertiliser by cutting back to a maintenance rate.
- Consider other factors: if pH (CaCl₂) is less than 4.5, the soil is water repellent or root disease levels are high, then the availability of soil test P is reduced and a yield increase to fertiliser P can occur even when the soil test P results are adequate.
- Work with an adviser to refine your fertiliser strategy.
- P reserves have been run down over several decades of cropping.
- Adding fertiliser to the topsoil in systems that rely on stored moisture does not always place nutrients where crop needs them.
- Testing subsoil (10–30 cm) P levels using both Colwell-P and BSES-P soil tests is important in developing a fertiliser strategy.
- Applying P at depth (15–20 cm deep on 50 cm bands) can improve yields over a number of cropping seasons (if other nutrients are not limiting).
- Addressing low P levels will usually increase potential crop yields, so match the application of other essential nutrients, particularly N, to this adjusted yield potential.³³
- Plants have a high requirement for phosphorus during early growth. As phosphorus is relatively immobile in the soil, topdressed or sprayed fertiliser cannot supply enough to correct a deficiency.
- Phosphorus does leach on very low PBI (a measure of phosphorus retention) sands, particularly on coastal plains. Topdressing is effective on these soils.
- WARNING: The optimum P requirement for hay and grain appear to be different. Oat varieties may differ in their P requirements. ³⁴

Place phosphorous with or near the seed at seeding time or band prior to seeding. High application rates can lead to both salt burning of the seedlings and a thin plant stand, reducing potential yield. ³⁵

Soil testing

Testing of the P levels in your soil is important and will help in the budgeting of your P dollar.



³² DAFWA (2016) Diagnosing phosphorus deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-oats</u>

³³ GRDC (2012) Crop nutrition: Phosphorus management—Southern region Factsheet, <u>www.grdc.com.au/GRDC-FS-PhosphorusManagement</u>

³⁴ DAFWA (2016) Diagnosing phosphorus deficiency in oats_ Department of Agriculture and Food Western Australia, https://www.agric. wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-oats

³⁵ Alberta Government (2016) Fall Rye Production, <u>http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/agdex1269/\$file/117_20-1.pdf</u>



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i MORE INFORMATION

Phosphorus in the South East Soils.

<u>Crop nutrition: Phosphorus</u> <u>management – Southern region</u> <u>Factsheet</u>





- The total amount of P in the soil.
- The abundance of iron and aluminium oxides.
- Organic carbon content.
- Free Lime/ Soluble Calcium Carbonate.
- P Buffer Index (PBI).

Available P tests like the Colwell and Olsen's P test don't measure available P. Rather, they express an indication of the rate at which P may be extracted from the soils. This indicator of rate is calibrated with field trials. There is a relationship between Total Soil P and Colwell P and this can enable you to predict when a given level of P input (fertiliser) or output (product removal) will result in a risk of P rate of supply becoming a limiting factor. ³⁶

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5.6 Sulfur

Sulfur (S) has an important role in the formation of proteins and is essential for the production of chlorophyll. Crops that have a high N requirement must have adequate S to optimise N utilisation and protein synthesis.

As with N and P, most of the S in the soil is in organic form. Soils with low amounts of organic matter are prone to S deficiency. Sulfur in organic matter must be mineralised to sulphate before being taken up by roots. Sulphate is mobile in soils and can be leached out of the rooting zone during winter. Deficiencies therefore most often occur in wetter years. On duplex soils, deficiency symptoms may be only temporary as roots grow into the deeper soil layers where more S is available.

Sulfur deficiency is expected to increase in oat crops in the future as more compound fertilisers containing lower S are used in oat production. Hay production, particularly on sandy soils is expected to increase the risk of S deficiency as hay crops remove about 1.5 kg S/ha per tonne of hay.

A soil-test value of less than 10 mg/kg in the soil surface (0–10 cm) may indicate likely S deficiency. However, S in the soil frequently increases down the soil profile, so knowledge of the distribution of S in the soil profile is required. This may involve deeper soil sampling to know the S supply in the soil. Applying P as superphosphate and compound fertilisers that applies S at 5–10 kg/ha can avoid S deficiency. ³⁷

5.6.1 Sulfur deficiency symptoms

The youngest leaves of S-deficient plants are pale green and then pale yellow across the whole leaf (no striping). Under severe deficiency the entire plant becomes a lemon-yellow colour with red stems. Chlorosis normally starts on the young leaves. The whole plant including the ears shows stunted growth and yields poorly (Photos 4 & 5). ³⁸

What to look for

Paddock:

Areas of pale plants.

Plant:

- Plants grow poorly, lack vigour with reduced tillering, delayed maturity and lower yields and protein levels.
- Youngest leaves are affected first and most severely.

- 17 DAFWA (2016) Oats: fertilisers and plant nutrition Sulfur. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C3</u>
- 38 Yara Crop Nutrition, Suphur deficiency oats, <u>http://www.yara.co.uk/crop-nutrition/crops/oats/crop-nutrition/deficiencies/s/13459-sulfur-deficiency--oats/</u>



³⁶ G Bailey, T Brooksby. <u>Phosphorus in the South East Soils</u>.



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• With extended deficiency the entire plant becomes lemon yellow and stems may become red. ³⁹



Photo 4: Areas of pale plants characterise sulfur deficiency (NOTE: also characteristic of iron, nitrogen and potassium deficiency).

Source: CSBP 2013



³⁹ DAFWA (2015) Diagnosing sulfur deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.</u> au/mycrop/diagnosing-sulfur-deficiency-cereals





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Photo 5: Affected leaves become uniformly pale.

Source: International Plant Nutrition Institute 2013

Table 6: What else could it be? 40

Condition	Similarities	Differences
<u>Diagnosing iron</u> deficiency in cereals	Pale new growth	Iron-deficient plants have interveinal chlorosis.
Diagnosing group B herbicide damage in cereals	Seedlings with pale new leaves	Plants generally recover from Group B herbicide damage and leaves often have interveinal chlorosis.
Waterlogging, nitrogen, molybdenum and manganese deficiency	Pale growth	The youngest leaves of sulfur-deficient plants are affected first while the middle or older leaves are affected first with waterlogging, manganese, nitrogen and molybdenum deficiency.

5.6.2 Managing sulfur:

- Topdressing 10–15 kg S/ha as gypsum or ammonium sulphate will overcome deficiency symptoms.
- Foliar sprays generally cannot supply enough sulfur for plant needs. ⁴¹



⁴⁰ DAFWA (2015) Diagnosing sulfur deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.</u> au/mycrop/diagnosing-sulfur-deficiency-cereals

⁴¹ DAFWA (2015) Diagnosing sulfur deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.</u> au/mycrop/diagnosing-sulfur-deficiency-cereals



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Potassium (K) is an important nutrient for oat production. Hay crops remove large amounts of K. Potassium is required for photosynthesis, transport of sugars, enzyme activation and controlling water balance within plant cells. Deficiency of K results in poor root growth, restricted leaf development, few grains per head and smaller grain size which affects yield and quality.

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Potassium deficiency is more common on lighter textured soils where there is less clay and organic matter to retain the K in the root zone. The deeper sands on coastal plains and peaty sands of the south coast are the most prevalent K-deficient soils of the high rainfall zone of WA. Potassium deficiency is likely to occur if the soil has less than 80 mg/kg of K in the topsoil.

Potassium deficiency can reduce the tolerance of plants to environmental stresses such as drought, frost and waterlogging, as well as pests and diseases. Potassium deficiency can reduce straw or stalk length leading to lodging problems.

Crop requirements for K change during the growing season. Potassium uptake is low when plants are small and increases during late vegetative and flowering stages. Research in WA has shown that oat yield response to added K depends on the soil-extractable K (Colwell K) and environmental conditions. Adding K has a positive effect on quality for hay and grain where soil K levels are low to deficient.

Potassium deficiency symptoms progress slowly and can be costly if not detected in time. Regular soil and plant analysis and nutrient budgeting can ensure that K deficiency does not occur. Muriate of potash (KCl) is the cheapest form of K. It is applied by topdressing either before seeding or up to 5 weeks after seeding. If K deficiency is diagnosed in the soil by Colwell extractable soil tests, applying 40–80 kg K/ha as muriate of potash (90–80 kg/ha) may give an economic yield increase. Potassium at low rates can be banded below or with the seed at sowing, with sulphate of potash safer than muriate of potash. Higher amounts of K drilled with seed can decrease seedling germination, mainly due to salt effect.

Hay crops remove greater amounts of K (about 10 kg K/tonne of Dry Matter) compared to K losses in grain. The removal of nutrients in hay has to be considered when planning fertiliser requirements for following crops. Practices such as swathing of canola and concentrating and burning of windrows can have significant effects on the spatial distribution of K across the paddock. For these reasons growers should use soil-test results in conjunction with plant-tissue testing and visual symptoms to determine application rates for paddocks. Decision support tools relate soil-test values and other soil characteristics to yield potential to determine recommended K application rates.⁴²

5.7.1 Potassium deficiency symptoms

Potassium is very mobile in plants. In deficient plants, K is redistributed to the new growth and the deficiency symptoms first appear in the older leaves, which turn pale green and bronze with yellow areas developing in the mid-section of the leaf between the edge and mid-vein. These areas quickly extend towards the leaf tip until the top two-thirds of the leaf is bronze-yellow. Grey-brown spots develop within the bronze-yellow areas. Typically, the deficient plant develops a three-tone appearance with green younger leaves, green with yellow to bronze colours on the middle leaves and brown older leaves (Photo 6). ⁴³



⁴² DAFWA (2016) Oats: fertilisers and plant nutrition Potassium. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C2</u>

⁴³ DAFWA (2016) Oats: fertilisers and plant nutrition Potassium. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C2</u>


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What to look for

Paddock:

- Smaller lighter green plants with bronze and necrotic leaf ends, generally on sandier parts of the paddock or between header or swathe rows.
- Affected areas are more susceptible to leaf disease.

Plant:

- Plants appear smaller and paler but tillering may not be affected.
- Plants may look unusually water-stressed despite adequate water and cool conditions.
- Older leaves are affected first with dark yellow chlorosis then necrosis that moves down from the leaf tip and edges.
- Another early symptom is development of bronze-yellow areas in the midsection of the leaf that quickly spread to the leaf tip. Grey-brown spots develop and cause the leaf to bend at that point.
- Typically, the deficient plant develops a three-tone appearance with green younger leaves, green with yellow to bronze colours on the middle leaves and brown dead older leaves. ⁴⁴



Photo 6: Drooping older leaves and three-tone appearance with green younger leaves, green with yellow to bronze colours on the middle leaves and brown dead older leaves.

Source: DAFWA

Table 7: What else could it be? 45

Condition	Similarities	Differences
<u>Diagnosing nitrogen</u> <u>deficiency in oats</u>	Pale plants with oldest leaves most affected	Plants and leaves are more uniformly pale
Diagnosing root lesion nematode in cereals	Same foliar symptoms	'Spaghetti' roots

5.7.2 Managing potassium:

- Topdressing potassium will generally correct the deficiency.
- 14 DAFWA (2016) Diagnosing potassium deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-potassium-deficiency-oats</u>
- 45 DAFWA (2016) Diagnosing potassium deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-potassium-deficiency-oats</u>





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• Potassium can be banded at seeding, or topdressed before or after seeding. Banded potassium can be more effective where root development is inhibited by factors such as water repellence or nematodes.

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5.8 Micronutrients

5.8.1 Zinc

Zinc (Zn) is a component of many plant enzymes and essential for healthy plant growth and leaf formation. Oats are highly susceptible to deficient levels of Zn in the soil. After the initial recommended application, most micronutrients have a long residual value in the soil. Therefore, both tissue testing and soil testing, in conjunction, can be used to determine the need for re-application.

Plant symptoms may help to diagnose Zn deficiency; however a tissue test may be required. Zinc concentrations in the young leaves of less than 14 mg/kg indicate that the plant is Zn deficient.

An initial application of 1–2 kg/ha zinc oxide (75% Zn) will correct a deficiency for many years. A foliar spray of 1 kg/ha zinc sulphate (23% Zn) in 50–100 L of water should be applied as soon as Zn deficiency is detected to prevent grain and hay yield losses. ⁴⁶

Zinc-deficiency symptoms

Zinc deficiency causes patchy growth, with plants in poor areas stunted with pale green leaves and yellow or orange-red tips. Youngest leaves usually remain green, middle and older leaves turn pale green and pale yellow areas develop between the leaf edge and mid-vein at the tip. Brown spots occur in the affected areas, increasing in size until the leaf tip dies, often turning red-brown to black (Photo 7).

With severe deficiency the stem remains very short and youngest leaves have difficulty emerging fully. The symptoms can be mistaken for that of barley yellow dwarf virus and severe P deficiency. ⁴⁷

What to look for

Paddock:

- Patchy growth, with plants in poor areas.
- Heavily limed soils, sands and gravels or alkaline grey clays tend to be most affected, often in cold wet weather. Plants frequently recover in spring and produce (fewer) normal panicles.
- Zinc-deficient crops are often patchy in appearance.

Plant:

- Middle and older leaves turn pale green; pale yellow areas develop between the mid-vein and leaf edge towards the tip. Discolouration spreads downwards and darkens.
- Brown edged spots appear in the affected areas, increasing in size until the leaf tip dies, often turning red-brown to black (main characteristic).
- Base of the leaf remains green, mid-section yellow and tips red-brown to black.
- Youngest leaves usually remain green.
- Severely deficient plants have very short stems and young leaves have difficulty emerging fully.



⁴⁶ DAFWA (2016) Oats: fertilisers and plant nutrition Zinc. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C4</u>

⁴⁷ DAFWA (2016) Oats: fertilisers and plant nutrition Zinc. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C4</u>





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Photo 7: Oat plants showing zinc-deficiency symptoms including tan colour end half of leaf with pale/brown edged lesions that spread.

Source: © 2012 The State of Queensland in DAFWA

Table 8: What else could it be? 48

Condition	Similarities	Differences
Diagnosing barley yellow dwarf virus	Red/yellow leaf colours and necrosis that starts at the tip	Necrotic areas lack red-brown lesions. The disorder tends to be circular or near the edge of the paddock and not associated with soil type
Diagnosing zinc deficiency in oats	Unevenly distributed areas of pale plants with tip death, browning and mottling of older leaves	Zn deficiency affects tillers more, leaf tips usually turn red to black and deficiency occurs earlier in cold wet weather, and on limed soils

Managing zinc:

- Foliar spray (effective only in current season) or drilled fertiliser.
- A foliar spray of 1 kg/ha zinc sulphate (23% Zn) in 50–100 L of water should be applied as soon as Zn deficiency is detected to prevent grain and hay yield losses.
- As zinc is immobile in the soil, topdressing is ineffective, only being available to the plant when the topsoil is wet.
- Mixing zinc throughout the topsoil improves availability due to more uniform nutrient distribution.
- Zinc drilled deep increases the chances of roots being able to obtain enough zinc when the topsoil is dry.

48 DAFWA (2016) Diagnosing zinc deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/</u> mycrop/diagnosing-zinc-deficiency-oats





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 Zinc present in compound fertilisers often meets the current requirements of the crop where Zn soil supply is marginal.⁴⁹

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5.8.2 Manganese

Oats can be found to be highly susceptible to manganese (Mn) deficiency which can cause significant yield losses. In severe cases, the crop may die entirely.

Tissue tests and visual symptoms can be used to help diagnose Mn deficiency. Mn concentrations less than 20 ppm (mg/kg) in whole shoots indicate Mn deficiency. The concentrations of Mn in tissues vary for different oat varieties.

Applying manganese sulphate (25% Mn) as a foliar spray at a rate of 4 kg/ha (1 kg Mn/ha in 50–100 L of water) immediately when symptoms appear is usually effective in correcting a Mn deficiency; however, a repeat spray a few weeks later may be necessary.

The application of ammonium sulphate and ammonium nitrate can markedly reduce Mn deficiency symptoms. Drilling fertilisers enriched with Mn can reduce the risk of crop damage from Mn deficiency. However, even where an ammonium-enriched fertiliser has been used severely deficient patches may still require a foliar Mn spray.

Manganese deficiency symptoms

In oats, Mn deficiency produces a condition called 'grey speck' which occurs in patches. Oats become pale green and young leaves have spots or lesions of grey/ brown necrotic tissue with orange margins. These lesions will coalesce under severe Mn-deficient conditions. Plants are weak, stunted, floppy and pale green-yellow and appear water-stressed even when adequate soil moisture is available.

Close examination of the leaf may show slight interveinal chlorosis. The distinction between green veins and yellow interveinal areas is poor. Symptoms can be confused with red leather leaf, which is favoured by prevailing high humidity in high rainfall areas. Symptoms can also be mistaken for take-all. ⁵⁰

What to look for

Paddock:

• Manganese deficiency often appears as patches of pale, floppy plants in an otherwise green healthy crop (Photo 8).

Plant:

- Initially, middle leaves are affected first, but it can be difficult to determine which leaves are most affected as symptoms rapidly spread to other leaves and the growing point.
- Plants become pale green. Small linear grey flecks appear on interveinal tissue in the basal half of old leaves, extending towards the tip as symptoms develop (Photo 9).
- Flecks often join to form large lesions in the basal half of the leaf between the margin and mid-vein, eventually affecting the vein. Leaves often kink, collapse and eventually die giving plants a wilted appearance.
- Tillering is reduced, with extensive leaf and tiller death. With extended deficiency, the plant may die.
- Surviving plants produce fewer and smaller heads. ⁵¹
- 49 DAFWA (2016) Diagnosing zinc deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/</u> mycrop/diagnosing-zinc-deficiency-oats
- 50 DAFWA (2016) Oats: fertilisers and plant nutrition Manganese. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C5</u>
- 51 DAFWA (2016) Diagnosing manganese deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-manganese-deficiency-oats</u>







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Photo 8: *Patches of stunted and wilted plants.* Source: DAFWA 2015



Photo 9: *Small linear grey interveinal flecks that join to form large lesions.* Source: DAFWA 2012





SECTION 5 OALS

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Condition	Similarities	Differences
Diagnosing nitrogen deficiency in oats	Pale plants	No wilting, leaf kinking, grey lesions
Diagnosing waterlogging and salinity in oats	Pale plants	No grey lesions or leaf kink
Diagnosing iron deficiency in cereals	Pale plants	New leaves affected first
Diagnosing sulfur deficiency in cereals	Pale plants	New leaves are affected first

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Managing manganese:

- A foliar spray will correct the deficiency, but a repeat spray a few weeks later may be necessary.
- Acidifying ammonium nitrogen fertilisers can reduce manganese deficiency by lowering pH and making manganese more available to growing crops.
- Manganese fertiliser is effective but expensive as high rates and several applications are required to generate residual value.
- Seed manganese coating treatments have little effect in correcting the deficiency.⁵³

5.8.3 Copper

Oats are less susceptible to copper deficiency when compared to wheat and barley; however copper (Cu) is essential for growth and development. Plants need Cu to produce new cells and for pollen development (sterile pollen), and hence Cu deficiency severely effects grain yield. Deficient plants that apparently look healthy can produce shrivelled grain reducing both grain yield and quality.

Tissue tests, using the youngest emerged leaf can help diagnose Cu deficiency. Tissue tests with Cu concentrations less than 1.3 mg/kg indicate the plant is severely Cu deficient. Applying 3–9 kg/ha of copper sulphate (25% Cu) with fertiliser at seeding in areas suspected to be deficient in Cu corrects the deficiency. Copper fertiliser has a long residual in the soil, and a single Cu application at recommended rates can last 20–30 years. Intermittent tissue testing of youngest leaves can maintain Cu at adequate levels.

Copper deficiency symptoms

Copper-deficient crops have a patchy appearance with plants in poor areas stunted, pale green and looking limp and wilted even with ample soil water. Late tillers may develop at nodes or joints above round. Young leaves turn pale green while old leaves remain green. Under conditions of severe deficiency, plants may have leaves which die back from the tip and twist into curls.

The ears of Cu-deficient plants are shrunken with gaps such as 'frosted heads'. The heads of Cu-deficient plants have poor seed-set from sterile pollen thus resulting in 'white heads', similar to the ear heads affected by drought, heat stress, take-all and frost. ⁵⁴



⁵² DAFWA (2016) Diagnosing manganese deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-manganese-deficiency-oats</u>

⁵³ DAFWA (2016) Diagnosing manganese deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-manganese-deficiency-oats</u>

⁵⁴ DAFWA (2016) Oats: fertilisers and plant nutrition Copper. Department of Agriculture and Food Western Australia, <u>https://www.agric.</u> wa.gov.au/oats/oats-fertilisers-and-plant-nutrition?page=0%2C6



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Paddock:

• Before head emergence, deficiency shows as areas of pale, wilted plants with dying new leaves in an otherwise green healthy crop.

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- After head emergence, few grains are set and plants become discoloured and mature later.
- Symptoms are often worse on sandy or gravelly soils, where root pruning herbicides have been applied and recently limed paddocks.

Plant:

- Youngest growth is affected first.
- Young leaves turn pale green and wilted, then die back from the tip (Photo 10).
- Dead tissue usually rolls or twists into a tight tube or spiral (Photo 11).
- Old leaves remain green, but paler than normal.
- Tiller production before flowering is often unaffected but they may die prematurely. After flowering, very late tillers often appear.



Photo 10: Young leaves turn pale green and wilted, then die back from the tip. Source: QLD State Gov. 2012







Photo 11: Dead tissue usually rolls or twists into a tight tube or spiral. Source: QLD State Gov. 2012

Table 10: What else could it be? 55

Condition	Similarities	Differences
Diagnosing stem and head frost damage in cereals	Aborted seed	Rarely affects the whole panicle, plants are not discoloured or produce late tillers.

Managing copper:

- Foliar spray (only effective in the current season) or drilled soil fertiliser.
- Copper foliar sprays are not effective after flowering as sufficient copper is required pre-flowering for pollen development.
- Mixing copper throughout the topsoil improves availability due to more uniform nutrient distribution.
- As copper is immobile in the soil, topdressing is ineffective, only being available to the plant when the topsoil is wet.
- In long-term no-till paddocks frequent small applications of copper via drilled or in-furrow application reduce the risk of plant roots not being able to obtain the nutrient in dry seasons.
- Copper drilled deep increases the chances of roots being able to obtain enough copper when the topsoil is dry.
- Copper seed treatment is insufficient for plant requirement in the current season.
- Applying 3–9 kg/ha of copper sulphate (25% Cu) with fertiliser at seeding in areas suspected to be deficient in Cu corrects the deficiency. Copper fertiliser has a long residual in the soil, and a single Cu application at recommended rates can last 20–30 years. ⁵⁶



⁵⁵ DAFWA (2015) Diagnosing copper deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.</u> <u>au/mycrop/diagnosing-copper-deficiency-oats</u>

⁵⁶ DAFWA (2015) Diagnosing copper deficiency in oats. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.</u> <u>au/mycrop/diagnosing-copper-deficiency-oats</u>



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Key messages:

- Oats are more competitive with weeds than most other crops but weed control is still critical, particularly in hay crops as weeds can cause downgrading or rejection of export hay.
- Caution is needed when spraying oats, as it has a much lower tolerance of 2,4-D and MCPA sprays than the other cereals. Refer to the chemical label before spraying oats.¹
- Chemical control should be timely with respect to both weed threat and development of the crop.
- There are few pre-emergent herbicide options for oats as most of these chemicals are targeted at controlling wild or black oats and will subsequently kill white oats.

Weeds cost Australian agriculture an estimated AU\$2.5–4.5 billion per annum. For winter cropping systems alone, the cost is \$1.3 billion. Consequently, any practice that can reduce the weed burden is likely to generate substantial economic benefits to growers and the grains industry. ² If given the right start, an oat crop has the necessary vigour to compete against weeds. Increasing crop density may improve competitiveness and ultimately impact on yield. ³ Oats competes better than barley, wheat, canola and pulses when sown at recommended seeding rates because of its greater tillering ability. However, caution is needed when spraying oats, as it has a much lower tolerance of 2,4-D and MCPA sprays than the other cereals. ⁴ Chemical control should be timely with respect to both weed size and development of the crop. Weed management should be planned well before planting and options such as chemical and non-chemical control should be considered. ⁵

How weeds damage crops:

- deplete the soil of valuable stored moisture
- deplete the soil of nutrients
- create issues at sowing time, restricting access for planting rigs (especially vinetype weeds such as melons, caltrop or wireweed, which wrap around tines)
- cause problems at harvest
- increase moisture levels of the grain sample (green weeds)
- contaminate the sample
- prevent some crops being grown where in-crop herbicide options are limited; i.e. broadleaf crops
- can be toxic to stock
- host disease

3

- 1 GRDC (2014) Integrated weed management hub. GRDC, https://grdc.com.au/weedlinks
- 2 GRDC (2014) Integrated weed management hub. GRDC, <u>https://grdc.com.au/weedlinks</u>
 - G Troup (2015) Oats: weeds and integrated weed management. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-weeds-and-integrated-weed-management</u>
- 4 DAF Qld (2012) Disease management. Department of Agriculture and Fisheries Queensland, <u>https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/oats/diseases-and-weeds</u>
- 5 DAF Qld (2012) Wheat—planting information. Department of Agriculture and Fisheries Queensland, <u>http://www.daff.qld.gov.au/plants/</u> field-crops-and-pastures/broadacre-field-crops/wheat/planting-information







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Weed ID: The Ute Guide

Weed ID: The Ute Guide application is designed to assist growers in the identification of the most common weeds found in paddocks throughout Australia. Where possible, photos have been provided for each stage of the weed's lifecycle, from seed and seedling through to mature and flowering plants.

These are categorised by plant type, and results for each can be refined by state and lifecycle, and whether they are native, currently flowering or have a distinctive smell.

The application allows users to search, identify, compare photos of their own paddock weeds to those in the app.

What's new in the latest version:

- Filter weeds by region.
- Predictive search weeds by common and scientific names.
- Compare photos of weeds side by side with weed photos in the app.
- Refine weed results by lifecycle, whether they are native, currently flowering or have a distinctive smell.
- Opt to download content updates in-app to ensure you are aware of new weeds affecting each region.⁶

Weed ID: The Ute Guide App is available on iPhone and Android.

6.1 Integrated weed management

Integrated weed management (IWM) is the control of weeds through a long-term management approach, using several weed management techniques such as:

- physical control
- chemical control
- biological control
- <u>cultural control</u>.

By using several techniques to control weeds you reduce the chance that weed species will adapt to the control techniques, which is likely if only one technique is used. Weed competition can be affected by crop species, crop variety, weed species, crop and weed density and time of emergence of the crop relative to the weed.

Preventing weeds from entering or establishing in a paddock is the best method of weed management, especially when combined with physical, agronomic and chemical options. Some of the non-chemical options available in IWM include:

- use of weed-free seed
- cleaning machinery when moving between paddocks and on farms
- covering loads when moving grain

6 GRDC, https://grdc.com.au/Resources/Apps



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i) MORE INFORMATION

<u>GRDC Integrated weed management</u> manual



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VIDEOS

WATCH: <u>Managing herbicide</u>resistant ryegrass with IWM



- controlling weeds along roadsides at the edge of paddocks
- eradicating small patches of new invading weeds
- considering weeds when importing hay onto the farm
- not importing grain or products that may contain certain herbicideresistant weed seeds
- crop and pasture rotations using species with different competitive abilities, sowing dates and harvesting techniques such as swathing
- increased seeding rates and reduced row spacings to maximise crop-weed competition and yield without reducing grain size
- sowing cereals in an east-west direction
- implementing a tickle cultivation to stimulate germination of ryegrass and other weeds prior to seeding or grazing with sheep or cattle.

Cutting hay is a common method used for reducing the weed seed bank, as it removes any weeds that have survived the in-crop spray. Effective weed management in-season for hay crops is also essential as weed contamination is directly related to quality of the end product. Weed seeds in a sample may prevent the hay making export grade, decrease its feed value or may contain weeds that are toxic to stock.

6.1.1 Review past actions

From all available paddock records, calculate or estimate the number of years in which different herbicide modes of action (MOAs) have been used. The number of years in which a herbicide MOA has been used is of far greater relevance than the number of applications in total. For most weeds, use of a herbicide MOA in two consecutive years presents a far greater selection pressure for resistance than two applications of the same herbicide MOA in the one year. If the entire paddock history is unavailable to you, state what is known and estimate the rest. Collate separate data on MOA use for summer and winter weed spectrums. Further subdivide these into broadleaf and grass weeds. Account for double-knocks. Where survivors of one tactic would have been largely controlled by the use of another tactic, reduce the number of MOA uses accordingly.

Paddock history can also provide useful information when evaluating the likely reasons for herbicide spray failures, in prioritising strategies for future use and deciding which paddocks receive extra time for scouting to find potential patches of weed escapes. Information on MOA use history should be added to paddock records. ⁸

6.1.2 Crop choice and sequence

Many agronomic and weed management issues arise from the sequence in which crops are sown:

- Rotations provide options for different weed-management tactics.
- Crop rotations can improve crop fertility and help to manage disease and insects. Healthy crops are more competitive against weeds.
- Many weeds are easier or more cost-effective to control in specific crops, pastures or fallows.

In paddocks with high weed pressure, a competitive crop, such as oats, will enhance the reduction in weed seedset obtained through other weed-management tactics. It will also reduce the impact that surviving weeds have on crop yield and the quantity of seedset by any surviving weeds.

Some key issues:



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⁷ G Troup (2015) Oats: weeds and integrated weed management. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-weeds-and-integrated-weed-management</u>

GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, https://grdc.com.au/IWMM



MORE INFORMATION

Integrated weed management

manual

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- Select crop sequences and varieties to deal with the significant pathogens and nematode issues for each paddock.
- Weeds are alternate hosts to some crop pathogens. Effective weed management can reduce disease pressure.

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- Rhizoctonia can affect seedling crop growth, leaving the crop at greater threat from weed competition. Removing weeds for a period prior to sowing can significantly reduce the level of Rhizoctonia inoculum.
- Weed growth in the fallow or in-crop can increase moisture use and exacerbate yield loss from diseases such as crown rot.
- Residual herbicides used in the fallow or preceding crop may limit crop options.⁹

6.1.3 Assess current weed status

Record the key broadleaf and grass-weed species for summer and winter and include an assessment of weed density, with notes on weed distribution across the paddock. Include GPS locations or reference to spatial location of any key weed patches or areas tested for resistance. Include any data, observations or information relating to the known or suspected herbicide-resistance status of weeds in this paddock. Add this information to paddock records.¹⁰

6.1.4 Improving crop competition

The impact of weeds on crop yield can be reduced and the effectiveness of weed control tactics increased by crop competition. The rate and extent of crop canopy development are key factors influencing a crop's competitive ability with weeds. A crop that rapidly establishes a vigorous canopy, intercepting maximum sunlight and shading the ground and inter-row area, will provide optimum levels of competition. Leaf area index at the end of tillering in cereals is highly correlated with the crop's ability to compete with weeds.

Key issues in improving crop competition:

- Good agronomy generally means a competitive crop.
- A competitive crop greatly improves weed control by reducing weed biomass and seedset.
- Different crops and varieties compete with and suppress weeds differently.
- High crop sowing rates reduce weed biomass and weed seed production and may improve crop yield and grain quality. Optimising for yield and quality is advised.
- Take care to sow seed at optimum depth.
- Fertiliser placement can improve crop growth, yield and competitive ability.
- Many studies show a reduction in weeds with increased sowing rate and narrower rows.
- Furrow-sowing or moisture-seeking techniques at sowing can help establish the crop before the weeds.
- Sowing at the recommended time for the crop type and variety maximises crop competitive ability, which will reduce weed biomass and seedset.
- When delaying sowing to allow for control of the first germination of weeds, choose the crop type and variety most suited to later sowing to minimise yield loss.
- Sow problem weedy paddocks last to allow a good weed germination and subsequent kill prior to sowing.¹¹



⁹ GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, https://grdc.com.au/IWMM

¹⁰ GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, https://grdc.com.au/IWMM

¹¹ GRDC (2014) Section 2. Agronomy to enhance weed management, Integrated weed management manual, Integrated Weed Management Hub, GRDC, https://grdc.com.au/Resources/IWMhub/Section-2-Agronomy-to-enhance-weed-management



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6.1.5 Fallow weed control

Fallow weed control is essential if oats is to make full use of summer rainfall, and to prevent weed seeds from contaminating the grain sample at harvest. Fallows are defined as the period between two crops, or between a crop and a defined pasture phase. Fallows are used to reduce the weed seedbank, store and conserve soil moisture and nitrogen (N) for the next crop, and to stop weed growth that could impede the sowing operation.

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Benefits of fallow weed control:

- A fallow period on its own, or in sequence with a number of crops, can be highly effective in reducing the weed seedbank.
- A fallow period can incorporate several tactics to reduce weed seedbanks.
- A double-knock of glyphosate followed by paraquat can give high levels of weed control and can assist control of some hard-to-kill or glyphosate-resistant survivors.
- If planned, it is sometimes possible to use other herbicide MOA groups with residual activity (Groups C, B, I or K) in fallow.
- In a fallow, it is easier to spot escapes and take action to stop seedset than in a crop, such as use of a WeedSeeker[®] spray rig.

Key factors for success:

- Control weeds of fallows when they are small.
- Try to include a range of tactics that include different MOA groups, paraquat and residual herbicides to avoid over-reliance on glyphosate alone. Occasional tillage should also be considered when there is a drying seedbed. ¹²

Effect of fallow weed on nitrogen levels:

- The higher levels of soil water in fallows where weeds are controlled are likely to see more nitrogen mineralised in the fallow period that will be available for use by the following crop.
- Extra nitrogen available to a crop through fallow weed control is reflected in both yield and potentially also in grain protein.
- Every 1 mm of moisture lost via summer weed growth also reduced mineral nitrogen levels by approx. 0.64 kg N/ha (McMaster, 2013). ¹³

Green bridge

Several diseases that damage crops and insects that act as vectors are hosted on weeds in the summer fallow. Diseases spread by insects living on weeds in summer fallow include: cereal rusts, wheat streak mosaic virus, crown rot, barley yellow dwarf virus, beet western yellow virus, bean leaf roll virus, diamondback moth, mites and Rhizoctonia. The ideal situation is to have a long period of no green bridge during the summer period. The critical period is the four to six weeks prior to sowing. All weeds and crop volunteers should be killed before and during this window.¹⁴

6.1.6 Grazing to manage weeds actively

Grazing management can aid weed management, especially in a crop so suited to grazing as oats, by:

- reducing weed seedset
- reducing weed competition
- encouraging domination by desirable species.
- 12 GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, https://grdc.com.au/IWMM
- 13 J Cameron, A Storrie (2014) Summer fallow weed management. GRDC, April 2014 <u>http://www.grdc.com.au/*/media/Documents</u> <u>Resources/Publications/Summer-fallow-weed-management-manual.pdf?la=en</u>
- 14 J Cameron, A Storrie (2014) Summer fallow weed management. GRDC, April 2014 <u>http://www.grdc.com.au/^//media/Documents/</u> <u>Resources/Publications/Summer-fallow-weed-management-manual.pdf?la=en</u>





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The impact is intensified when the timing of grazing coincides with the vulnerable stages of the weed life cycle. This can be achieved through:

- timing grazing pressure to manipulate pasture composition
- grazing being used in conjunction with herbicides (spray-grazing) to manage weeds effectively (e.g. winter application of sublethal rates of MCPA on broadleaf weeds in clover-based pasture)

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• exploiting differences in species acceptability to sheep, which can reduce weed numbers (e.g. grasses are more palatable in autumn) (Photo 1).

Problems encountered by farmers when using grazing to manage weeds include:

- grazing pressure often not high enough to prevent selective grazing
- incorrect timing of practices to obtain the desired level of weed control
- risk of livestock importing weeds or transporting them to other paddocks.¹⁵



Photo 1: Sheep are effective weed managers if stocking rates can be kept high enough.

Photo: Arthur Mostead, Source: GRDC

6.1.7 Fighting herbicide resistance

Rapid expansion of herbicide resistance and the lack of new MOA require that nonherbicide tactics must be a significant component of any farming system and weed management strategy. Inclusion of non-herbicide tactics is critical to prolong the effective life of remaining herbicides, as well as for new products and MOA.

The following plan will assist in developing a management plan for each paddock:

- 1. Review past actions and history.
- 2. Assess current weed status.
- 3. Identify weed-management opportunities.
- 4. Match opportunities and weeds with suitably effective management tactics.
- 5. Combine ideas into a management plan. Use of a rotational plan can assist.¹⁶



¹⁵ GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, <u>http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set</u>

¹⁶ G Troup (2015) Oats: weeds and integrated weed management. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-weeds-and-integrated-weed-management</u>



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6.1.8 Controlled traffic for optimal herbicide application

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Controlled traffic (or 'tramlining') refers to a cropping system designed to limit soil damage by confining all wheel traffic to permanent lanes for all paddock operations, including seeding, harvesting and all spraying (Photo 2). Some form of traffic lane will reduce compaction between the tramlines, resulting in increased health of the crop through improved soil characteristics, thus improving the competitive ability of the crop.

This form of precision agriculture results in:

- more efficient use of pesticide application through reduced overlaps
- ability to treat weeds in the inter-row more easily
- easier management of weed seeds at harvest.

Accurately spaced tramlines provide guidance and a firmer pathway for more timely and accurate application of herbicides after rainfall, which in turn improves weed control and reduces input costs by 5–10%. In wide-row controlled-traffic systems, inter-row-shielded and band spraying as well as inter-row tillage may be options. Precision-guidance technology potentially makes such options more practical, but there are very few registrations allowing use of herbicides in this manner.¹⁷



Photo 2: Controlled traffic cropping allows more options for weed control and management.

Photo: A Mostead







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IN FOCUS

Weed Seed Wizard

The Weed Seed Wizard helps growers to understand and manage weed seedbanks on farms across Australia's grain-growing regions. Weed Seed Wizard is a computer simulation tool that uses paddock-management information to predict weed emergence and crop losses. Different weed management scenarios can be compared to show how different crop rotations, weed control techniques, and irrigation, grazing and harvest management tactics can affect weed numbers, the weed seedbank and crop yields. The 'Wizard' uses farm-specific information, and users enter their own farm-management records, their paddock soil type, local weather and one or more weed species. The Wizard has numerous weed species to choose from including annual ryegrass, barley grass, wild radish, wild oat, brome grass and silver grass in the southern states, and liverseed grass, barnyard grass, paradoxa grass, feather-top Rhodes grass, bladder ketmia, fleabane, sowthistle, sweet summer grass, cowvine and bellvine in the north. A free download is available from: https://www.agric.wa.gov.au/ weed-seed-wizard-0.

6.2 Pre-emergent herbicides

There are few pre-emergent herbicide options for oats as most of these chemicals are targeted at controlling wild or black oats and will subsequently kill white oats. As such, paddock selection of a grass weed-free paddock for oats is imperative to ensure both maximum yield or dry matter (DM) production from the crop and to ensure weed seed numbers are minimised for the following year. ¹⁸

Good weed control is essential to make full use of stored summer rainfall, minimise yield losses, and prevent weed seed contamination at harvest. ¹⁹ With the continued evolution of herbicide resistance, growers are being forced to introduce a range of different weed control tactics. A tactic that has rapidly increased in recent seasons is the use of pre-emergent herbicides, especially in the summer crop and fallow. To predict field performance of these herbicides, an understanding is needed of their chemical properties and how they interact with the environment. When devising a weed control strategy, consider the use of pre-emergent herbicides as an additional tactic available to help drive weed numbers down. Pre-emergent herbicides control weeds at the early stages of the life cycle, between radicle (root shoot) emergence from the seed and seedling leaf emergence through the soil. Used alone they will not usually achieve the objective of driving down weed seedbank numbers, but when used amongst a suite of tactics, they can be particularly effective. ²⁰

Key points:

- Knowing which weeds are in the paddock and where the weed seeds are located (shallow or deep) is important in selecting a herbicide to be applied.
- Be aware of whether a herbicide is subject to volatilisation or photodegradation in order to determine an incorporation strategy that minimises loss to the environment.



G Brooke, C McMaster (2016) Weed control in winter crops 2016. New South Wales Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/_____data/assets/pdf__file/0019/123157/weed-control-in-winter-crops-2016.pdf</u>
 GRDC FINAL REPORTS - Durum expansion in SA through improved Agronomy - DGA00001

²⁰ GRDC (2014) Pre-emergent herbicide use Fact Sheet. GRDC Revised December 2015, <u>https://grdc.com.au/Resources/ Factsheets/2015/12/Preemergent-Herbicide-Use-Fact-Sheet</u>



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MORE INFORMATION

Understanding pre-emergent cereal herbicides



Mark Congreve & John Cameron

Solubility influences how much rain is required for herbicide incorporation, how easily a herbicide will be taken up by a germinating weed and crop, and if a herbicide will be subject to moving down the profile, potentially causing crop injury or loss to leaching.

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- Sandy or low organic matter soils will have less binding and allow for greater herbicide availability for crop and weed uptake.
- Herbicides that bind tightly to soil and organic matter generally require higher application rates, stay close to where they are applied (unless the soil moves), and persist for longer.
- Soil pH affects how long some herbicides persist for and how available they are for plant uptake and soil binding.
- The persistence of a herbicide and the way in which it breaks down will dictate the length of residual control and plant-back constraints to sensitive crops.
- Rainfall after application is important for incorporation of some herbicides and availability of the product to the weeds and crop. Rainfall and temperature also affect degradation.
- Choice of application rate will affect length of residual, and possibly crop selectivity.²¹

Choosing herbicides for weed control will depend on the specific weed species present in the paddock and the crop being grown. Consult your agronomist to discuss specific strategies.

Benefits

The residual activity of a pre-emergent herbicide controls the first few flushes of germinating weeds (cohorts) when the crop or pasture is too small to compete. The earliest emerged weeds are the most competitive. Therefore, pre-emergent herbicides are ideal tools to prevent yield losses from these 'early season' weeds. The residual activity gives control of a number of cohorts, not just those germinating around the time of application. Ideally, pre-emergent herbicides should be applied just prior to, or just after, sowing the crop or pasture. This maximises the length of time that the crop will be protected by the herbicide during establishment.²²

6.3 Post-plant pre-emergent herbicides

Few products are registered in this space for oats. Diuron®, however, is registered for suppression of annual ryegrass, barley grass and silver grass in a post-plant, preemergent situation (Photo 3). 23

- 21 GRDC (2014) Pre-emergent herbicide use Fact Sheet. GRDC Revised December 2015, https://grdc.com.au/Resources/ Factsheets/2015/12/Preemergent-Herbicide-Use-Fact-Sheet
- C Preston (2014), Understanding pre-emergent cereal herbicides. GRDC Update Papers 04 March 2014 https://exearch-and-Development/GRDC-Update-Papers/2014/03/Understanding-pre-emergent-cereal-herbicides
- G Brooke, C McMaster (2016) Weed control in winter crops 2016. New South Wales Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/_____data/assets/pdf_file/0019/123157/weed-control-in-winter-crops-2016.pdf</u>





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Photo 3: The important factors in getting pre-emergent herbicides to work effectively while minimising crop damage are: to understand the position of the weed seeds in the soil; the soil type (particularly amount of organic matter and crop residue on the surface); the solubility of the herbicide; and its ability to be bound by the soil. 24

6.4 In-crop herbicides: knock downs and residuals

When selecting a herbicide, it is important to know crop growth stage, weeds present and plant-back period. For best results, spray weeds while they are small and actively growing (Photo 4). Herbicides must be applied at the correct stage of crop growth, or significant yield losses may occur. Check product labels for up-to-date registrations and application methods.

Key points:

- Knowledge of a product's translocation and formulation type is important for selecting nozzles and application volumes.
- Evenness of deposit is important for poorly or slowly translocated products.
- Crop growth stage, canopy size and stubble load should influence decisions about nozzle selection, application volume and sprayer operating parameters.
- Robust rates of products and appropriate water rates are often more important for achieving control than the nozzle type, but correct nozzle type can widen the spray window, improve deposition and reduce drift risk.
- Travel speed and boom height can affect control and drift potential.
- Appropriate conditions for spraying are always important. ²⁵



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²⁴ C Preston (2014), Understanding pre-emergent cereal herbicides. GRDC Update Papers 04 March 2014 <u>https://www.grdc.com.au/</u> <u>Research-and-Development/GRDC-Update-Papers/2014/03/Understanding-pre-emergent-cereal-herbicides</u>

²⁵ GRDC (2014) In-crop herbicide use Fact Sheet. GRDC 04 August 2014, <u>https://grdc.com.au/Resources/Factsheets/2014/08/In-crop-herbicide-use</u>





Photo 4: Spraying to control weeds. Source: DAFWA

Effective post-emergent herbicide application is dependent upon adequate contact with above-ground plant shoots and leaves. Therefore, it is important that spray pressure and volume be adjusted for adequate plant coverage. Also, it is very important that the proper nozzles be used. Hollow-cone or flat-fan nozzles are generally recommended. Read the herbicide label for details. For post-emergence herbicides, the chemical and physical relationships between the leaf surface and the herbicide often determine the rate and amount of uptake (Table 1). Factors such as plant size and age, water stress, air temperature, relative humidity, and herbicide additives can influence the rate and amount of herbicide uptake. Additives such as crop oil concentrates, surfactants, or liquid fertiliser solutions can increase herbicide uptake by a plant. Application of herbicides under hot and dry conditions or application to older and larger weeds or weeds under water stress can decrease the amount of herbicide uptake. Differences in the rate and amount of herbicide uptake influence the potential for crop injury and weed control and often explain the year-to-year variation in the effectiveness of the herbicide. Also, the faster a herbicide is absorbed by a plant, the less likely it will be that rain will wash the herbicide off the plants. Like soil-applied herbicides, post-emergent herbicides differ in their ability to move within a plant. For adequate weed control, non-mobile post-emergent herbicides must thoroughly cover the plant. Other herbicides are mobile within the plant and can move from the site of application to their site of herbicidal activity. In general, injury symptoms will be most prominent at the sites at which the mobile herbicides concentrate. 26



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²⁶ Herbicide Mode of Action and Injury Symptoms. University of Minnesota Extension Service, North Central Regional Extension Publication No. 377, <u>http://www.cof.orst.edu/cof/fs/kpuettmann/FS%20533/Vegetation%20Management/Herbicide%20Mode%20of%20</u> <u>Action%20and%20Injury%20Symptoms.htm</u>



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Table 1: Post-emergence broadleaf weed control in oats and herbicide rates per hectare. ²⁷

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Chemical	Chlorsul- furon (1)	Metosulam (12)	Flumet- sulam (13)	Bromoxy- nil	Bromoxy- nil + MCPA	Diflu- fenican + MCPA (10)	Picolinafen +MCPA	Carfen- trazone- Ethyl	Dicamba	24-DB
Mode of action group ¹	В	В	В	С	C + I	F + I	F + I	G	1	1
Concentra- tion	750 g/kg	714 g/kg	800 g/kg	200 g/L	200 + 200 g/L	250 + 25 g/L	500 + 50 g/L	400 g/ kg	700 g/kg	400 g/L
Trade name	Smash 625 and other products	Eclipse	Broadstrike	Bromicide 200 & other products	Buctril MA and other products	Tigrex	Paragon	Affinity 400DF	Cadence	Buticide and other products
Rate/ha	g/ha	g/ha	g/ha	L/ha	L/ha	L/ha	L/ha	g/ha	g/ha	L/ha
Weeds										
Annual saltbush	20 g									
Climbing buckwheat	20 g			1.4–2.1 L + 2,4-D or MCPA (2)	1.4–2 L			50 g + MCPA Amine	0.2 g	
Deadnettle	15–20 g						500 mL			
Docks					1.4–2 L	1 L* (11)			0.2 g	2.8 -3.0 L
Fat hen				1.4–2.1 L +2,4-D or MCPA (2)	1.4–2 L	1 L* (11)				2.8 L
Hexham scent					1.4–2 L	1 L*				
Mexican poppy				2 L	1.4–2 L					3 L
Mintweed	20 g				1.4–2 L					
Mustards	15 g	7 g	25 g	2 L	1.4–2 L	500 mL-1 L	250–375 mL	50 g		2.8 L
NZ spinach	20 g		25 g*						0.2 g	
Peppercress				1.4–2 L	1.4–2 L	1 L*				
Prickly lettuce						500 mL-1 L		50 g		
Red pigweed										
Saffron thistle				1.4–2.1 L	1.4–2 L	1 L*				2.8–3.0 L
Sowthistle						1 L* (11)	500 mL	50 g + MCPA Amine		
Spiny emex			25 g*	2 L or 1.4 L+ 2,4-D or MCPA (2)	1.4–2 L	1 Ľ* (11)	500 mL	50 g + MC PA Amine	0.2 g	3.0 L
Sunflower										
Turnip weed	15 g	5 - 7 g	15–25 g	2 L	1.4–2 L	500 mL-1 L		50 g + MCPA Amine		2.8 L



27 DAF Old (2012) Disease management. Department of Agriculture and Fisheries Queensland, <u>https://www.daf.gld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/oats/diseases-and-weeds</u>



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Chemical	Chlorsul- furon (1)	Metosulam (12)	Flumet- sulam (13)	Bromoxy- nil	Bromoxy- nil + MCP/	Diflu- A fenican + MCPA (10)	Picolinafen +MCPA	Carfen- trazone- Ethyl	Dicamba	24-DB
Variegated thistle				1.4–2.1 L+ 2,4-D or MCPA (2)	1.4–2 L	1 L* (11)			0.2 g	2.8–3.0 L
Vetches						1 L* (11)				
Wild radish	15 or 20 g	7 g	25 g*	2 L	1.4–2 L	500 mL-1 L	250–375 mL	60 g + MCPA Amine		
Wireweed	20 g			1.4–2.1 L+ 2,4-D or MCPA (2)	1.4–2 L	750 mL*		50 g + MCPA Amine	0.2 g	
Crop growth	stages									
Oats	After 2 leaf to early tillering	2 leaf to first node	mid tillering till start of jointing	g 3 leaf to late tillering	Early to fully tillered	5 leaf to late tillering Z15-Z30	3 leaf to late tillering Z13-Z30	3 leaf to mid- tillering	3 leaf to mid- tillering	5 leaf to fully tillered
Chemical	MCPA Amine(3)	MCPA LVE	Picloram + MCPA	Picloram + 2,4-D	2,4-D Amine (3)	Dicamba (7)	Dicamba + MCPA	Fluroxyp	oyr Clopy	yralid (14)
Mode of action group ¹	I	I	+	+	I	I	+	I	Ι	
Concentra- tion	500 g/L	500 g/L	26 + 420 g/L	75 + 300 g/L	500 g/L	500 g/L	80 + 340 g/L	200 g/L	300 <u>(</u>	g/L
Trade name	MCPA 500 & other products	MCPA L.V.E. & other products	Tordon 242	Tordon 75-D	Amicide 500 & other products	Kamba 500 & other products	Kamba M & other products	Starane 200 & ot products	Lontr ther Rally other	el 300 & products
Rate/ha	L/ha	L/ha	L/ha	L/ha	L/ha	L/ha	L/ha	L/ha	L/ha	
Weeds										
Climbing buckwheat	0.7- 2.1 L		1 L	0.3 L			1.7 L	750 mL		
Deadnettle	0.7- 2.1 L							1.5 L		
Docks				0.3 L	0.7–1.1 L	400–700 mL + MCPA (8)	1–1.7 L			
Fat-hen	0.7- 2.1 L	1–1.6 L			0.7–1.1 L	700 mL + MCP4 (8)	4 1.7 L			
Hexham scent	0.7- 2.1 L			0.3 L + 0.47 L 2,4-D (5)	0.7–1.1 L	400–700 mL + MCPA (8)	1–1.7 L			
Mexican poppy					0.7–1.1 L					
Mintweed	0.7–2.1 L			0.3 L + 0.47 L 2,4-D (5)	0.7–1.1 L	700 mL + MCPA or 2,4-D (8,9)	4 1.7 L			
Mustards	0.7- 2.1 L L	0.56 L - 1 L	1 L	0.3 L + 0.47 L 2,4-D (5)	0.7–1.1 L	400–700 mL + MCPA or 2,4-D (8,9)	1–1.7 L			
NZ spinach			1 L	0.3 L		700 mL	1.7 L			
Peppercress										
Prickly lettuce								1 L		
Saffron thistle	0.7- 2.1 L	1.1—1.6 L	1 L	0.3 L	0.7–1.1 L	700 mL + MCPA or 2,4-D (8,9)	A 1.7 L		50 m (14)	L+MCPA



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Chemical	MCPA Amine(3)	MCPA LVE	Picloram + MCPA	Picloram + 2,4-D	2,4-D Amine (3)	Dicamba (7)	Dicamba + MCPA	Fluroxypyr	Clopyralid (14)
Sowthistle				0.3 L				1 L	
Spiny emex			1 L	0.3 L	0.7–1.1 L	400–700 mL + MCPA (8)	1—1.7 L	1.5 L	
Sunflower		1.5 L		0.3 L + 0.47L2,4-D (5)	0.7–1.1 L	700 mL			
Turnip weed		0.7 L-1.1 L		0.3 L + 0.47 L 2,4-D (5)	0.7–1.1 L	400–700 mL + MCPA or 2,4-D or (8,9)	1–1.7 L		
Variegated thistle	0.7- 2.1 L	0.84 L-1.1 L	1 L	0.3 L + 0.47 L 2,4-D (5)	0.7–1.1 L	700 mL	1.7 L		50 mL+MCPA (14)
Vetches						400–700 mL + MCPA (8)	1—1.7 L		
Wild radish	0.7- 2.1 L	1.1—1.6 L	1 L	0.3 L + 0.47 L 2,4-D (5)	0.7–1.1 L	400–700 mL + MCPA or 2,4- D(8,9)	1–1.7 L		
Wireweed			1 L	0.3 L + 0.47 L 2,4-D* (5)		400–700 mL + MCPA (8)	1—1.7 L	1.5 L	
Crop growth stages									
Oats	Early tillering to before boot stage	Early tillering to start of flag leaf (4)	Early tillering to start of jointing	3–4 tiller to start of jointing	Mid tillering to before booting (6)	Early to late tillering (6)	Early to late tillering	Early tillering to appearance of first node	4 - 5 leaf onwards



WATCH: <u>GRDC Grains Research</u> <u>Updates 2015 – In-crop herbicide</u> <u>developments</u>



* Weed suppression only.

¹Herbicide mode of action websites:

Stopping herbicide resistance in Queensland

Herbicide resistance mode of action groups booklet available from the Grains Research and Development Corporation website Understanding herbicide modes of action

- Chlorsulfuron (Glean, and other products): Add a non-ionic wetting agent as per label directions.
- Bromoxynil (Bromocide 200 and other products): See label for the required rate of MCPA or 2,4-D.
- MCPA amine and 2,4-D amine: Formulations vary in the percentage of active ingredient. Check the label and adjust the rate accordingly.
 For weed control in oats, use MCPA or its mixtures in preference to 2,4-D or its mixtures for optimum crop safety.
- MCPA LVE: The upper tolerance level for barley, oats, rye and triticale is 1.6 L/ha.
- Tordon 75-D + 2,4-D: Add 470 mL/ha of 500 g/L 2,4-D amine.
- 2,4-D amine: The upper tolerance level for oats is 1.1 L/ha.
- Dicamba (Kamba 500 and other products):Do not apply after the start of jointing as serious crop damage may result.
- Dicamba + MCPA: Add 700 mL-1.7 L of 500 g/L MCPA to dicamba when crop is from five leaf to early tillering growth stage.
- Dicamba + 2,4-D: Add 700 mL/ha of 500 g/L 2,4-D amine to dicamba. This application is restricted to mid to late tillering crop growth stage.
- Tigrex: Rates up to 750 mL/ha may be applied 3 leaf to late tillering of cereal crops. May be applied to cereals undersown with clover.
- Tigrex: Weeds will be suppressed with application up to 2 leaf stage.
- Eclipse: Apply with Uptake or DC-Tron spraying oil or non-ionic wetter as per label.
- Broadstrike: Apply with Uptake spraying oil as per label.
- Clopyralid (Lontrel and other products): Add MCPA amine at 1 L/ha or MCPA LVE at 700 mL/ha.

Note: These tables are intended as a guide only. Registrations may differ between individual products and change over time. Always check the label.



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VIDEOS

WATCH: <u>GRDC Grains Research</u> <u>Updates 2015 – Tech for efficient</u> <u>herbicide use</u>



How to get the most out of post-emergent herbicides:

• Consider application timing—the younger the weeds the better. Frequent crop monitoring is critical.

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- Consider the growth stage of the crop.
- Consider the crop variety being grown and applicable herbicide tolerances.

Know which species were historically in the paddock and the resistance status of the paddock (if unsure, send plants away for <u>plant testing</u>).

Do not spray a crop stressed by waterlogging, frost, high or low temperatures, drought or, for some chemicals, cloudy/sunny days. This is especially pertinent for frosts with grass-weed chemicals.

Use the correct spray application:

- Consider droplet size with grass-weed herbicides, water volumes with contact chemicals and time of day.
- Observe the plant-back periods and withholding periods.
- Consider compatibility if using a mixing partner.
- Add correct adjuvant.

IN FOCUS

Weed control in Oats – Southern Wimmera – 1998

Ryegrass and broadleaf weeds such as toadrush and capeweed are the main weeds to control in oat crops on the rising hill country in the southern Wimmera. In this trial, the most cost-effective option to control these weeds was Diuron® and chlorsulfuron applied at the 3 leaf stage of the oats. The main broadleaf weed present was sub-clover, in a wet year weeds such as toadrush could be a problem. The ryegrass population was quite dense at more than 50 plants per square metre. The Glean® treatments had good suppression of the ryegrass. There were no significant differences between the treatments due to quite high variability in yield between the replicates. Weed control options for the rising hill country south of Marnoo has to include the control or suppression of ryegrass, toadrush, capeweed, erodium, sorrel and onion grass. In the trial the most cost-effective option, which has good control of these weeds, is Diuron® with Glean®. Small ryegrass (2 to 3 leaf) can be controlled effectively with Glean®. Igran has a role where oats have been undersown with clover (Glean[®] cannot be used). Another option which requires further investigation is a mixture between Dual Gold and Diuron[®], especially where water weeds are common. ²⁸

6.4.1 Reducing glyphosate resistance

Glyphosate is a key herbicide in Australia's farming system and responsible use is required to prolong its effective life. IWM should be applied by growers to sustain glyphosate and reduce the incidence of resistance in weeds, particularly ryegrass. A double knockdown technique will minimise the risk of resistance developing. Double knockdown is the sequential use of glyphosate followed by a mixture of paraquat + diquat.

Best practices for double knockdown include:

glyphosate followed by paraquat or a diquat/paraquat mix such as Spray.Seed®









i) MORE INFORMATION

In-crop herbicide use Factsheet

- spraying the first herbicide at the 3–6 leaf stage of ryegrass results in the best control
- ensuring the interval between knockdowns is at least 1 day when using the glyphosate followed by paraquat + diquat but a 2–10 day interval is more effective if seasonal conditions permit
- allowing a longer interval before the second spray will ensure plants emerging after the first knockdown are killed. ²⁹

6.5 Potential herbicide damage effect

When researching the residual activity and cropping restrictions following herbicide application, the herbicide label is the primary source of information and it should be read thoroughly.

Herbicide damage on non-target plants may cause slight to serious injury symptoms and can occasionally cause economic damage as well. Herbicide chemistry and physical properties usually determine how herbicides interact with the biological and physical systems of the plant. Factors determining herbicide efficacy and crop safety are complex and include plant species, plant size, stage of growth, soil chemical and physical properties, soil moisture, temperature, and relative humidity. Post-emergent herbicide uptake and efficacy can be affected by spray additives that enhance the performance of the herbicide but may also increase the risk of crop injury. Herbicides can injure foliage, shoots, flowers, and fruits. Several herbicide injury symptoms include general and interveinal chlorosis, mottled chlorosis, yellow spotting, purpling of the leaves, necrosis, and stem dieback (Photo 5). ³⁰



Photo 5: Contact with herbicide can cause yellow blotching and necrotic spotting of leaves in oats.

Source: Manitoba

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 should thus 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. ³¹Timely and correct application of herbicides is essential. Seek local advice from advisers/agronomists and follow label directions. 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. Where herbicide residue may remain in the soil, avoid the use of herbicides from the same mode of action group in following crops. It is not uncommon to see a herbicide stress acting on top of an existing herbicide stress to make a potentially damaging residual situation worse.



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²⁹ G Troup (2015) Oats: weeds and integrated weed management. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/oats/oats-weeds-and-integrated-weed-management</u>

³⁰ K Al-Khatib, Herbicide damage. University of California Division of Agriculture and Natural Resources, <u>http://herbicidesymptoms.ipm.ucanr.edu/HerbicideDamage</u>

³¹ J Cameron, M Congreve (2016), Recropping issues with pre-emergent herbicides. GRDC 26 February 2016, <u>https://grdc.com.au/</u> <u>RecroppinglssuesWithPreEmergentHerbicides</u>





6.5.1 Residuals

Some herbicides can remain active in the soil for weeks, months or years. This can be an advantage, as it ensures good long-term weed control. However, if the herbicide stays in the soil longer than intended it may damage sensitive crop or pasture species sown in subsequent years (Photo 6). For example, chlorsulfuron is used in oats, but it can remain active in the soil for several years and damage legumes and oilseeds, especially in dry seasons or on certain soil types, such as high pH soils. A real difficulty for growers lies in identifying herbicide residues before they cause a problem. Currently, we rely on information provided on the labels about soil type and climate. Herbicide residues are often too small to be detected by chemical analysis, or if testing is possible, it is too expensive to be part of routine farming practice. Once the crop has emerged, diagnosis is difficult because the symptoms of residual herbicide damage can often be confused with, and/or make the crop vulnerable to, other stresses, such as nutrient deficiency or disease.³²



Photo 6: Paraquat damage in a young oat crop Photo: David Pfeiffer

6.5.2 How can I avoid damage from residual herbicides?

Select a herbicide appropriate for the weed population you have. Make sure you consider what the recropping limitations may do to future rotation options. Users of chemicals are required by law to keep good records, including weather conditions, but particularly spray dates, rates, batch numbers, rainfall, soil type and pH (including different soil types in the paddock). In the case of unexpected damage, good records can be invaluable. If residues could be present, choose the least susceptible crops (refer to product labels). Optimise growing conditions to reduce the risk of compounding the problem with other stresses such as herbicide spray damage, disease and nutrient deficiency. These stresses make a crop more susceptible to herbicide residues (Photo 7). ³³ An option for assessing the potential risk of herbicide



³² DEPI (2013) Avoiding crop damage from residual herbicides. Department of Environment and Primary Industries Victoria, Updated August 2013 <u>http://agriculture.vic.gov.au/agriculture/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/</u> managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

³³ DEPI (2013) Avoiding crop damage from residual herbicides. Department of Environment and Primary Industries Victoria, Updated August 2013 <u>http://www.edpivic.govau/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemicalresidues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides</u>



residues is to conduct a bioassay involving hand-planting small test areas of crop into the field in question.

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Photo 7: Oats with damage from Sakura® residues in the spray tank. Photo. Rural Directions

Group B. Sulfonylureas, triazolopyrimidines (sulfonamides) and imidazolinones

The sulfonylureas persist longer in alkaline soils (pH >7), where they rely on microbial degradation. Residual life within the sulfonylurea family varies widely, with chlorsulfuron (Lusta^{*}) persisting for \geq 2 years, depending on rate, and not suitable for highly alkaline soils. Triasulfuron (Logran[®]) persists for 1–2 years and metsulfuron (Ally[®]) generally persists for <1 year. Legumes and oilseeds, particularly lentils and medic, are most vulnerable to sulfonylureas. However, oats can also be more sensitive to sulfonylureas than other cereals-check the label. Debate remains about the ideal conditions for degradation of triazolopyrimidines (sulfonamides) herbicides which include Crusader® and Eclipse®. However, research in the alkaline soils of the Victorian Wimmera and Mallee, and the Eyre Peninsula in South Australia, has shown that the sulfonamides are less likely to persist than the sulfonylureas in alkaline soils. Plant-back periods should be increased in shallow soils. The imidazolinones are very different from the sulfonylureas; the main driver of persistence is soil type, not soil pH. They tend to be more of a problem on acid soils, but carryover does occur on alkaline soils. Research has shown that in sandy soils, such as on the Eyre Peninsula, they can break down very rapidly (within 15 months in alkaline soils), but in heavy clay soils in Victoria they can persist for several years. Breakdown is by soil microbes. Oilseeds are most at risk. Widespread use of imidazolinone-tolerant canola and wheat in recent years has increased the incidence of imidazolinone residues. Longer residues exist for oats than for other cereal crops, an example being for Spinnaker®, the plant-back to non-Clearfield wheat and barley is 10 months provided greater than 300 mm has fallen in the fallow period. For oats the recropping interval is 22 months.

Group C. e.g. Triazines

Usage of triazines has increased to counter Group A resistance in ryegrass, in particular in triazine-tolerant canola. Atrazine persists longer in soil than simazine. Both generally persist longer on high pH soils, and cereals are particularly susceptible to damage. Research in the US indicates that breakdown rates tend to increase when triazines are used regularly, because the number of microbes able



Herbicide damage





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to degrade the herbicide can increase. This may mean that breakdown can take an unexpectedly long time in soils that have not been exposed to triazines for some years. Many triazines are registered for the control or suppression of wild oats and as such would be very damaging to cereal sown oats.

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Group D. Dinitroanilines

Trifluralin tends not to leach through the soil, but it can be moved into the seedbed during cultivation or ridging. Trifluralin binds strongly to stubble and organic matter and is more likely to be a problem in paddocks with stubble retention. Trifluralin is not registered in oats but is registered for control of both wild oats and cereal oats.

Group H. Isoxazoles

Persistence in acid soils (pH <7) has not been fully tested, but research shows that with isoxazoles, such as Balance^{*}, persistence is expected to be longer than the label recommendations for legume crops and pastures. Isoxazoles will also persist longer in clay soils and those with low organic matter.

Group I. Phenoxies and pyridines

Clopyralid (Lontrel[®]) and aminopyralid can be more risky on heavy soils and in conservation cropping, where they can accumulate on stubble. Even at low rates they can cause crop damage up to two years after application. They cause twisting and cupping, particularly for crops suffering from moisture stress. 2,4-D used for fallow weed control in late summer may cause a problem with autumn-sown crops if plant-back periods are not observed. Changes have been made to the 2,4-D label recently and not all products can be used for fallow weed control—check the label. The label recommends that you do not sow sensitive crops, especially canola, until after a significant rainfall event. Oilseeds and legumes are very susceptible to injury from 2,4-D. Oats are less tolerant of Group I products than wheat and barley. Oats is not registered on as many of the phenoxys as wheat and barley e.g. Estercide[®] Xtra 680. The maximum in-crop rates can be less than that for the other cereals e.g. Amicide[®] and the plant-back periods are generally longer than wheat and barley.

Group K. Chloroacetamides and isoxazolines

Metolachlor, a component of Boxer[®] Gold, and pyroxasulfone (Sakura[®]), would be the two most common Group K chemicals used in winter cropping. Both of which are effective in controlling wild oats and would consequently kill cereal oats if applied to a crop. Pyroxasulfone (Sakura[®]) relies on microbial degradation, which is favoured by in-season rainfall. Label plant-back periods are important particularly for oats, durum wheat and canola. Residues will lead to crop stunting.

6.5.3 Plant-back intervals

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

Some herbicides have a long residual. The residual is not the same as the halflife. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods (e.g. sulfonylureas (chlorsulfuron)). This is shown in Tables 2 and 3 where known. Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the "Protection of crops etc." heading in the "General Instructions" section of the label.

Part of the management of herbicide resistance includes rotation of herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonyl urea,





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triazines etc.) may be an issue in some paddocks. Remember that plant-back periods begin after rainfall occurs. $^{\rm 34}$

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Table 2: Residual persistence of common pre-emergent herbicides, and note residual persistence in broad-acre trials and paddock experiences. ³⁵

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high pH soils. Weed control commonly drops off within 6 weeks.
Glean® (chlorsulfuron)	28–42	High. Persists longer in high pH soils. Weed control longer than Logran.
Diuron	90 (range 1 month to 1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Has had observed longlasting activity on grass weeds such as black/stink grass (Eragrostis spp.) and to a lesser extent broadleaf weeds such as fleabane.
Atrazine	60–100, up to 1 year if dry	High. Has had observed long lasting (>3 months) activity on broadleaf weeds such as fleabane.
Simazine	60 (range 28–149)	Med./high. 1 year residual in high pH soils. Has had observed long lasting (>3 months) activity on broadleaf weeds such as fleabane.
Terbyne® (terbulthylazine)	6.5–139	High. Has had observed long lasting (>6 months) activity on broadleaf weeds such as fleabane and sow thistle
Triflur [®] X (trifluralin)	57–126	High. 6–8 months residual. Higher rates longer. Has had observed long lasting activity on grass weeds such as black/ stink grass (Eragrostis spp.).
Stomp® (pendimethalin)	40	Medium. 3–4 months residual.
Avadex® Xtra (triallate)	56–77	Medium. 3–4 months residual.
Balance® (isoxaflutole)	1.3 (metabolite 11.5)	High. Reactivates after each rainfall event. Has had observed long lasting (> 6 months) activity on broadleaf weeds such as fleabane and sow thistle.
Boxer Gold [®] (prosulfocarb)	12–49	Medium. Typically quicker to break down than trifluralin, but tends to reactivate after each rainfall event.
Sakura® (pyroxasulfone)	10–35	High. Typically quicker breakdown than Trifluralin and Boxer Gold, however, weed control persists longer than Boxer Gold.



³⁴ B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/_____data/assets/pdf__file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf</u>



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Table 3: Minimum re-cropping intervals and guidelines (NOTE: always read labels to confirm

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Group and type	Product	pH (H ₂ O) or product rate (ml/ha) as applicable	Minimum re-cropping interval (months after application), and conditions
B, sulfonyl urea	Chlorsulfurons	<6.5	3 months
(SU)	eg Glean", Seige", Tackle"	6.6–7.5	3 months, minimum 700 mm
		7.6–8.5	18 months, minimum 700 mm
B, sulfonyl urea (SU)	triasulfuron, eg Logran®,	7.6–8.5	12 months, >250 mm grain, 300 mm hay
	Nugrain®	>8.6	12 months, >250 mm grain, 300 mm hay
B, Sulphonamide	Flumetsulam eg Broadstrike®		0 months
B, sulfonyl urea	metsulfuron	5.6–8.5	1.5 months
(SU)	eg Ally", Associate [®]	>8.5	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area.
B, sulfonyl urea (SU)	Metsulfuron + thifensulfuron	7.8–8.5 Organic matter >1.7%	3 months
	Eg Harmony* M	>8.6 or organic matter <1.7%	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area.
B, sulfonyl urea	Sulfosulfuron	<6.5	0 months
(SU)	eg Monza®	6.5–8.5	10 months

Source: Pulse Australia

Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the "Protection of crops etc." heading in the "General Instructions" section of the label. ³⁶

Conditions required for breakdown

Warm, moist soils are required to breakdown most herbicides through the processes of microbial activity. For the soil microbes to be most active they need good moisture and an optimum soil temperature range of 18°C to 30°C. Extreme temperatures above or below this range can adversely affect soil microbial activity and slow herbicide breakdown. Very dry soil also reduces breakdown. To make matters worse, where the soil profile is very dry it requires a lot of rain to maintain topsoil moisture for the microbes to be active for any length of time.

For up-to-date plant-back periods, see <u>Weed control in winter crops.</u>



herbicides

MORE INFORMATION

Avoiding crop damage from residual



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Herbicide resistance facts:

Resistance is the inherited ability of an individual plant to survive and reproduce following a herbicide application that would kill a "wild type" individual of the same species.

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• Thirty-six weed species in Australia currently have populations that are resistant to at least one herbicide mode-of-action (MOA).

As at June 2014, Australian weed populations had developed resistance to 13 distinct MOAs (<u>click here</u> for up-to-date statistics).

Herbicide resistant individuals are present at very low frequencies in weed populations before the herbicide is first applied.

The frequency of naturally resistant individuals within a population will vary greatly within and between weed species.

A weed population is defined as resistant when a herbicide at a label rate that once controlled the population is no longer effective (sometimes an arbitrary figure of 20% survival is used for defining resistance in testing).

The proportion of herbicide resistant individuals will rise (due to selection pressure) in situations where the same herbicide MOA is applied repeatedly and the survivors are not subsequently controlled.

Herbicide resistance in weed populations is permanent as long as seed remains viable in the soil. Only weed density can be reduced, not the ratio of resistant-to-susceptible individuals. The exception is when the resistance gene(s) carry a fitness penalty so that resistant plants produce less seed than susceptible ones—but this is rare.

Key messages

Resistance:

- Remains for many years, until all resistant weed seeds are gone from the soil seed bank.
- Evolves more rapidly in paddocks with frequent use of the same herbicide group, especially if no other control options are used.

Action points:

- Assess your level of risk with the online glyphosate resistance toolkit.
- Aim for maximum effectiveness in control tactics, because resistance is unlikely to develop in paddocks with low weed numbers.
- Do not rely on the same mode of action group.
- Monitor your weed control regularly.
- Stop the seed set of survivors. ³⁷

Herbicide resistance has become far more widespread, reducing the effectiveness of a wide range of herbicide modes-of-action (MOAs) (Photo 8). Rapid expansion of herbicide resistance and the lack of new modes of action (MOA) require that non-herbicide tactics must be a significant component of any farming system and weed management strategy. Inclusion of non-herbicide tactics is critical to prolong the effective life of remaining herbicides, as well as for new products and modes of action that have not yet been released or indeed invented. Effective herbicides are key components of profitable cropping systems. Protecting their efficacy directly contributes to the future sustainability and profitability of cropping systems.



³⁷ DAFF QLD (2015) Stopping herbicide resistance in Queensland, <u>https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance</u>



MORE INFORMATION

GRDC IWM Hub - Herbicide

resistance.



Photo 8: 2,4-D resistant radish, WA.

How does resistance start?

Resistance starts in a paddock in several ways. Some rare mutations can occur naturally in weeds already in the paddock, with the likelihood varying from 1 plant in 10,000 to 1 in a billion plants, depending on the weed and herbicide. A grower may also import weed seed with the herbicide-resistant gene in contaminated feed, seed or machinery.

Resistance may also be introduced by natural seed spread by wind and water or by pollen, which may blow short distances from a contaminated paddock.

6.6.1 General principles to avoid resistance

Herbicides have a limited life before resistance develops, if they are used repeatedly and exclusively as the sole means of weed control—particularly in zero and minimum tilled systems. Resistance can develop within four to eight years for Group A and B herbicides and after 15 years for Group L and M herbicides (see Table 4 and Figure 1). This can be avoided by:

- keeping weed numbers low
- changing herbicide groups
- using tillage
- rotating crops and agronomic practices

We have gained further insight into the <u>impact and efficacy of integrated weed</u> <u>management strategy components</u> through a computer-simulated model.

Table 4: Rules of thumb for the number of years of herbicide application before resistance evolves

Herbicide group	Years to resistance
А	6–8
В	4–6
С	10–15
D	10–15
L	15+
Μ	15+

Source: Chris Preston, University of Adelaide, in DAFF



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Figure 1: *How a weed population becomes resistant to herbicides.*

Strategies to prevent or minimise the risk of resistance developing are based on IWM principles as outlined below:

- Ensure survivors do not set seed and replenish the soil seed bank.
- Keep accurate paddock records of herbicide application and levels of control. Monitor weeds closely for low levels of resistance, especially in paddocks with a history of repeated use of the same herbicide group.
- Rotate between the different herbicide groups, and/or tank mix with an effective herbicide from another mode of action group. It is important to use effective "stand-alone" rates for both herbicides in the mix.
- Aim for maximum effectiveness to keep weed numbers low. The primary aim of weed control is to minimise their impact on productivity, and resistance is much less likely to develop in paddocks with fewer weeds than in heavily infested paddocks.
- Use a wide range of cultural weed control tools in your weed management plan. Sowing different crops and cultivars provides opportunities to use different weed management options on key weeds. Tillage is useful when it targets a major weed flush and minimises soil inversion, as buried weed seed generally persists longer than on the soil surface. Competitive crops will reduce seed production on weed survivors.
- Avoid introduction or spread of weeds by contaminated seed, grain, hay or machinery. Also, manage weeds in surrounding non-crop areas to minimise risk of seed and pollen moving into adjacent paddocks.

Specific guidelines for reducing the risk of glyphosate resistance are outlined in Table 5. Aim to include as many as possible risk-decreasing factors in your crop and weed management plans.



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Table 5: Balancing the risk for weeds developing glyphosate resistance, devised by the national Glyphosate Sustainability Working Group with minor modifications for the Queensland cropping region.

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Risk increasing	Risk decreasing
Continuous reliance on glyphosate pre- seeding	Double knock technique
Lack of tillage	Strategic use of alternative knockdown groups
Lack of effective in-crop weed control	Full-disturbance cultivation at sowing
Inter-row glyphosate use (unregistered)	Effective in-crop weed control
Frequent glyphosate-based chemical fallow	Use alternative herbicide groups or tillage for inter-row and fallow weed control
High weed numbers	Non-herbicide practices for weed seed kill
Pre-harvest desiccation with glyphosate	Farm hygiene to prevent resistance movement

Source: DAFE

Glyphosate resistant weeds in Australia

Glyphosate resistance was first documented for annual ryegrass (*Lolium rigidum*) in 1996 in Victoria. Since then glyphosate resistance has been confirmed in 11 other weed species. Resistance is known in eight grass species and four broadleaf species. There are four winter-growing weed species and eight summer-growing weed species. The latter have been selected mainly in chemical fallows and on roadsides (Photo 9).



Photo 9: *Winter fallow showing an early glyphosate resistant sowthistle infestation.* Photo: A Storrie. Source: <u>GSWG</u>

All of the glyphosate resistant weed populations have occurred in situations where there has been intensive use of glyphosate, often over 15 years or more, few or no other effective herbicides used and few other weed control practices are used. This suggests that the following are the main risk factors for the evolution of glyphosate resistance:

- Intensive use of glyphosate—every year or multiple times a year for 15 years or more.
- Heavy reliance on glyphosate for weed control.
- No other weed controls targeted to stop seed set.

i) MORE INFORMATION

Australian glyphosate resistance register.

Strategic risk management factsheet

Farm business management factsheet

RIM model









WATCH: <u>Act now: Plan your weed</u> <u>management program.</u>









Farming practices in chemical fallows are heavily dependent on glyphosate for weed control. Therefore, it is highly likely that unconfirmed populations of glyphosate resistant summer and winter weeds are present in this system.

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Farming practices under the vines in vineyards across Australia are heavily dependent on glyphosate for weed control. Therefore, it is highly likely that unconfirmed populations of glyphosate resistant annual ryegrass are present in this system.

These unconfirmed glyphosate-resistant populations are not recorded on the register of glyphosate resistant populations in Australia. ³⁸

The <u>online glyphosate resistance toolkit</u> enables growers and advisors to assess their level of risk for developing glyphosate-resistant weeds on their farm.

6.6.2 10-point plan to weed out herbicide resistance

Act now to stop weed seed set.

1.

Creating a plan of action is an important first step of integrated weed management. A little bit of planning goes a long way.

- Destroy or capture weed seeds.
- Understand the biology of the weeds present.
- Remember that every successful WeedSmart practice can reduce the weed seedbank over time.
- Be strategic and committed—herbicide resistance management is not a oneyear decision.
- Research and plan your WeedSmart strategy.
- You may have to sacrifice yield in the short term to manage resistance be proactive.

A couple of areas to consider include:

- Understanding the biology of your weeds
- Being consistent—every successful WeedSmart practice can reduce the weed seed bank over time
- Being strategic and committed—herbicide resistance management is not a oneyear decision
- Being proactive—you may have to sacrifice yield in the short term to manage resistance
- 1. Capture weed seeds at harvest.

Destroying or capturing weed seeds at harvest is the number one strategy for combating herbicide resistance and driving down the weed seed bank.

Tow a chaff cart behind the header.

Check out the new Harrington Seed Destructor. (Photo 10)

Create and burn narrow windrows.

Produce hay where suitable.

Funnel seed onto tramlines in controlled traffic farming (CTF) systems.

Use a green or brown manure crop to achieve 100% weed control and build soil nitrogen levels.

Controlling weed seeds at harvest is emerging as the key to managing the increasing levels of herbicide resistance, which are putting Australia's no-till farming system at risk.



³⁸ C Preston. The Australian Glyphosate Sustainability Working Group, http://www.glyphosateresistance.org.au







WATCH: <u>The art of narrow windrow</u> <u>burning.</u>



WATCH: <u>Chaff funneling onto</u> <u>tramlines.</u>



WATCH: <u>Capture weed seeds at</u> harvest: Bale Direct System.



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Photo 10: Harrington weed seed destructor at work in the paddock. Source: <u>GRDC</u>

For information on harvest weed seed control and its application, see <u>Section</u> <u>12: Harvest</u>.

3. Rotate crops and herbicide modes of action.

Crop rotation is great for farming systems! Make sure weed management is part of the decision when planning crop rotation.



<u>Crop rotation</u> offers many opportunities to use different weed control tactics, both herbicide and non-herbicide, against different weeds at different times.

Rotating crops also gives us a range of intervention opportunities. For example, we can crop top lupins/pulses, swath canola, and delay sowing some crops (like field peas).

Rotations that include both broadleaf crops, like pulses and oilseeds, and cereals allow the use of a wider range of tactics and chemistry.

Growers also have the option of rotating to non-crop, e.g. pastures and fallows.

Within the rotation it is also <u>important to not repeatedly use herbicides from the same</u> <u>mode of action (MOA) group.</u> Some crops have less registered herbicide options than others so this needs to be considered too, along with the opportunities to use other tactics in place of one or more herbicide applications, such as harvest weed seed control.

Repeated use of herbicides with the same MOA is the single greatest risk factor for herbicide resistance evolution.




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WATCH: <u>Crop rotation with Colin</u> McAlpine.



WATCH: <u>Test for resistance to</u> <u>establish a clear picture of paddock-</u> <u>by-paddock farm status.</u>



WATCH: <u>IWM: Resistance Testing</u> <u>– Quick test sample collection.</u>



WATCH: IWM: Seed test – What's involved.

WEED SEED BANK DESTRUCTION



- 4. Test for resistance to establish a clear picture of paddock-by-paddock farm status.
- Sample weed seeds prior to harvest for resistance testing to determine effective herbicide options.

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- Use the "Quick Test" option to test emerged ryegrass plants after sowing to determine effective herbicide options before applying in-crop selective herbicides.
- Collaborate with researchers by collecting weeds for surveys during the doubleknock program.

Visit WeedSmart for more information on herbicide-resistance survey results.

It is clearly too late to prevent resistance evolution for many of our common herbicides. However, a resistance test when something new is observed on-farm can be very useful in developing a plan to contain the problem, and in developing new strategies to prevent this resistance evolving further.

Perhaps the best use for herbicide resistance tests is to use them in a game changing situation such as the discovery of a rare resistance gene (e.g. glyphosate resistance) or to determine if a patch of surviving weeds are any worse than what the grower has observed before. This bad patch of weeds gives insight into the future resistance profile of the farm if it is not contained and resistance testing in these situations can be very useful in building preventative strategies.

5. Never cut the rate.

AHRI researcher Dr. Roberto Busi found that ryegrass receiving below the rate Sakura[®] evolved resistance not only to Sakura[®] but also to Boxer Gold[®] and Avadex[®].

Imagine developing these multiple resistant, monster weeds just because you cut the rate!

- Use best management practice in spray application.
- Consider selective weed sprayers such as WeedSeeker or WeedIt.
- 6. Don't automatically reach for glyphosate.

Glyphosate has long been regarded as the world's most important herbicide, so it's natural to reach for it at the first sign of weeds. But what if it didn't work anymore?

Resistance to this herbicide is shooting through the roof in some areas and this could be the first year we see it fail for growers all across Australia. Why? Too much reliance on one herbicide group gives the weeds opportunity to evolve resistance.

To preserve glyphosate as the wonder weed-killer we know and love we need to break the habit and stop automatically reaching for glyphosate. Introduce paraquat products when dealing with smaller weeds and for a long-term solution, farm with a very low seed bank.

- Use a diversified approach to weed management.
- Consider post-emergent herbicides where suitable.
- Consider strategic tillage.





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WATCH: <u>Don't automatically reach for</u> glyphosate.



WATCH: Manage spray drift.



WATCH: <u>Plant clean seed into clean</u> paddocks with clean borders.



WATCH: <u>Best results with double</u> <u>knock tactic.</u>



GRDC

7. Carefully manage spray events.

It's important to set up your spray gear to maximise the amount of herbicide applied directly to the target. This makes the spray application more cost effective by killing the maximum number of weeds possible and protects other crops and pastures from potential damage and/or contamination.

Spray technology has improved enormously in the last ten years making it far easier for growers to get herbicides where they need to be. Also, many herbicide labels specify the droplet spectrum to be used when applying the herbicide (so take the time to read the label beforehand).

As a general rule, medium to coarse droplet size combined with higher application volumes provides better coverage of the target. Using a pre-orifice nozzle slows droplet speed so they are less prone to bouncing off the target.

Using oil-based adjuvants with air-induction nozzles can reduce herbicide deposition by reducing the amount of air in the droplets. These droplets then fail to shatter when they hit the target, which increases droplet bounce.

- Stop resistant weeds from returning into the farming system.
- Focus on management of survivors in fallows.
- Where herbicide failures occur, do not let the weeds seed. Consider cutting for hay or silage, fallowing or brown manuring the paddock.
- Patch-spray areas of resistant weeds only if appropriate.
- 8. Plant clean seed into clean paddocks with clean borders.

Keep it clean! With herbicide resistance on the rise, planting clean seed into clean paddocks with clean borders has become a top priority.



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Controlling weeds is easiest before the crop is planted, so be sure to plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant ones.

Introducing systems that increase farm hygiene will also prevent new weed species and resistant weeds. These systems could include crop rotations, reducing weed burdens in paddocks or a harvest weed seed control such as the HSD or windrow burning.

Lastly, roadsides and fence lines are often a source of weed infestations. Weeds here set enormous amounts of seed because they have little competition, so it's important to control these initial populations by keeping clean borders.

- It is easier to control weeds before the crop is planted.
- Plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant weeds.
- A recent Australian Herbicide Resistance Initiative (AHRI) survey showed that 73% of grower-saved crop seed was contaminated with weed seed.
- The density, diversity and fecundity of weeds are generally greatest along paddock borders and areas such as roadsides, channel banks and fence lines.





VIDEOS

WATCH: <u>Double knock application – a</u> Grower's Experience.





WATCH: Spray application of herbicides – Double Knock.

SPRAY APPLICATION OF HERBICIDES



WATCH: <u>Double knock applications -</u> target weed species & application <u>strategy</u>



(i) MORE INFORMATION

CropLife Australia

Australian Glyphosate Sustainability Working Group

Australian Herbicide Resistance Initiative

Cotton Catchment Communities CRC (Weedpak)

9. Use the double-knock technique.

What's better than an attack on weeds? A second one. Come at them with a different strategy and any survivors left over don't stand a chance, that's the beauty of the double-knock.



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To use the double-knock technique, combine two weed control tactics with different modes of action, on a single flush of weeds. These two "knocks" happen in sequential strategies; the second application designed to control any survivors from the first.

One such strategy is the glyphosate/paraquat double-knock. These two herbicides use different MOAs to eliminate weeds and so make an effective team when paired up. When using this combination ensure the paraquat rate is high.

The best time to initiate a glyphosate/paraquat double-knock is after rainfall. New weeds will quickly begin to germinate and should be tackled at this small stage.

10. Employ crop competitiveness to combat weeds.

Help your crops win the war against weeds by increasing their competitiveness against them:

- Consider <u>narrow row spacing</u> and <u>seeding rates.</u>
- Consider twin-row seeding points.
- Consider east-west crop orientation.
- Use barley and varieties that tiller well.
- Use high-density pastures as a rotation option.
- Consider brown manure crops.
- Rethink bare fallows.

If you think you have resistant weeds

When resistance is first suspected, it is recommended that growers contact their local agronomist.

The following steps are then recommended.

Consider the possibility of other common causes of herbicide failure by asking:

- 1. Was the herbicide applied in conditions and at a rate that should kill the target weed?
- 2. Did the suspect plants miss herbicide contact or emerge after the herbicide application?
- 3. Does the pattern of surviving plants suggest a spray miss or other application problem?
- 4. Has the same herbicide or herbicides with the same mode of action been used in the same field or in the general area for several years?
- 5. Has the uncontrolled species been successfully controlled in the past by the herbicide in question or by the current treatment?
- 6. Has a decline in the control been noticed in recent years?

7. Is the level of weed control generally good on the other susceptible species?

If resistance is still suspected:

- 1. Contact crop and food science researchers via the <u>Customer Service Centre</u> for advice on sampling suspect plants for testing of resistance status.
- 2. Ensure all suspect plants do not set any seed.









WATCH: <u>Learn to think outside the</u> <u>drum.</u>



WATCH: <u>Crop Competition –</u> increasing wheat seeding rate.



WATCH: <u>Crop competition—Row</u> <u>Spacing.</u>



 If resistance is confirmed, develop a management plan for future years to reduce the impact of resistance and likelihood of further spread. ³⁹

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Testing services

For testing of suspected resistant samples, contact:

Charles Sturt University Herbicide Resistance Testing School of Agricultural and Wine Sciences Charles Sturt University Locked Bag 588 Wagga Wagga, NSW 2678 02 6933 4001 http://www.csu.edu.au/weedresearchgroup/herbicide-resistance CSU plant testing application form.

Plant Science Consulting P/L 22 Linley Avenue, Prospect SA 5082, Australia info@plantscienceconsulting.com.au Phone: 0400 66 44 60

6.7 Monitoring weeds

Monitoring of weed populations before and after any spraying is an important part of management.

- Keep accurate records.
- Monitor weed populations and record results of herbicide used.
- If herbicide resistance is suspected, prevent weed seed-set.
- If a herbicide does not work, find out why.
- Check that weed survival is not due to spraying error.
- Conduct your own paddock tests to confirm herbicide failure and determine which herbicides remain effective.
- Obtain a herbicide-resistance test on seed from suspected plants, testing for resistance to other herbicide (MOA) groups.
- Do not introduce or spread resistant weeds in contaminated grain or hay.

Regular monitoring is required to assess the effectiveness of weed management and the expected situation following weed removal or suppression. Without monitoring, we cannot assess the effectiveness of a management program or determine how it might be modified for improved results. Effective weed management begins with monitoring weeds to assess current or potential threats to crop production, and to determine best methods and timing for control measures.

Regular monitoring and recording details of each paddock allows the grower to:

- spot critical stages of crop and weed development for timely cultivation or other intervention;
- identify the weed flora (species composition), which helps to determine best short- and long-term management strategies; and
- detect new invasive or aggressive weed species while the infestation is still localized and able to be eradicated.

Watch for critical aspects of the weed-crop interaction, such as:

- Weed seed germination and seedling emergence.
- Weed growth sufficient to affect crops if left unchecked.
- Weed density, height, and cover relative to crop height, cover, and stage of growth;



³⁹ QLD DAFF (2015) Stopping herbicide resistance in Queensland, <u>https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops/herbicide-resistance</u>



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 Weed impacts on crops, including harbouring pests, pathogens, or beneficial organisms; or modifying microclimate, air circulation, or soil conditions; as well as direct competition for light, nutrients, and moisture.

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- Flowering, seed-set, or vegetative reproduction in weeds.
- Efficacy of cultivations and other weed management practices.

Information gathered through regular and timely field monitoring helps growers to select the best tools and timing for weed-control tactics. Missing vital cues in weed and crop development can lead to costly efforts to rescue a crop, efforts that may not be fully effective. Good paddock scouting can help the grower to obtain the most effective weed control for the least fuel use, labour cost, chemical application, crop damage and soil disturbance.

6.7.1 Tips for monitoring

To scout weeds, walk slowly through the paddock, examining any vegetation that was not planted. In larger paddocks, walk back and forth in a zigzag pattern to view all parts of the paddock, noting areas of particularly high or low weed infestation. Identify weeds with the help of a good weed guide or identification key for your region, and note the weed species that are most prominent or abundant. Observe how each major weed is distributed through the paddock. Are the weeds randomly scattered, clumped or concentrated in one part of the paddock?

Keep records in a field notebook. Prepare a page for each paddock or crop sown, and take simple notes of weed observations each time the paddock is monitored. Over time, your notes become a timeline of changes in the weed flora over the seasons and in response to crop rotations, cover crops, cultivations and other weed control practices. Many growers already maintain separate records for each paddock; weed observations (species, numbers, distribution, size) can be included with these.





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Key messages:

- Regular occurrences of insects are not a major factor for oat crops, however significant damage can occur if insect populations build up; such as armyworm, aphids or mites.
- Planning rotations to minimise pest carryover, timely sowing, adequate crop nutrition and good control of weed and root diseases will all assist in reducing the likelihood of crop attack by insect pests.
- Check crops regularly throughout their growth for field insects. There is zero tolerance to insects in export hay.
- Control redlegged earth mite and lucerne flea during the seedling stage if necessary.
- Aphids should be checked for and controlled in crops considered to be high yielding. Aphids can also transmit Barley Yellow Dwarf Virus (BYDV) particularly in early sown crops.
- If growing susceptible varieties in areas with moderate-to-high BYDV risk then treating seed with imidacloprid is recommended. Spraying the crop with a synthetic pyrethroid at 5–6 weeks after sowing may also be required if mild autumn/winter conditions/aphids are still present.





Correctly identifying the insect is critical for their successful management.¹

7.1 Integrated Pest Management

Pests are best managed by using an integrated pest management (IPM) approach. Careful planning prior to sowing, followed by regular monitoring of crops after sowing, will ensure that potential problems are identified and, if necessary, treated early.

The IPM approach uses a range of management tactics to keep pest numbers below the level where they cause economic damage. It focuses on natural regulation of pests, particularly by encouraging natural enemies, and on using broad-spectrum chemicals only as a last resort. IPM relies on monitoring the crop regularly, having pests and beneficial insects correctly identified, and making strategic control decisions according to established damage thresholds.

IPM uses a combination of biological, cultural and chemical control methods to reduce insect pest populations. A key aim of IPM is to reduce reliance on insecticides as the sole and primary means of pest control. IPM can improve growers' profitability while reducing environmental damage and limiting the risk of on-farm pesticide exposure.

Key IPM strategies

- Where the risk of establishment pest incidence is low (e.g. earth mites), regular monitoring can be substituted for the prophylactic use of seed dressings.
- Where establishment pests and aphid infestations are clearly a result of invasion from weed hosts around the field edges or neighbouring pasture, a border spray of the affected crop may be sufficient to control the infestation.

Insecticide choices

- Redlegged earth mite (RLEM), blue oat mite (BOM), and other mite species can occur in mixed populations. Determine species composition before making decisions as they have different susceptibilities to chemicals (Table 1). Ensure to consider pesticide withholding periods when planning treatments (Table 2).
- Establishment pests have differing susceptibilities to insecticides (synthetic pyrethroids and organophosphates in particular). Be aware that the use of some pesticides may select for pests that are more tolerant.

Stay up to date with registered chemical treatments and ensure to consider the withholding periods they incur. This is now important in milling oats. All growers are required to complete a Vendor Declaration and as authorities will check the withholding period accompanying the chemicals growers use.

Agronomist's view

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Table 1: Registered insecticides for winter spring cereal pests 2015 (Chemical active ingredient names are listed. Rates are given as millilitres per hectare (mL/ ha) unless specified otherwise. g/L refers to grams per litre. g/ha refers to grams per hectare. N/A refers to Not applicable).

N	Aphids	Armyworm
Alpha-cypermethrin 100 g/L	BYDV only	160–240
Alpha-cypermethrin 250 g/L	BYDV only	96
Chlorpyrifos 500 g/L	N/A	700–900
Cypermethrin 200 g/L	N/A	170

G Troup (2016) Oats: insect pests. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-insect-pests</u>





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N	Aphids	Armyworm
Cypermethrin 250 g/L	N/A	135
Cypermethrin 260 g/L	N/A	130
Deltamethrin 27.5 g/L	N/A	500
Dimethoate 400 g/L	500+++	N/A
Esfenvalerate 50 g/L	BYDV only	N/A
Gamma-cyhalothrin 150 g/L	BYDV only	N/A
Lambda-cyhalothrin 250 g/L	BYDV only	N/A
Methidathion 400 g/L	N/A	1400
Sulfoxaflor 240 g/L	50–100*g/ha	N/A
Sulfoxaflor 500 g/kg	24–48*g/ha	N/A
Trichlorfon 500 g/L	N/A	1200
Pirimicarb 500 g/kg (pest specific)	150–300 g/ha	N/A

Dose rates with three plus symbols (+++) indicate 300–500 mL/ha of dimethoate may be used up to early tillering. Trial results show that 800 mL/ha may be required in advanced high yielding crop. Dose rates with an asterisk (1) indicate the chemical can only be applied up to flag leaf stage. References to 'BYDV only' in the table means the chemical can only be applied for the control of cereal aphids in autumn for barley yellow dwarf virus disease (BYDV). Source: <u>DAFWA</u>.

Table 2:	Withholding	period after	application	for common	chemicals.

Active ingredient	Crops not to be harvested for:	No grazing or cutting as stock fodder for:
Insecticides/miticides		
Abamectin	20 days	20 days
Acetamiprid	10 days	Do not graze or cut for stock fodder.
Alphamethrin	14 days	not stated
Alpha-cypermethrin	14 days	not stated
Amitraz	21 days	not stated
Amorphous silica	0	0
Bacillus thuringiensis	0	0
Bifenthrin	14 days	Do not allow livestock to graze crops, stubble or gin trash
Beta-cyfluthrin	28 days	not stated
Chlorantraniliprole	28 days	Do not allow livestock to graze crops, stubble or gin trash
Chlorfenapyr	28 days	Do not graze or cut for fodder
Chlorpyrifos-methyl	28 days	Do not graze crop or stubble
Clothianidin	5 days	Do not allow livestock to graze crops, stubble or gin trash
Cypermethrin	14 days	not stated
Deltamethrin	7 days	not stated
Dicofol	7 days	Do not graze or cut for fodder
Diafenthiuron	14 days	Do not feed treated cotton fodder or cotton trash to livestock.





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	A	
Active ingredient	Crops not to be harvested for:	No grazing or cutting as stock fodder for:
Dimethoate	14 days	Do not graze or cut for stock food for 14 days after application. (Per13155)
Disulfoton	70 days	70 days
Emamectin benzoate	28 days	Do not harvest, graze or cut for stock for 4 weeks after application. Do not feed trash to animals including poultry.
Esfenvalerate	7 days	not stated
Ethion + Zeta- cypermethrin	28 days	Not stated
Etoxazole	21 days	Do not graze treated area or cut treated area for stock feed
Fipronil	28 days	Do not graze or cut for fodder
Gamma-cyhaldthrin	21 days	See label for the Export Slaugher Interval (ESI).
Imidacloprid	91 days	Do not allow livestock to graze crops, stubble or gin trash
Indoxacarb	28 days	Do not allow livestock to graze crops, stubble or gin trash
Lambda-cyhalothrin	21 days	not stated
Magnet(R)	Insecticide WHP + 7 days	Insecticide WHP + 7 days
Methidathion	3 days	not stated
Methomyl	0	Do not graze or feed crop to animals
Methoxyfenoziole	28 days	Do not graze or cut for fodder
NPV	0	0
Omethoate	21 days	not stated
Paraffinic oil	1 day	not stated
Parathion	14 days	Do not graze or cut for fodder
Pirimicarb	21 days	21 days
Phorate	70 days	70 days
Profenofos	28 days	not stated
Propargite	28 days	Do not graze or cut for fodder
Pymetrozine	28 days	Do not graze crop stubble or gin trash
Pyriproxyfen	28 days	Do not graze on or cut for stock feed. Do not feed treated cotton trash to livestock
Spinosad	28 days	Do not graze or cut for fodder
Spirotetramat	21	Do not feed cotton fodder, stubble or trash to livestock.
Thiamethoxam	28 days	Do not graze or feed cotton trash to stock
Thiodicarb	21 days	21 days





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WATCH : <u>Integrated Pest</u> Management.



Insecticide resistance

- RLEM has been found to have high levels of resistance to synthetic pyrethroidssuch as bifenthrin and alpha-cypermethrin.
- Helicoverpa armigera has historically had high resistance to pyrethroids and the inclusion of NPV is effective where mixed populations of armyworm and helicoverpa occur in maturing winter cereals.²

7.1.1 Insect sampling methods

Monitoring for insects is an essential part of successful integrated pest management programs. Correct identification of immature and adult stages of both pests and beneficials, and accurate assessment of their presence in the field at various crop stages, will ensure appropriate and timely management decisions. Good monitoring procedure involves not just a knowledge of and the ability to identify the insects present, but also good sampling and recording techniques and a healthy dose of common sense.

Factors that contribute to quality monitoring

- Knowledge of likely pests/beneficials and their life cycles is essential when planning your monitorng 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 a representative portion of the crop has been monitored since pest activity is often patchy. Having defined sampling parameters (e.g. number of samples per paddock and number of leaves per sample) helps sampling consistency. 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 regarding time constraints and distance covered.
- Balancing random sampling with areas of obvious damage is a matter of common sense. Random sampling aims to give a good overall picture of what is happening in the 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.

Keeping good records

Accurately recording the results of sampling is critical for good decision making and being able to review the success of control measures (Figure 1). Monitoring record sheets should show the following:

- numbers and types of insects found (including details of adults and immature stages);
- size of insects—this is particularly important for larvae;
- date and time; and
- 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 photographs for later reference.





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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	6
3	3	ß	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)	22-4		
Mean estimate of larval number (Adjusted S)+M+L	0.6=3.2			
Adjust for row spacing divide by row spacing (m) $\frac{3.2}{0.75}$	4.2	Density E per squar	stimate e metre	

Figure 1: An example of a field check sheet for chickpeas, showing adjustments for field mortality and row spacings.

Source: DAFF

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; and
- any other relevant details.

Sampling methods

Beat sheet

A beat sheet is the main tool used to sample row crops for pests and beneficial insects (Photo 1). 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 between 1.3–1.5 m wide by 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.

How to use the beat sheet:

- Place the beat sheet with 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.
- Using a one-metre 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 nonconsecutive one-metre long lengths of row, taken within a 20 m radius, i.e. 5 beats = 1 sample unit. This should be repeated at six locations in the field (i.e. 30 beats per field).



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The more samples that are taken, the more accurate is the assessment of pest activity, particularly for pests that are patchily distributed such as pod sucking bug nymphs.

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When to use the beat sheet:

- 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 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/m²). Hence, insect counts in crops with row spacing less than one metre must be converted to pests/m². To do this, divide the "average insect count per row metre" across all sites by the row spacing in metres.

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 going in terms of average growth stage 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 (Photo 1). It is also useful if the field is wet. Sweep netting works best for smaller pests found in the tops of smaller crops (e.g. mirids in mungbeans), is less efficient against larger pests such as pod-sucking bugs, and is not practical in tall crops with a dense canopy. At least 20 sweeps must be taken along a single 20 m row.
- Suction sampling is a quick and relatively easy way to sample for mirids. Its main drawbacks are unacceptably low sampling efficiency, a propensity to suck up flowers and bees, noisy operation, and 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.³



IPM Guidelines website.

IPM Guidelines for Monitoring tools and techniques.



³ DAFF (2012) Insect monitoring techniques for field crops, <u>https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/insect-monitoring</u>





WATCH: <u>GCTV16: Extension files</u>— IPM Beatsheet Demo.



WATCH : <u>How to use a sweep net to</u> sample for insect pests.



WATCH : GRDC's Insect ID App.



WATCH : <u>Biopesticides emerge as an</u> <u>alternative cropping tool.</u>





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Photo 1: Sweep-netting for insects (left) and use of a beatsheet (right). Source: DAFWA and The Beatsheet

The South Australian Research and Development Institute (SARDI) Entomology Unit provides an insect identification and advisory service. The unit identifies insects to the highest taxonomic level for species where this is possible and can also give farmers biological information and guidelines for control.⁴

Insect ID: The Ute Guide



The Insect ID Ute Guide is a comprehensive reference guide for insect pests commonly affecting broadacre crops across Australia, and includes the beneficial insects that may help to control them. Photos have been provided for multiple lifecycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored and other pests that they may be confused with. Use of this app should result in better management of pests, increased farm profitability and improved chemical usage. ⁵

App features:

- Region selection.
- Predictive search by common and scientific names.
- Compare photos of insects side by side with insects in the app.
- Identify beneficial predators and parasites of insect pests.
- Opt to download content updates in-app to ensure you are aware of the latest pests affecting crops for each region.
- Ensure awareness of international bio-security pests.

Insect ID, The Ute Guide is available on Android and iPhone.



⁴ PIR SA (2015) Insect Diagnostic Service, Primary Industries and Regions SA, <u>http://pir.sa.gov.au/research/research_specialties/</u> sustainable_systems/entomology/insect_diagnostic_service

⁵ GRDC, https://grdc.com.au/Resources/Apps



7.2 Blue Oat Mite (Penthaleus spp.)

Blue oat mites (BOM) (*Penthaleus spp.*) are species of earth mites which are major agricultural pests of southern Australia and other parts of the world, attacking various pasture, vegetable and crop plants. BOM were introduced from Europe and first recorded in New South Wales in 1921. Management of these mites in Australia has been complicated by the recent discovery of three distinct species of BOM, whereas prior research had assumed just a single species.

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Adult BOM are 1 mm in length and approximately 0.7–0.8 mm wide, with 8 red-orange legs. They have a blue-black-coloured body with a characteristic red mark on their back (Photo 2). Larvae are approximately 0.3 mm long, are oval in shape and have three pairs of legs. On hatching, BOM are pink-orange in colour, soon becoming brownish and then green.



Photo 2: Blue Oat Mite. Notice that adults have a red mark on their back.

BOM are often misidentified as redlegged earth mites (RLEM) in the field, which has meant that the damage caused by BOM has been under-represented. Despite having a similar appearance, RLEM and BOM can be readily distinguished from each other. RLEM have a completely black-coloured body and tend to feed in larger groups of up to 30 individuals. BOM have the red mark on their back and are usually found singularly or in very small groups. The distribution of BOM is likely to be limited by the environmental conditions needed to successfully enter and complete the oversummering phase (known as diapause), as well as conditions needed for emergence to coincide with the growth of winter pastures and crops.

BOM are widespread throughout most agricultural regions of Australia with a Mediterranean-type climate. BOM are one of the most important pest mites in cropping and pastoral areas of Victoria, Tasmania and New South Wales. They are also a pest in the south-east of South Australia, southern Queensland and the southwest of Western Australia (Figure 2). Recent surveys have shown an expansion of the range of BOM in Australia over the last 30 years.







Figure 2: The distribution of blue oat mites in Australia (shaded areas indicate known distribution).

Source: <u>AgVic</u>

During winter, individual adult BOM move between plants over distances of several metres. Long-range dispersal is thought to occur via movement of eggs carried on soil adhering to livestock and farm machinery, and through the transportation of plant material. Movement also occurs during summer when diapause eggs are blown by winds. BOM are active in the cool wet part of the year, usually between April and late October. Eggs hatch in autumn following cool temperatures and adequate rainfall, when conditions are optimal for mite survival. Swarms of mites may then attack emerging crop and pasture seedlings. ⁶

7.2.1 Damage caused by BOM

BOM spend the majority of their time on the soil surface, rather than on the foliage of plants. They are most active during the cooler parts of the day, tending to feed in the mornings and in cloudy weather. They seek protection during the warmer part of the day on moist soil surfaces or under foliage, and may even dig into the soil under extreme conditions.

P. major primarily feeds on oats and thick-bladed grasses within pastures and *P. tectus* prefers cereals. These preferences can be used as an indication of the species present in a particular paddock; however confirmation by an expert is recommended.

Typical mite damage appears as 'silvering' or 'whitening' of the attacked foliage. Mites use adapted mouthparts to lacerate the leaf tissue of plants and suck up the discharged sap. Resulting cell and cuticle destruction promotes desiccation, retards photosynthesis and produces the characteristic silvering that is often mistaken as



⁶ Agriculture Victoria (2007) Blue oat mite. Ag note AG1300 July 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/</u> pest-insects-and-mites/blue-oat-mite



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frost damage (Photo 3). BOM are most damaging to newly establishing pastures and emerging crops, greatly reducing seedling survival and retarding development.

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Young mites prefer to feed on the sheath leaves or tender shoots near the soil surface, while adults feed on more mature plant tissues. BOM feeding reduces the productivity of established plants and is directly responsible for reductions in pasture palatability to livestock. Even in established pastures, damage from large infestations may significantly affect productivity.

The impact of mite damage is increased when plants are under stress from adverse conditions such as prolonged dry weather or waterlogged soils. Ideal growing conditions for seedlings enable plants to tolerate higher numbers of mites.⁷



Photo 3: Silver or white discolouration of leaves caused by Blue Oat Mite. Source: <u>GRDC</u>

7.2.2 Management of BOM

There are three pest species of BOM in Australia, which complicates control. These species differ in their distribution, pesticide tolerance and crop plant preferences. Despite these differences, all BOM species are often treated identically in terms of control. This is a concern as eradication of one species may result in another BOM species becoming relatively more abundant. Unlike many agricultural pests in Australia, BOM reproduce asexually. This mode of reproduction results in populations made up of female 'clones' that can respond differently to environmental and chemical conditions. This may influence the likelihood of populations developing resistance and means BOM populations could respond differently to control strategies.

Monitoring

Check paddocks prior to sowing in autumn and throughout winter. Carefully inspect susceptible pastures and crops from autumn to spring for the presence of mites and evidence of damage. It is especially important to inspect crops regularly in the first three to five weeks after sowing. Mites are best detected feeding on the leaves in the morning or on overcast days. Examine plants for damage and search for mites on leaves and on the ground, especially in late-sown crops. Distinguishing between the BOM species in the field is difficult because a microscope is needed to see the morphological traits that separate each species. Preliminary work has started on developing a rapid and simple paddock test to determine the mite species present in individual properties. ⁸



⁷ Agriculture Victoria (2007) Blue oat mite. Ag note AG1300 July 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite</u>

⁸ Agriculture Victoria (2007) Blue oat mite. Ag note AG1300 July 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite</u>



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Chemicals are the most common method of control against earth mites. Unfortunately, all currently registered pesticides are only effective against the active stages of mites; they do not kill mite eggs.

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While a number of chemicals are registered in pastures and crops, differences in tolerance levels between species complicate management of BOM. *P. falcatus* has a high natural tolerance to a range of pesticides registered against earth mites in Australia and is responsible for many control failures involving earth mites. The other BOM species have a lower level of tolerance to pesticides and are generally easier to control with chemicals in the field.

Chemical sprays are commonly applied at the time of infestation, when mites are at high levels and crops already show signs of damage. Control of first generation mites before they can lay eggs is an effective way to avoid a second spray. Hence, pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, as adults will then begin laying eggs. While spraying pesticides in spring can greatly reduce the size of RLEM populations the following autumn, this strategy will generally not be as effective for the control of BOM.

Pesticides with persistent residual effects can be used as bare-earth treatments. These treatments can be applied prior to or at sowing to kill emerging mites and protect the plants throughout their seedling stage.

Systemic pesticides are often applied as seed dressings to maintain the pesticide at toxic levels within the plants as they grow. This can help minimise damage to plants during the sensitive establishment phase; however, if mite numbers are high, significant damage may still occur before the pesticide has much effect.

To prevent the build-up of resistant populations, spray pesticides only when necessary and rotate pesticides from chemical classes with different modes of action. To avoid developing multiple pesticide resistance, rotate chemical classes across generations rather than within a generation.

Information on the registration status, rates of application and warnings related to withholding periods, OH&S, residues and off-target effects should be obtained before making decisions on which pesticide to use. This information is available from the Department of Environment and Primary Industries (DEPI) Chemical Standards Branch, chemical resellers, Australian Pesticides and Veterinary Medicines Authority (APVMA) and the pesticide manufacturer. Always consult the label and Material Safety Data Sheets (MSDS) before using any pesticide. ⁹

Biological and cultural control

Integrated pest management programs can complement current chemical control methods by introducing non-chemical options, such as cultural and biological control.

Although no systematic survey has been conducted, a number of predator species are known to attack earth mites in Australia. The most important predators of BOM appear to be other mites, although small beetles, spiders and ants may also play a role. The French anystis mite is an effective predator but is limited in distribution. Snout mites will also prey upon BOM, particularly in pastures. The fungal pathogen, Neozygites acaracida, is prevalent in BOM populations during wet winters and could be responsible for observed 'population crashes'.

Preserving natural enemies when using chemicals is often difficult because the pesticides generally used are broad-spectrum and kill beneficial species as well as the pests. Impact on natural enemies can be reduced by using a pesticide that has the least impact and by minimising the number of applications. Although there are few registered alternatives for BOM control, there are groups such as the chloronicotinyls, which are used in some seed treatments, that have low to moderate impacts on many natural enemies.



⁹ Agriculture Victoria (2007) Blue oat mite. Ag note AG1300 July 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/</u> pest-insects-and-mites/blue-oat-mite



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Cultural controls such as rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival, decreasing the need for chemical control. When *P. major* is the predominant species, canola and lentils are potentially useful rotation crops, while pastures containing predominantly thick-bladed grasses should be carefully monitored and rotated with other crops. In situations where *P. falcatus* is the most abundant mite species, farmers can consider rotating crops with lentils, while rotations that involve canola may be the most effective means of reducing the impact of *P. tectus*.

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Many cultural control methods for BOM can also suppress other mite pests, such as RLEM. Cultivation will significantly decrease the number of over-summering eggs, while hot stubble burns can provide a similar effect. Many broad-leaved weeds provide an alternative food source, particularly for juvenile stages. As such, clean fallowing and the control of weeds within crops and around pasture perimeters, especially of bristly oxtongue and cat's ear, can help reduce BOM numbers.

Appropriate grazing management can also reduce mite populations to below damaging thresholds. This may be because shorter pasture results in lower relative humidity, which increases mite mortality and limits food resources. Grazing pastures in spring to less than 2 t/ha Feed On Offer (dry weight), can reduce mite numbers to low levels and provide some level of control the following year.¹⁰

7.3 Redlegged earth mite

The redlegged earth mite (RLEM) (*Halotydeus destructor*) is a major pest of pastures, crops and vegetables in regions of Australia with cool wet winters and hot dry summers. The RLEM was accidentally introduced into Australia from the Cape region of South Africa in the early 1900s. These mites are commonly controlled using pesticides; however, non-chemical options are becoming increasingly important due to evidence of resistance and concern about long-term sustainability.

Adult RLEM are 1 mm in length and 0.6 mm wide (the size of a pinhead) with 8 red-orange legs and a completely black velvety body (Photo 4). Newly hatched mites are pinkish-orange with 6 legs, only 0.2 mm long and not generally visible to the untrained eye. The larval stage is followed by three nymphal stages in which the mites have 8 legs and resemble the adult mite, but are smaller and sexually undeveloped. ¹¹



Photo 4: Redlegged earth mite (Halotydeus destructor).

Other mite pests, in particular blue oat mites and the Balaustium mite, are sometimes confused with RLEM in the field. Blue oat mites can be distinguished from RLEM by an oval orange/reddish mark on their back, while the Balaustium mite has short hairs covering its body and can grow to twice the adult size of RLEM. Unlike other species that tend to feed singularly, RLEM generally feed in large groups of up to 30 individuals.

RLEM are widespread throughout most agricultural regions of southern Australia. They are found in southern NSW, on the east coast of Tasmania, the south-east of



¹⁰ Agriculture Victoria (2007) Blue oat mite. Ag note AG1300 July 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite</u>

¹¹ Agriculture Victoria (2007) Redlegged earth mite. Ag Note AG1404 January 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-</u> diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite



SA, the south-west of WA and throughout Victoria (Figure 3). Genetic studies have found high levels of gene flow and migration within Australia. Although individual adult RLEM only move short distances between plants in winter, recent surveys have shown an expansion of the range of RLEM in Australia over the last 30 years. Long-range dispersal is thought to occur via the movement of eggs in soil adhering to livestock and farm machinery or through the transportation of plant material. Movement also occurs during summer when over-summering eggs are transported by wind. ¹²

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Figure 3: Distribution of Redlegged earth mite indicated by shaded area.

7.3.1 Conditions favouring development

Earth mites are active in the cool, wet part of the year, usually between April and November. During this winter–spring period, RLEM may pass through three (sometimes only two) generations, with each generation surviving six to eight weeks. RLEM eggs hatch in autumn following exposure to cooler temperatures and adequate rainfall. It takes approximately two weeks of exposure to favourable conditions for over-summering eggs to hatch. This releases swarms of mites, which attack delicate crop seedlings and emerging pasture plants. Towards the end of spring, physiological changes in the plant, the hot dry weather and changes in light conditions combine to induce the production of over-summering or 'diapause eggs'.¹³

7.3.2 Damage caused by RLEM

The RLEM is called an earth mite because it spends 90% of its time on the soil surface, rather than on the foliage of plants. The mites feed on the foliage for short periods and then move around before settling at another feeding site. Other mites



¹² Agriculture Victoria (2007) Redlegged earth mite. Ag Note AG1404 January 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-</u> diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

¹³ Agriculture Victoria (2007) Redlegged earth mite. Ag Note AG1404 January 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite</u>



are attracted to volatile compounds released from the damaged leaves, which results in feeding aggregations.

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Typical mite damage appears as 'silvering' or 'whitening' of the attacked foliage. Mites use adapted mouthparts to lacerate the leaf tissue of plants and suck up the discharged sap. The resulting cell and cuticle damage promotes desiccation, retards photosynthesis and produces the characteristic silvering that is often mistaken as frost damage. RLEM are most damaging to newly establishing pastures and emerging crops, greatly reducing seedling survival and development. In severe cases, entire crops may need re-sowing following RLEM attack.¹⁴

7.3.3 Managing RLEM

Monitoring

Carefully inspect susceptible pastures and crops from autumn to spring for the presence of mites and evidence of damage. It is especially important to inspect crops regularly in the first three to five weeks after sowing. Mites are best detected feeding on the leaves in the morning or on overcast days. In the warmer part of the day RLEM tend to gather at the base of plants, sheltering in leaf sheaths and under debris. They will crawl into cracks in the ground to avoid heat and cold. When disturbed during feeding they will drop to the ground and seek shelter.

RLEM compete with other pasture pests, such as blue oat mites, for food and resources. Competition within and between mite species has been demonstrated in pastures and on a variety of crop types. This means control strategies that only target RLEM may not entirely remove pest pressure because other pests can fill the gap. This can be particularly evident after chemical applications, which are generally more effective against RLEM than other mite pests.

Chemical control

Chemicals are the most commonly used control option against earth mites. While a number of chemicals are registered for control of active RLEM in pastures and crops, there are no currently registered pesticides that are effective against RLEM eggs.

Autumn sprays:

Controlling first generation mites before they have a chance to lay eggs is the only effective way to avoid the need for a second spray. Hence, pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, before adults begin to lay eggs. Timing of chemical application is critical.

- 1. Pesticides with persistent residual activity can be used as bare-earth treatments, either pre-sowing or at sowing to kill emerging mites. This will protect seedlings which are most vulnerable to damage.
- 2. Foliage sprays are applied once the crop has emerged and are generally an effective method of control.
- 3. Systemic pesticides are often applied as seed dressings. Seed dressings act by maintaining the pesticide at toxic levels within the growing plant, which then affects mites as they feed. This strategy aims to minimise damage to plants during the sensitive establishment phase. However, if mite numbers are high, plants may suffer significant damage before the pesticide has much effect.

Spring sprays:

Research has shown that one accurately timed spring spray of an appropriate chemical can significantly reduce populations of RLEM the following autumn. This approach works by killing mites before they start producing diapause eggs in midlate spring. The optimum date can be predicted using climatic variables, and tools such as TIMERITE[®] can help farmers identify the optimum date for spraying. Spring RLEM sprays will generally not be effective against other pest mites.



¹⁴ Agriculture Victoria (2007) Redlegged earth mite. Ag Note AG1404 January 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite</u>



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Repeated successive use of the 'spring spray' technique is not recommended as this could lead to populations evolving resistance to the strategy. To prevent the development of resistance, the selective rotation of products with different modes of action is advised.

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Biological control

There is evidence of natural RLEM populations showing resistance to some chemicals; therefore, alternative management strategies are needed to complement current control methods.

At least 19 predators and one pathogen are known to attack earth mites in eastern Australia. The most important predators of RLEM appear to be other mites, although small beetles, spiders and ants also play a role in reducing populations. A predatory mite (Anystis wallacei) has been introduced as a means of biological control; however, it has slow dispersal and establishment rates. Although locally successful, the benefits of this mite are yet to be demonstrated.

Preserving natural enemies may prevent RLEM population explosions in established pastures but this is often difficult to achieve. This is mainly because the pesticides generally used to control RLEM are broad-spectrum and kill beneficial species as well as the pests. The chemical impact on predator species can be minimised by choosing a spray that has least impact and by reducing the number of chemical applications. Although there are few registered alternatives for RLEM, there are groups that have low-moderate impacts on many natural enemies such as cyclodienes.

Natural enemies residing in windbreaks and roadside vegetation have been demonstrated to suppress RLEM in adjacent pasture paddocks. When pesticides with residual activity are applied as border sprays to prevent mites moving into a crop or pasture, beneficial insect numbers may be inadvertently reduced, thereby protecting RLEM populations.

Cultural control

Using cultural control methods can decrease the need for chemical control. Rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival. For example, prior to planting a susceptible crop like canola, a paddock may be sown to cereals or lentils to help reduce the risk of RLEM population build-up. Cultivation can also help reduce RLEM populations by significantly decreasing the number of over-summering eggs. Hot stubble burns can provide a similar effect.

Clean fallowing and controlling weeds around crop and pasture perimeters can also act to reduce mite numbers. Control of weeds, especially thistles and capeweed, is important, as they provide important breeding sites for RLEM. Where paddocks have a history of damaging, high density RLEM populations, it is recommended that sowing pastures with a high-clover content be avoided.

Appropriate grazing management can reduce RLEM populations to below damaging thresholds, possibly because shorter pasture results in lower relative humidity, which increases mite mortality and limits food resources.

Other cultural techniques including modification of tillage practices, trap or border crops, and mixed cropping can reduce overall infestation levels to below the economic control threshold, particularly when employed in conjunction with other measures.

This note was prepared with the assistance of Michelle Pardy (DPI), Andrew Weeks (Centre for Environmental Stress and Adaptation Research) and the Grains Research and Development Corporation through the National Invertebrate Pest Initiative. ¹⁵



¹⁵ Agriculture Victoria (2007) Redlegged earth mite. Ag Note AG1404 January 2007, <u>http://agriculture.vic.gov.au/agriculture/pests-</u> diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite



7.4 Balaustium mite (Balaustium medicagoense)

The Balaustium mite, *Balaustium medicagoense* (Acari: Erythreidae), has recently been identified within the Australian grains industry as an emerging pest of winter crops and pasture. This mite is the only species of the genus *Balaustium* recorded in Australia and was probably introduced from South Africa, along with the redlegged earth mite (*Halotydeus destructor*), in the early 1900s. Balaustium mites are found throughout areas of southern Australia that have a Mediterranean-type climate, attacking a variety of agriculturally important plants.

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Balaustium mites are quite often confused with other pest mites, such as the redlegged earth mite and blue oat mite (*Penthaleus spp.*). They have a rounded dark red/brown-coloured body and red legs similar to other pest mites; however they have distinct short stout hairs covering their entire body giving them a velvety appearance (Photo 5). Adults reach about 2 mm in size, which is twice the size of other earth mite species. Balaustium mites also have distinct 'pad-like' structures on their front legs and move slower than redlegged earth mites and blue oat mites. ¹⁶



Photo 5: Balaustium mite.

Source: <u>Cesar</u>

Newly laid eggs of Balaustium mites are light maroon in colour, becoming darker prior to egg hatch. Larvae are bright orange in colour and have six pairs of legs. The larval stage is followed by a number of nymphal stages in which mites have eight legs and resemble adults, but are much smaller. The mites have a preference for grasses, cereals and weeds, particularly oats, barley, wheat, barley grass and capeweed.

Balaustium mites are widespread throughout most agricultural regions in southern Australia with a Mediterranean-type climate. They are found in Victoria, South Australia, New South Wales and Western Australia. They are generally restricted to coastal areas and do not occur too far inland or in the drier Mallee areas of Victoria and South Australia. Balaustium mites have been found in Tasmania; however there has been no systematic sampling conducted and the distribution across the state remains unknown (Figure 4).

Similar to other pest mites, long-range dispersal is thought to occur via the movement of eggs in soil adhering to livestock and farm machinery or through the transportation of plant material. Movement may also occur when over-summering eggs are moved by summer winds.¹⁷



¹⁶ A Arthur, P Umina (2010) Balaustium mite. Ag note AG1413 May 2010, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/balaustium-mite</u>

¹⁷ A Arthur, P Umina (2010) Balaustium mite. Ag note AG1413 May 2010, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/</u> pest-insects-and-mites/balaustium-mite





Figure 4: Distribution of Balaustium mite. Shaded areas indicate known distribution.

Source: <u>Cesar</u>

7.4.1 Conditions favouring development

Balaustium mites are active in the cool, wet part of the year. Mites generally emerge in March–April and can be found through until December. Numbers peak in autumn and spring when they are most active. They typically go through two generations a season, one in autumn/winter and one in spring/early summer. The secondgeneration hatching of larvae occurs in August–September. Balaustium mites typically have a longer active season than other earth mites and are still found in late spring/ early summer. Unlike redlegged earth mites and blue oat mites, Balaustium mites are most active in the warmer parts of the day, where they can be found on the foliage, particularly near the tips of plants.¹⁸

7.4.2 Damage caused by Balaustium mite

Balaustium mites feed on plants using their adapted mouthparts to probe leaf tissue of plants and suck up sap. In most situations Balaustium mites cause little damage; however when numbers are high and plants are already stressed due to other environmental conditions, significant damage to crops can occur. Typical damage to cereals, grasses and pulses is 'silvering' or 'whitening' of the attacked foliage, similar in appearance to damage caused by redlegged earth mites and blue oat mites. However, Balaustium mite damage differs in that they tend to attack the edges and tips of plants. Adult mites are likely to be responsible for the majority of feeding damage to plants. ¹⁹



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¹⁸ A Arthur, P Umina (2010) Balaustium mite. Ag note AG1413 May 2010, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/balaustium-mite</u>

¹⁹ A Arthur, P Umina (2010) Balaustium mite. Ag note AG1413 May 2010, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/balaustium-mite</u>



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Monitoring

The impact of mite damage is increased when plants are under stress from adverse conditions such as prolonged dry weather or waterlogged soils. Ideal conditions for seedling growth enable plants to tolerate higher numbers of *Balaustium* mites. Carefully inspect susceptible pastures and crops from autumn to spring for the presence of mites and evidence of damage. It is especially important to inspect crops regularly in the first three to five weeks after sowing.

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Crops sown into paddocks that were pasture the previous year should be regularly inspected for *Balaustium* mites. Weeds present in paddocks prior to cropping should also be checked for the presence and abundance of *Balaustium* mites. Mites are best detected feeding on the leaves, especially on or near the tips, during the warmest part of the day. *Balaustium* mites are difficult to find when conditions are cold and/or wet.

One of the most effective methods to sample mites is using a D-vac which is based on the vacuum principle, much like a vacuum cleaner used in the home. Typically, a standard petrol-powered garden blower/vacuum machine is used, such as those manufactured by Stihl[®] or Ryobi[®]. A sieve is placed over the end of the suction pipe to trap mites vacuumed from plants and the soil surface.

Control

Currently no product has been registered to control *Balaustium* mite in any state or territory of Australia. The APVMA maintains a database of all chemicals registered for the control of agricultural pests in Australia. Reference to the <u>APVMA website</u> will confirm the registration status of products for *Balaustium* mite, or consult chemical resellers or a local chemical standards officer.

Ensure the relevant Maximum Residue Limits (MRLs) for the chemical in the end market are met, be it domestic or export.

Chemical users must read and understand all sections of chemical labels prior to use.

There have been no biological control agents (predators or parasites) identified in Australia that are effective in controlling Balaustium mites. Alternative methods such as cultural control can prove to be effective at controlling this mite. Early control of summer weeds, within and around paddocks, especially capeweed and grasses can help prevent mite outbreaks. Rotating crops or pastures with non-host crops can also reduce pest colonisation, reproduction and survival. For example, prior to planting a susceptible crop like cereals or canola, a paddock could be sown to a broadleaf plant that Balaustium mites have not been reported to attack, such as vetch.²⁰

7.5 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 species of aphid can infest winter cereals: oat aphid, corn aphid, rose-grain aphid (Photos 6, 7 and 8), rice root aphid with the Russian wheat aphid recently making its way to Australian crops. Aphids can impair growth in the early stages of the 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 grainfill may result in low-protein grain. Because 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 oats, aphids can spread barley yellow dwarf virus (BYDV). In virus-prone areas, use resistant plant varieties and insecticidal seed dressing to minimise losses due to BYDV.



²⁰ A Arthur, P Umina (2010) Balaustium mite. Ag note AG1413 May 2010, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/</u> pest-insects-and-mites/balaustium-mite



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Russian wheat aphid (RWA) (*Diuraphis noxia*) is found in all major cereal production regions around the world, however never in Australia until recently.

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It is a major pest of cereal crops that injects toxins into the plant during feeding which retards growth and with heavy infestations, kills the plant. Overseas studies have shown they have a greater preference for wheat followed by barley and then oats. This is no reason to be less proactive in oats when checking crops.

The aphid is spread easily by the wind and on live plant material.

Affected plants will show whitish, yellow leaf markings and rolling leaves.

Russian wheat aphid is approximately 2 mm long, pale yellowish green with a fine waxy coating. The body is elongated compared with other cereal aphid species. See absence of exhaust pipes. (Photo 6). 21



Photo 6: Russian wheat aphids.

Managing Russian wheat aphid

The Grains Research and Development Corporation (GRDC) is encouraging Southern region grain growers to adopt a simple four-point plan in dealing with RWA.

As the GRDC implements a multi-faceted research, development and extension approach to better inform future control of the pest—detected in Australia for the first time in 2016—growers are reminded to continue to scout fields and implement a considered management strategy.

The "FITE" strategy revolves around four basic principles:

- Find (look for characteristic leaf streaking or rolling symptoms on cereal crops and grasses).
- Identify (positively identify RWA in consultation with an industry specialist).
- Threshold approach (consider international thresholds for control, factoring crop growth stage and potential yield losses).
- Enact an appropriate management strategy that where possible encourages beneficial insects.²²
- 21 PIR SA (2016) Russian wheat aphid Primary Industries and Regions SA, <u>http://www.pir.sa.gov.au/biosecurity/plant_health/exotic_plant_pest_emergency_response/russian_wheat_aphid</u>
- 22 S Watt (2016) Gloves are up in sustained FITE against Russian wheat aphid. GRDC 17 June 2016, <u>https://grdc.com.au/Media-Centre/</u> Media-News/South/2016/06/Gloves-are-up-in-sustained-FITE-against-Russian-wheat-aphid





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Growers and agronomists are asked to take an image of the pest and its damage and to report any suspected infestations so that the range and rate of spread of the pest can be monitored. Samples of the aphids might be requested for identification.

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Chlorpyrifos and pirimicarb are chemicals that are now listed for control of Russian wheat aphid under Emergency Use Permit APVMA 82792 but there are good reasons to hold off spraying until high thresholds are seen:

- Sprays are not preventative.
- Insecticides will reduce numbers of predators and other beneficials, which is likely to result in a spike in numbers of Russian wheat aphid (and other aphids) in spring when temperatures increase.
- Foraging honey bees will succumb to sprays and must be protected. Speak to local beekeepers.
- Spraying can also foster resistance in pests so must be used only when required.

A blanket spraying approach is not recommended; rather overseas experience suggests that an integrated pest management strategy that protects beneficials is the best approach in the longer term.

If growers face a heavy infestation sprays are permitted. International advice for determining whether sprays should be used supports an economic threshold of 20% of plants infested up to the start of tillering and 10% of plants infested thereafter. Research is underway to provide local advice on thresholds for spraying.

Trial work is underway to provide more specific advice on management of Russian wheat aphid in Australia, including the effectiveness of a broader range of insecticide options to better inform future control. ²³

7.5.2 Other aphids



Photo 7: Oat or wheat aphid.

Oat or wheat aphids (*Rhopalosiphum padi*) are one of the most common aphids that infest winter cereals. Typically this species colonises the base and lower portions of the plant. 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. Adult Oat or wheat aphids 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



²³ PHA (2016) Russian wheat aphid management Plant Health Australia 18 August 2016, <u>http://www.planthealthaustralia.com.au/russian-wheat-aphid-management/</u>



the body length (Photo 7). Nymphs are similar but smaller. Wheat and oat aphids are very similar to corn aphids (Photo 8). It is a species that produces many generations through the growing season with winged and non-winged forms occurring. ²⁴

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Photo 8: Corn aphid Source: QDAFF



Photo 9: Rose-grain aphid. Source: QDAFF

24 DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland 30 July 2012, https://www.daf.gld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals







Photo 10: *Rice root aphid.*

7.5.3 Damage caused by aphids

Aphids affect cereals by direct feeding on plants, and/or by transmitting BYDV. BYDV affects wheat, oats and barley and is spread by flying aphids. Direct damage occurs when colonies of 10–100 aphids develop on stems, leaves and heads, from seedling stage through to head filling. The degree of damage depends on the percentage of tillers infested, aphids per tiller, and the duration of the infestation.²⁵

Aphids can impair growth in the early stages of crop and prolonged infestations can reduce tillering and result in earlier leaf senescence. Some research indicates that aphid infestations can reduce yield by ~10% on average. 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 grainfill 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.

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 oats. $^{\rm 26}$

7.5.4 Thresholds for control

The decision to control aphids on winter cereals depends on the size of the aphid population and the duration and timing of the infestation. Research is underway into damage thresholds and control options for cereal aphids. Some research indicates that aphid infestations can reduce yield by ~10% on average. Current national thresholds suggest that control is warranted when there are >10–20 aphids on 50% of the tillers. ²⁷

7.5.5 Management of aphids

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



²⁵ G Troup (2016) Oats: insect pests. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-insect-pests?page=0%2C3</u>

²⁶ DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland 30 July 2012, <u>https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals</u>

²⁷ DAF QId (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland 30 July 2012, <u>https://www.daf.dq.ovau/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/in-winter-cereals</u>



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into head, and other species usually decline in abundance about this time as natural enemy populations build up. The rice root aphid (Photo 10) feeds below ground and cannot be controlled effectively by non-systemic foliar treatments. ²⁸ Delay any planned chemical control if rain is forecast, and check again after rain; intense rainfall can reduce aphid infestations by dislodging aphids from the plants. Crops expected to yield 3 t/ha or more are most at risk. Crops sprayed before Zadoks stage 30 may need respraying at Zadoks stage 50 or later, if aphid numbers build up again. ²⁹ For current chemical control options see <u>Pest Genie</u> or <u>APVMA</u>.

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Monitoring

Inspect for aphids throughout the growing season by monitoring leaves, stems and heads as well as exposed roots. For corn aphids inspect the furled growing tips, and for wheat/oat aphids inspect stems, backs of leaves and in the crown. Choose six, widely spaced positions in the crop, and at each position examine five consecutive plants in a row. ³⁰

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 autumn is generally a precursor to an aphid outbreak, because of the abundance of alternative hosts to breed on. The use of such seed dressings can also reduce the spread of diseases such as BYDV. Seed dressings are available that suppress aphid feeding and reduce the spread of BYDV. They contain imidacloprid alone (e.g. Gaucho[®], Senator[®]) or with a second active ingredient such as tebuconazole (Hombre[®]), triadimenol (Zoro[®]) or flutriafol (Veteran[®], Arrow[®]). ³¹

Natural enemies

Foliar insecticides registered for aphid control are generally broad-spectrum, meaning that they kill natural enemies (beneficial insects such as ladybird beetles and larvae, hover fly larvae, lacewing larvae or parasitic wasps (Photo 11) 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.



²⁸ DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland 30 July 2012, <u>https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals</u>

²⁹ G Troup (2016) Oats: insect pests. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-insect-pests?page=0%2C3</u>

³⁰ G Troup (2016) Oats: insect pests. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-insect-pests?page=0%2C3</u>

³¹ DAF Qid (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland 30 July 2012, <u>https://www.dfa/di.gov.au/blants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipmi-information-by-crop/insect-pest-management-in-winter-cereals</u>





Photo 11: Preserving natural enemies is important in managing aphid populations in the long term.

Photo: DAF Qld

IBroad-leaved weeds can provide alternative food sources, particularly for juvenile stages. Clean fallowing and the control of weeds within crops and around pasture perimeters, especially of capeweed, can therefore help reduce lucerne flea numbers.

Other cultural techniques such as cultivation, trap and border crops, and mixed cropping can help reduce overall infestation levels to below economically damaging levels, particularly when employed in conjunction with other measures. Grasses are less favourable to the lucerne flea and as such can be useful for crop borders and pastures.

In pastures, avoid clover varieties that are more susceptible to lucerne flea damage and avoid planting susceptible crops such as canola and lucerne into paddocks with a history of lucerne flea damage. $^{\rm 32}$

7.6 Desiantha weevil

The larvae are white, legless creatures 6 mm long and with orange-brown heads. They remain under the soil and are difficult to locate although some painstaking digging may reveal the larvae close to plants. The adults are grey-black weevils approximately 5 mm long with the typical weevil snout (Photo 12).



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³² J Roberts, P Umina (1995) Lucerne flea. Agriculture Victoria Ag Note AG0415 June 1995 Updated June 2008, <u>http://agriculture.vic.gov.</u> <u>au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/lucerne-flea</u>





Photo 12: Desiantha larva (left) and adult (right) (Not to scale). Source: DAFWA 2013

Eggs are laid in autumn and hatch after opening rain and the larvae commence feeding on young pasture seedlings. When cereal crops are planted into heavily infested paddocks, they are attacked by the larvae which may be well grown. In spring the larvae pupate and become adults, which are grey-black weevils approximately 5 mm long with the typical weevil snout. The adults are common in spring and summer hiding under wood or stones or they may be found on cereal heads and can be harvested with the grain. ³³

7.6.1 Damage caused by Desiantha weevil

Desiantha weevil is a sporadic pest of cereal seedlings in south coast areas . It is the larval stage which can completely destroy hundreds of hectares or may affect smaller areas by feeding on underground parts of the seedlings. Plant growth may be slowed or plants may wilt and die in which case they may be easily pulled from the soil.

What to look for

Paddock:

- Patches of dead, weak or dying plants that are mainly found on sandysurfaced soils.
- Symptom severity patterns can vary with practices that may alter weevil egglaying preference, plant density, or plant nutrition.

Plant:

Larvae chew the swollen seed, or bore into the underground stem of seedlings causing them to wither and die.



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³³ G Troup (2016) Oats: insect pests. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-insect-pests?page=0%2C0</u>





Control with chemicals is not possible after planting. The problem is most likely to occur where shallow sand occurs over gravel or clay. As larvae will be larger following summer rain, crops should be planted early and shallow to minimise attack. Where the pest is confirmed, planting with treated seed at 90 kilograms per hectare (kg/ha) is recommended. ³⁴

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Effective control of grass weeds in previous season and of green bridge following summer rain will minimise the risk of crop losses from Desiantha weevil. The only incrop treatment is to reseed with insecticide-coated seed. ³⁵

7.7 Cutworm

There are several species (*Agrotis infusa, A. munda*, various other species) in southern Australia, which vary in appearance but the larvae are all smooth and plump. The larva of the most common species, the pink cutworm, is grey-green with a pink tinge and is usually found in sandy soils. The larva of another common species, the bogong moth, is dark grey. The larvae usually hide by day but may be found under the surface and often close to a damaged plant. They curl up when disturbed (Photo 13). At times, brown cutworms with a herringbone pattern along the back damage crops. The adult moths of herringbone cutworm are of various species, and range from black, through grey to brown (Photo 14).



Photo 13: Cutworms curl up when disturbed. Source: DAF Qld



G Troup (2016) Oats: insect pests. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-insect-pests?page=0%2C0</u>

³⁵ DAFWA (2015) Diagnosing Desanthia weevil in cereals. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/</u> diagnosing-desiantha-weevil-cereals





Photo 14: Cutworm moths. Source: DAFWA 2013



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Photo 15: *Cutworm feeding on plant.* Source: DAFWA 2013

7.7.1 Damage caused by cutworm

As the name implies, the cutworm chews through plant parts, often felling the plant at ground level (Photo 15). Just two or three large caterpillars would seriously damage a square metre of crop and almost all crop and pasture plants are susceptible to attack. This is not a regular pest but large areas may be affected.

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.

In the paddock damage can be seen as patches with plants that have leaves lopped or are cut off at the base. Damage is worst at the seedling stage but can persist for several weeks. Larvae hide in the soil during the day, often at the base of lopped plants and on the edge of the patch. ³⁶

7.7.2 Thresholds for control

Chemical control is warranted when there is a rapidly increasing area or proportion of crop damage.

36 DAFWA (2015) Diagnosing cutowrm in cereals. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/</u> <u>diagnosing-cutworm-cereals</u>





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7.7.3 Management of cutworm

Monitoring

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 or at the interface between the wet and the dry soil. Inspect crop twice weekly in seedling and early vegetative stage.

Occasionally, autumn attack by armyworm in cereals resembles cutworm damage. This is significant, because armyworm are harder to kill with insecticides than are cutworm.

Control

Cutworm caterpillars are usually easily controlled with registered rates of synthetic pyrethroid chemicals (refer to currently registered products). Early and complete control of green bridge two weeks before planting will minimise survival of cutworm larvae. ³⁷ Insecticide application is cost-effective. The whole crop may not need to be sprayed if distribution is patchy; spot spraying may suffice. See <u>Pest Genie</u> or <u>APVMA</u> for current control options.

7.8 Armyworm

Armyworms are caterpillar pests of grass pastures and cereal crops. They are the only caterpillars that growers are likely to encounter in cereal crops, although occasionally native budworm will also attack grain when underlying weed hosts dry out. Armyworms mostly feed on leaves, but under certain circumstances will feed on the seed stem, resulting in head loss. The change in feeding habit is caused by depletion of green leaf material or crowding. In the unusual event of extreme food depletion and crowding, they will 'march' out of crops and pastures in search of food, which gives them the name 'armyworm' (Photo 16).



Photo 16: Armyworm caterpillar.

There are three common species of armyworm found in southern Australia:

- Common armyworm (Mythimna convecta)
- Southern armyworm (Persectania ewingii)



³⁷ DAFWA (2015) Diagnosing cutowrm in cereals. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-cutworm-cereals</u>


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Inland armyworm (Persectania dyscrita)

Caterpillars of the three species are similar in appearance. They grow from about 2–40 mm in length. They have three prominent white or cream stripes running down the back and sides of their bodies. These are most obvious where they start on the thoracic segment ('collar') immediately behind the head. These become particularly apparent in larvae that are >10 mm. They have no obvious hairs, are smooth to touch and curl up when disturbed. Armyworms have four abdominal prolegs.

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Mature caterpillars are 30–40 mm long. For an accurate identification, they must be reared through to the adult (moth) stage.

Armyworms can be distinguished from other caterpillar pests that may be found in the same place by three pale stripes running the length of the body; these stay constant no matter what variation in the colour of the body.

Moths are often seen flying on warm, humid nights. They are medium-sized, with a wingspan of 30–40 mm. Each species has a characteristic colour and wing markings:

- Southern armyworm: grey-brown to red-brown forewings with white zig-zag markings on the outer tips and a pointed white "dagger" in the middle of the forewing. The hind wings are dark grey (Photo 17).
- Inland armyworm: similar to the southern armyworm except the white 'dagger' in the centre of the forewing is divided into two discrete light ellipses which almost touch. The hind wings are pale grey.
- Common armyworm: the forewings are dull yellow to red-brown, speckled with tiny black dots, and a small white dot near the centre.



Photo 17: Adult armyworms are generally dull coloured moths with some species having metallic looking markings on their wings.

Source: DAFWA 2013

Pupae of all three species are about 20 mm long, shiny brown and are found under clods or within cracks in the soil.

Moths are most active on warm humid evenings during spring and autumn. Armyworm eggs are laid in batches of about 5–30, glued together in the hidden,





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twisted crevices of dried grasses, straw and stubble or sometimes in seed heads. The eggs may take 6–20 days to hatch, depending on local temperatures. The young larvae, which are about 2–3 mm in length, may disperse away from the egg-laying sites on fine silken threads. These are used to allow wind dispersal within a few metres of the egg-laying site.

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Major outbreaks occasionally occur across Victoria, particularly after periods of drought. There are many factors which may lead to an outbreak. They may arise from large invasions of moths which have bred in arid regions of New South Wales, South Australia or western Queensland. Alternatively, they may arise because of significantly less mortality of eggs and young caterpillars. Droughts appear to trigger outbreaks because of the adverse effects they have on the natural enemies of armyworms; these predators and parasites are much slower in recovering from a drought than are armyworms.³⁸

7.8.1 Damage caused by armyworm

The young larvae feed initially from the leaf surface of pasture grasses and cereals. As the winter and spring progress and the larvae grow, they chew 'scallop' marks from the leaf edges. This becomes increasingly evident by mid to late winter. By the end of winter or early spring, the larvae are reaching full growth and maximum food consumption. It is this stage that farmers most frequently notice as complete leaves and tillers may be consumed or removed from the plant.



Photo 18: Larvae climb the drying stem and lop the head at a green area where it joins the stem.

Source: DAFWA 2013

Damaging infestations or outbreaks occur in three situations:

- In winter when young tillering cereals are attacked and can be completely defoliated. The caterpillars may come from:
- the standing stubble from the previous year's cereal crop, in which the eggs are laid;



³⁸ G McDonald (1995) Armyworms. Agriculture Victoria Ag Note AG0412 June 1995, <u>http://agriculture.vic.gov.au/agriculture/pests-</u> diseases-and-weeds/pest-insects-and-mites/armyworms



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 neighbouring pastures which dry out, resulting in the resident armyworms being forced to march into the crop;

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- In spring/early summer when crops commence ripening and seed heads may be lopped; and
- In early summer when grass pastures are cut for hay, particularly in Gippsland.

Leaves of cereal plants or grasses appear chewed ('leaf scalloping') along the edges. The most damage, however, is caused in ripening crops when the foliage dries down. The armyworms then begin to eat any green areas remaining. In cereals, the last section of the stem to dry out is usually the last node just below the seed head. Armyworms, particularly the older ones chew at this vulnerable spot cause lopping of the heads and can devastate a crop nearing maturity in one or two nights (Photo 18). Generally larger armyworm cause more damage. In wheat and barley whole heads are severed, while in oats individual grains are bitten off below the glumes.³⁹

7.8.2 Thresholds for control

For winter outbreaks (during tillering), economic thresholds of 8–10 larvae/m² provide a guide for spray decisions. For spring outbreaks (during crop ripening) spraying is recommended when the density of larvae exceeds 1–3 larvae/m² although this figure must be interpreted in the light of:

- timing of harvest,
- green matter available in the crop,
- expected return on the crop, and
- Larval development stage (if most are greater than 35–40 mm or pupating, it may not be worth spraying). $^{\rm 40}$

7.8.3 Management of armyworm

Monitoring

Early detection is essential, particularly when cereals or hay crops are at the late ripening stage. Although accurate estimates of caterpillar densities require considerable effort, the cost saving is worthwhile. Armyworms are often found in patches starting on the perimeters of oat crops and advance into the paddock dropping heads. Hence their name "armyworm".

Signs of the presence of armyworms include:

- Chewing/leaf scalloping along the leaf margins.
- Caterpillar excreta or 'frass' which collects on leaves or at the base of the plant. These appear as green or yellow cylindrical pellets 1–2 mm long or as small 'hay bales' on the ground.
- Cereal heads or oat grains on the ground. Oat grains may be attached to a small piece of stalk (1–2 mm), whereas wind-removed grains are not. Barley heads may be severed completely, or hang from the plant by a small piece of stalk. ⁴¹

The sweep-net/bucket method provides a rapid and approximate estimate of infestation size. The net or bucket should be swept across the crop in 180° arcs several times, preferably 100 times, at different sites within the crop to give an indication of density and spread. Armyworms are most active at night, so sweeping will be most effective at dusk. Average catches of more than 5–10 per 100 sweeps suggest that further searches on the ground are warranted to determine approximate densities.



³⁹ G McDonald (1995) Armyworms. Agriculture Victoria Ag Note AG0412 June 1995, <u>http://agriculture.vic.gov.au/agriculture/pests-</u> diseases-and-weeds/pest-insects-and-mites/armyworms

⁶ G McDonald (1995) Armyworms. Agriculture Victoria Ag Note AG0412 June 1995, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/armyworms</u>

⁴¹ G McDonald (1995) Armyworms. Agriculture Victoria Ag Note AG0412 June 1995, <u>http://agriculturevic.gov.au/agriculture/pestsdiseases-and-weeds/pest-insects-and-mites/armyworms</u>



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When ground sampling, it is necessary to do at least ten 'spot checks' in the crop, counting the number of caterpillars within a square metre.

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Most farmers fail to detect armyworms until the larvae are almost fully grown and 10–20% damage may result. The earlier the detection, the less the damage. The young larvae (up to 8 mm) cause very little damage, and are more difficult to find. The critical time to look for armyworms is the last 3–4 weeks before harvest. ⁴²

Chemical control

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 where uniform coverage is not possible, particularly when larvae are resting under soil at the base of plants. Insecticides should target larvae 10–20 mm long. Larvae >20 mm long can be difficult to kill and may require higher rates of insecticide. Larvae are most active at night; therefore, spraying in the afternoon or evening may produce the best results. If applying sprays close to harvest, be aware of relevant withholding periods.

Cultural and biological 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).

Biological control agents may be important in some years. These include parasitic flies and wasps, predatory beetles and diseases. Helicoverpa NPV (nuclear polyhedrosis virus) is not effective against armyworm.⁴³

7.9 Cockchafer

There are several important pest species and adults range in size from 5-20 mm. Adults are usually brown or blackish beetles (Photo 19). The beetles fly readily and are attracted to lights. Cockchafer larvae are characteristically 'C' shaped creamy white grubs ranging from 2-25 mm long.



Photo 19: Blackheaded Pasture Cockchafer.

The complete life cycle may take one or two years. Some species have a long larval stage which extends over 12 to 18 months. In most species the larva is active during late autumn and winter. In these species pupation occurs in spring and adults emerge in early summer. Feeding, mating and egg-laying may occur throughout summer.

7.9.1 Conditions favouring development

Larvae live underground in tunnels and rain events stimulate them to come to the surface to feed on foliage, which may cause large bare patches in crops during late autumn and early winter. $^{\rm 44}$



⁴² G McDonald (1995) Armyworms. Agriculture Victoria Ag Note AG0412 June 1995, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/armyworms</u>

⁴³ DAF Old (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland 30 July 2012, <u>https://</u> www.daf.gld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/ insect-pest-management-in-winter-cereals

⁴⁴ GRDC, Blackheaded Pasture Cockchafer (South). GRDC Ute Guide, <u>https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-Iarvae/</u> South/Blackheaded-Pasture-Cockchafer





Cockchafer larvae feed underground and some species are serious pests which may cause patches and poor growth in pasture and may slow growth or kill large areas of cereals and lupins. Young plants without extensive root systems are worst affected. The adult beetles are also very destructive as they feed on tree foliage.

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7.9.3 Management of cockchafer

Control of cockchafer larvae is rarely warranted. Cultivation, shallow planting and a high seeding rate may help to overcome the problem. The problem is most serious when early growth is slow. Large populations may be present under young crops and in pasture without causing significant damage.⁴⁵

7.10 Webworm

Webworm caterpillars are seldom seen as they come above ground level only when conditions are cool and damp and usually at night. They may be located in their web-lined tunnels from which plant parts may be seen protruding. The caterpillars are pale to deep brown with a tinge of the green gut contents showing through. The head appears black or dark brown. Fully grown caterpillars are about 15 mm long (Photo 20).



Photo 20: Pasture Webworm Hednota spp. Source: <u>GRDC</u>

Caterpillars hatch from eggs laid amongst grass in autumn and feed throughout the winter. Spring and summer are passed in the tunnels as resting stage caterpillars. After this, the insects proceed through the pupal stage and emerge as adult moths, which are about 10 mm long and may be seen flying in large numbers on autumn nights (Photo 21). By day they hide in dry grass, the colour of which they closely resemble.









Photo 21: Pasture Webworm Moth.

7.10.1 Damage caused by webworm

Large areas of emerging wheat or barley crops may be destroyed by the continual chewing damage of a heavy webworm infestation. The caterpillars sever leaves or whole plants which they scatter on the ground or pull into holes near the plants. In pasture, the grass component may be removed from large areas.

7.10.2 Management of webworm

The paddock condition in autumn and the weather are very important in determining webworm numbers. Eggs will not be laid in great numbers and will not survive well in a bare paddock or in stubble. Grassy situations favour survival. Cultivations leading to a weed free paddock over a three-week period destroy the young stages but reduced tillage cropping methods allow a greater survival. Hot and dry conditions during May and June, resulting in a lack of feed, could destroy most webworms. If a quarter of the plants is being seriously damaged at or just after emergence, spraying should not be delayed as the continued feeding will kill many plants and result in bare ground or thin areas. ⁴⁶



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⁴⁶ G Troup (2016) Oats: insect pests. DAFWA, https://www.agric.wa.gov.au/oats/oats-insect-pests?page=0%2C1



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Key messages:

Cereal cyst nematode (CCN) and Stem nematode (SN) are major soil-borne diseases limiting the yield of oats in certain areas of southern Australia (Table 1). ¹



P Zwer, S Hoppo, P McCormack, M Hill, P Wheeler, KL McMurray, M Williams (2015) Oat variety sowing guide 2015. SARDI, <u>http://aexco.com.au/wp-content/uploads/2014/03/SARDI-2015-Oats-Sowing-Guide.pdf</u>



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 CCN is effectively managed through strategic use of non-host crops and resistant cultivars.

• The SN oat species is found in parts of Yorke Peninsula and the Mid North of South Australia usually occurring in high rainfall areas on clay soils.

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- Conduct soil testing using PreDicta B.
- It may be necessary to halt cereal production in favour of a non-host crop (canola, lupin) to reduce CCN numbers in the soil.
- Control volunteer grasses and cereals, especially wild oats, and uphold hygienic use of equipment.

Nematodes are tiny but complex unsegmented roundworms that are anatomically differentiated for feeding, digestion, locomotion, and reproduction. These small animals occur worldwide in all environments. Most species are beneficial to agriculture. They make important contributions to organic matter decomposition and the food chain. Some species, however, are parasitic to plants or animals.²

Varieties grown where Cereal cyst nematode (CCN) or Stem nematode (SN) is present should be resistant to the particular nematode which is a problem so that multiplication of the nematode is limited. The variety should also be tolerant so that it yields well in the presence of the nematode. Yield penalties of up to 80% can occur if an intolerant variety is sown in a paddock where CCN or SN is a problem. ³

Table 1: Guide to nematodes in oats. This table has been developed frominformation in the publications Wallwork H (2000) (Ed) Cereal Root and CrownDiseases (Grains Research and Development Corporation, SARDI) and WallworkH (2000) (Ed) Cereal Leaf and Stem Diseases (Grains Research and DevelopmentCorporation, SARDI).

Nematode	Organism	Symptoms	Occurrence	Hosts	Control
Cereal cyst nematode (CCN)	Heterodera avenae	Yellow or pale green patches in crop. Stunted, weak plants with knotted root systems.	Can survive in soil between susceptible cereal crops for up to two years.	Cereals and some grasses, especially wild oats.	Resistant or tolerant varieties, crop rotation, weed control.
Stem nematode	Ditylenchus dipsaci	Swollen base of plant, stunted & numerous tillers.	Encouraged by moist conditions and can reproduce 4–5 times per season.	Wide host range including peas, beans, wild oats and many weeds. Nematode spread in infected hay.	Crop rotation and weed control. Avoid susceptible varieties.
Root-lesion nematode	Pratylenchus Thornei & Pratylenchus neglectus	Reduced tillering, ill thrift; lack of branching of root system, lesions on roots.	Favoured by wheat in rotation with wheat chickpea, medic and vetch.	Survive as dormant nematodes in soil.	Crop rotation using resistant crops.

Source: <u>AgVic</u>

8.1 Cereal cyst nematode (Heterodera avenae)

Key points:

- Cereal Cyst Nematode (CCN) *Heterodera avenae* infects cereal roots and can cause serious yield losses in wheat and oat crops in the Southern Region.
- CCN is most likely to become a problem in intensive cereal programs.
- CCN is most damaging in low rainfall districts/seasons, especially with late breaks.



² RW Smiley, G Yan (2010) Cereal cyst nematodes. A Pacific Northwest Extension Publication PNW620 Oregon State University University of Idaho Washington State University October 2010, <u>https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw620.pdf</u>

³ P Zwer, S Hoppo, P McCormack, M Hill, P Wheeler, KL McMurray, M Williams (2015) Oat variety sowing guide 2015. SARDI, <u>http://aexco.com.au/wp-content/uploads/2014/03/SARDI-2015-Oats-Sowing-Guide.pdf</u>



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CCN is effectively managed through strategic use of non-host crops and resistant cultivars. ⁴

Only one species of CCN, *Heterodera avenae*, occurs in Australia and it causes cereal crop damage in South Australia, Victoria, Southern NSW and Western Australia. Barley varieties are tolerant, whereas wheat, and particularly oat, range significantly from moderately tolerant to very intolerant depending on the variety. ⁵ Non-cereal crops will not host the nematode, so are useful in rotations to limit damage caused to cereals. ⁶

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In a survey of 385 paddocks in western Victoria, during 2014 and 2015 (Table 2), CCN was identified in 4% and 12% of paddocks in the Wimmera and Mallee, respectively, showing the effect of good control through the cultivation of resistant cereal varieties and crop rotation. However, if CCN levels increase large yield losses are possible.⁷

Table 2: Percentage of paddocks (n = 385) surveyed in three regions in western Victorian during 2014 and 2015 within each nematode risk category and the corresponding potential yield loss (%).

Predicta B risk	Victorian region (%)			Potential	
Risk category	Number/g soil	Mallee (n = 73)	Wimmera (n = 182)	Western district (n = 30)	(%)
BDL	<0.05	96	88	100	<5
Low	0.05–5	4	9	0	5–25
Medium	5–10	0	2	0	10-50
High	>10	0	1	0	50–70

Source: GRDC

8.1.1 Threshold for control

Just two CCN eggs per gram of soil can cause significant economic loss to intolerant cereal crops. Levels of 1–5 eggs per gram of soil can reduce yield of wheat and oat by up to 20%. $^{\rm 8}$

8.1.2 Damage caused by CCN

Cereal cyst nematode can cause yield loss of up to 80% in intolerant oat varieties.⁹



⁴ A McKay, Cereal cyst nematode—South Australia. Soilquality.com.au Fact Sheet, <u>http://www.soilquality.org.au/factsheets/cereal-cyst-nematode-south-australia</u>

^{5 &}lt;u>GRDC Plant parasitic nematodes Factsheet</u> –Southern and Western regions. (2009), <u>https://grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW</u>

⁶ A McKay, Cereal cyst nematode—South Australia. Soilquality.com.au Fact Sheet, <u>http://soilquality.org.au/factsheets/cereal-cyst-nematode</u>

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Cereal-disease-management-in-Victoria-2016
 A McKay, Cereal cyst nematode—South Australia. Soilquality.com.au Fact Sheet, <u>http://soilquality.org.au/factsheets/cereal-cyst-nematode</u>

^{9 &}lt;u>GRDC Plant parasitic nematodes Factsheet</u> – Southern and Western regions. (2009), <u>https://grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW</u>





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 Table 3: Nematode resistance of oat varieties – field reactions.

Variety	Cereal cyst nem	atode	Stem nematode				
	Resistance	Tolerance	Resistance	Tolerance			
Semi-dwarf (h	Semi-dwarf (husked)						
Bannister	VS	1	-	MI			
Echidna	S	I	MS	MT			
Mitika	VS	1	S	1			
Possum	VS	I	S	I			
Potoroo	R	Т	S	MI			
Wombat	R	MT	MR	MT			
Semi-dwarf (naked)							
Numbat	S	I	S	I			
Tall (husked)							
Brusher	R	MI	MS	I			
Forester	MS	MI	S	1			
Glider	MS	I	R	Т			
Kangaroo	R	MT	MS	MI			
Mulgara	R	MT	R	MT			
Tammar	MR	MT	R	MT			
Tungoo	R	MT	R	MT			
Wallaroo	R	MT	MS	MI			
Williams	S	I	-	I			
Wintaroo	R	MT	MR	MT			
Yallara	R		S				

VS = very susceptible, S = susceptible, MS = moderately susceptible, MR = moderately resistant, R = resistant, VI = very intolerant, I = intolerant, MI = moderately intolerant, MT = tolerant, VT = very tolerant. Source: <u>SARDI Oat Newsletter-October 2016</u>

8.1.4 Symptoms and detection

What to look for

Paddock:

- Poor emergence and establishment.
- Pale green patches of unthrifty plants in young crops (particularly on sandy, less fertile soils).
- Plants wilt despite moist soil.
- Patchy appearance of crops.

Plant:

- Affected plants are stunted with yellowing and few tillers.
 - Roots are thickened, shortened and distinctly 'knotted' with lots of small laterals.
- In spring, white pinhead-sized nematode cysts are visible on roots when soil is carefully washed off.
- Cysts turn brown at the end of the season. ¹⁰
- 10 DAFWA (2015) Diagnosing cereal cyst nematode in cereals. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/</u> mycrop/diagnosing-cereal-cyst-nematode



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Cereal cyst nematode infection appears in the paddock as areas of stunted chlorotic growth (Photo 1).

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Field symptoms of CCN infection can resemble symptoms of other diseases or soil constraints, so examination of roots is important. Plant root symptoms include knots in wheat, barley and triticale (Photo 2) and stunted root growth on oats (Photo 3). Short matted root growth indicates severe infection.



Photo 1: *Poor emergence and establishment caused by Cereal cyst nematode.* Source: DAFWA







Photo 2: CCN infection causes knots in the roots of cereal plants. Photo: Vivien Vanstone



Photo 3: CCN infection causes stunted growth on oat roots. Photo: Hugh Wallwork

White cysts are visible on the knots around the time of head emergence (Photo 4).



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Photo 4: Characteristic white cysts (about the size of a pinhead) are visible on the knots around the time of head emergence.

Photo: John Fisher

As the crop matures the cysts turn brown (Photo 5). The mature cysts contain several hundred eggs, so populations can increase rapidly on susceptible cereals. Affected plants show stunted growth, with fewer tillers (Photo 6).



Photo 5: Cysts turn brown when the crop matures; each cyst contains 200–300 eggs.

Photo: John Fisher







Photo 6: Affected plants are stunted with few tillers. Source: <u>DAFWA</u>

Table 4: What else could it be. ¹¹

Condition	Similarities	Differences
Diagnosing root-lesion nematode in cereals	Stunted plants with brown roots.	Root-lesion nematodes do not cause the distinctive knotted roots.
Nutrient deficiency	Small plants.	Nutrient deficient plants

8.1.5 Conditions favouring development

Cereal cyst nematodes have only one generation per year (Figure 1). The juveniles hatch in response to low temperatures and autumn rains. Hatching is delayed by late breaks and this increases the risk of crop damage. Cysts are particularly hardy and remain in the soil over summer. CCN populations in soil are not affected by summer rain. ¹²



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¹¹ DAFWA (2015) Diagnosing cereal cyst nematode in cereals. Department of Agriculture and Food WA.<u>https://www.agric.wa.gov.au/</u> mycrop/diagnosing-cereal-cyst-nematode

¹² A McKay, Cereal cyst nematode—South Australia. Soilquality.com.au Fact Sheet, <u>http://www.soilquality.org.au/factsheets/cereal-cyst-nematode-south-australia</u>



Adult nematodes

4th molt

Syncytia of male begins to

degenerate

IV Stage larvae 3rd molt

¥

feeding on syncytia formation of syncytia **Figure 1:** Cereal cyst nematode life cycle and damage to plant.

Source: GRDC Plant parasitic nematodes Factsheet—South and West region. (2009)

1.

II Stage male and female larvae

8.1.6 Thresholds for control

Less than five eggs per gram of soil can produce yield loss for intolerant cereals. ¹³

100

II Stage larvae invades root and causes

II Stage larvae

II Stage

in soil

Il Stage larvae

attack young roots

larvae free

emerge from

cvst

Females at various stages of development

2nd molt

attached to root

8.1.7 Management

Key points:

- It may be necessary to halt cereal production in favour of a non-host crop (canola, lupin) to reduce CCN numbers in the soil.
- Severe infestations might require more than one non-host crop to lower CCN below yield-limiting levels.
- Some oat, barley and wheat varieties are resistant to CCN.
- Control volunteer grasses and cereals—especially wild oats.
- Cultivation is not an effective control measure as it spreads the nematodes around the paddock making the problem worse.

Cereal cyst nematode multiplies on susceptible cereals and wild oats and is best controlled by rotation with non-host crops, for example, oilseeds and pulses, and use of resistant cereal varieties. Only 50–80% of the nematode eggs hatch in the following season, so a two-year break is needed to reduce high populations to non-damaging levels. It is important to control susceptible cereals and wild oats in break crops, fallows and pastures.

To reduce yield losses when CCN populations have reached damaging levels and cereals have to be sown, consider using tolerant varieties/crops, sow early and provide adequate nutrition. Make sure the variety is also resistant to prevent CCN increasing further—see current crop disease variety guides. Sowing between the rows of the last crop also helps to reduce the risk of infection. ¹⁴



¹³ GRDC Plant parasitic nematodes Factsheet—South and West region. (2009), <u>https://grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW</u>

¹⁴ A McKay, Cereal cyst nematode—South Australia. Soilquality.com.au Fact Sheet, <u>http://www.soilquality.org.au/factsheets/cereal-cyst-nematode-south-australia</u>



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CCN populations can be assessed during summer/autumn through the $\underline{\text{PreDicta B}}$ soil test service.

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The use of CCN-resistant cereals and non-host crops, such as pulses and oilseeds, in rotation is the required management strategy. Where CCN levels are moderate to high the best choice is two years of resistant and tolerant cereal or non-host crops. The most profitable option will often be chosen, but growers should also be mindful of management of other diseases and weeds when making these choices to produce longer-term profits. While two years is generally accepted to reduce CCN to low levels, exceptions do occur. Monitoring paddocks and the use of diagnostic services to check CCN levels is encouraged. If susceptible cereal varieties are continually used in a rotation CCN can cause ongoing significant yield losses. Predicta B Soil testing can help ascertain the risk. Break crops must be maintained free of wild oats and susceptible cereal volunteers. The benefit of a two-year break should be regarded as temporary because the nematode population rises quickly when susceptible cereals are returned to the system. The solution is not instant and it can take several years to reduce high levels. ¹⁵

Nematicides

Nematicides provide significant improvements in grain yield when applied to nematode-infested plots, but are no longer used commercially in Australia. They are not recommended because of their cost and inherent mammalian toxicity, and also because rotational crops are available for nematode management. If they were used commercially, it is likely their efficacy would be poor, particularly in situations where the nematode occurs at depth. ¹⁶

FAQ

Q: Is CCN ever likely to be a major problem in Australian farming again?

A: Yes. In SA and Victoria, the widespread adoption of resistant cereal varieties and non-host rotations has significantly reduced the problem. However, if susceptible varieties are grown in continuous rotation, CCN levels could easily increase again. Intensive cultivation of susceptible cereals can lead to significant increase in CCN levels. So it is not a major problem at the moment but could be again if precautions are not taken.¹⁷

8.1.8 Development of molecular markers for Cereal cyst nematode resistance and tolerance

Resistance to CCN is an essential trait for cereal crop production. Traditionally, CCN resistance is quantified in pot-based assays. Molecular markers are increasingly replacing the expensive and time-consuming pot assays in wheat and barley.

Markers for CCN resistance and tolerance were developed and applied on oat breeding lines in this project. A reliable marker for CCN tolerance (crop yield in the presence of CCN) works across the entire germplasm in the National Oat Breeding Program. For CCN resistance, (CCN is unable to multiply but can cause yield loss) the markers are able to track some but not all resistance sources in the breeding program, a gap currently being addressed. Ultimately, this project will help to develop tolerant and resistant lines of oats.¹⁸



MORE INFORMATION

GRDC Plant parasitic nematodes

Factsheet

¹⁵ GRDC Plant parasitic nematodes Factsheet – Southern and Western regions. (2009), <u>https://qrdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW</u>

¹⁶ GRDC Plant parasitic nematodes Factsheet – Southern and Western regions. (2009), <u>https://grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW</u>

¹⁷ GRDC Plant parasitic nematodes Factsheet – Southern and Western regions. (2009), <u>https://grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW</u>

¹⁸ DAS00101 - Development of Molecular Markers for Cereal Cyst Nematode Resistance and Tolerance. (2012), <u>http://finalreports.grdc.com.au/DAS00101</u>





There are two races of Stem nematode (*Ditylenchus dipsaci*) recorded in South Australia: the oat and the lucerne race. The oat species is found in parts of Yorke Peninsula and the Mid North of South Australia. The nematode usually occurs in high rainfall areas on clay soils. The main hosts are susceptible oat and faba bean varieties. Populations can build up rapidly as the nematode can reproduce four or five times in a season.¹⁹

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The value of pulses and oats as disease breaks to Cereal cyst nematode and other major cereal root and leaf diseases is threatened by the spread of Stem nematode in SA. $^{\rm 20}$

8.2.1 Varietal resistance or tolerance

Refer to Table 5 for resistant and tolerant oat varieties.

Table 5: Nematode resistance of oat varieties – field reactions.

Variety	Cereal cyst nematode		Stem nematode	
	Resistance	Tolerance	Resistance	Tolerance
Semi-dwarf (h	usked)			
Bannister	VS	L	-	MI
Echidna	S	I	MS	MT
Mitika	VS	L	S	L
Possum	VS	I	S	I
Potoroo	R	Т	S	MI
Durack	R	MI-MT	-	L
Wombat	R	MT	MR	MT
Semi-dwarf (na	aked)			
Numbat	S	I	S	I
Tall (husked)				
Brusher	R	MI	MS	I
Forester	MS	MI	S	L
Glider	MS	I	R	Т
Kangaroo	R	MT	MS	MI
Mulgara	R	MT	R	MT
Tammar	MR	MT	R	MT
Tungoo	R	MT	R	MT
Wallaroo	R	MT	MS	MI
Williams	S	I	-	I
Wintaroo	R	MT	MR	MT
Yallara	R	I	S	I

Source: SARDI Oat Newsletter-October 2016

VS = very susceptible, S = susceptible, MS = moderately susceptible, MR = moderately resistant, R = resistant, VI = very intolerant, I = intolerant, MI = moderately intolerant, T = tolerant, VT = very tolerant.

19 Stem nematode Fact Sheet. Plant Health Australia, <u>http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf</u>

20 Stem nematode (1998). GRDC Ground Cover Issue 22, 01 January 1998, <u>https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover/Ground-Cover/Jonana/Media-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Centre/Ground-Cent</u>





Symptoms and detection

Symptoms on oats include stunted plants and the bases of each tiller becoming swollen. Stem nematode feeds on the emerging shoot, crown and above-ground parts of host plants, resulting in distorted and stunted growth. ²¹ Early signs are poor emergence and establishment, stunting and distortion of plants, swollen stem bases, premature plant death, lodging and fewer seed heads (Photos 7, 8 and 9). ²²

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Some symptoms may be confused with herbicide damage, water-logging or nutrient deficiency. $^{\rm 23}$



Photo 7: Oat plants affected by Stem nematode are stunted and distorted with swollen stem bases (plants on right).

Source: Plant health Australia

23 Stem nematode PestFacts south eastern Issue 6 15 July 2011, <u>http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2011/pestfacts-issue-no-6-15th-july-2011/stem-nematode/</u>



²¹ Stem nematode (1998). GRDC Ground Cover Issue 22, 01 January 1998, <u>https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover/Ground-Cover/Jonana</u>

²² Stem nematode Fact Sheet. Plant Health Australia, <u>http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf</u>





Photo 8: Stem nematode tolerant oat cultivars (right) produce strong growth when Stem nematode is present, in contrast to intolerant cultivars (left). Source: <u>Plant health Australia</u>



Photo 9: Patchy and stunted growth in a stem nematode infected crop. Source: <u>Plant health Australia</u>

8.2.2 Damage caused by stem nematode

Symptoms usually occur in patches, but the entire crop can be affected in severe cases. Severe cases of SN can eventually lead to plant death. $^{\rm 24}$

8.2.3 Conditions favouring development

The nematode can survive and spread between districts in infected hay. It can also survive in the seed of some crops, especially faba beans. Localised spread is possible by soil contamination of stock and machinery and in surface water, windblown stubble or soil. Stem nematode can survive in a dehydrated form in hay and seed for 10 years or more. Weeds can play a key role in the survival of SN when



²⁴ Stem nematode PestFacts south eastern Issue 6 15 July 2011, <u>http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2011/pestfacts-issue-no-6-15th-july-2011/stem-nematode/</u>



there are no host crops. This explains why the nematode can recur after paddocks have not grown susceptible crops for a number of years. Wild oats and cleavers are major weed hosts. Minor hosts include ryegrass, brome grass, soursobs, wild turnips and poppies. 25

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When significant moisture is available (usually in autumn) they become active again and can invade young growing stem tissues of plants, especially seedlings that are still below the soil surface. Stem nematodes prefer heavier soil types and cooler, moist conditions. ²⁶

8.2.4 Management

Key points:

- Include resistant crops and varieties in planned rotations.
- Control host weeds.
- Observe farm hygiene.
- Growers with a stem nematode problem should not grow oats in succession with faba beans or peas. ²⁷

Controlling Stem nematodes is difficult once they have invaded plants, so control efforts should focus on rotations involving non-host crops (e.g. wheat and barley) or controlling volunteer hosts in paddocks and avoiding the spread of infested plant material, hay, seed and soil. ²⁸

Ensure that potentially infected material is not allowed to enter the property. Check your farm frequently for the presence of new pests and unusual symptoms. ²⁹

Resistance starts to operate four to six weeks after emergence. The nematodes leave or die and the plants recover. However, if the plants are also invaded by CCN, Echidna will remain susceptible to SN, resulting in crop failure. ³⁰

8.3 Root-lesion nematode (Pratylenchus spp.)

Key points:

- Root-lesion nematodes (RLN) are species of *Pratylenchus* nematodes that feed on the roots of crops and can cause yield loss.
- The main RLN species in the Southern Region are Pratylenchus neglectus and P. thornei, with over 90% of paddocks in the Wimmera and Mallee regions having RLNs present. ³¹
- The *Pratylenchus* species present in the soil will affect choice of management practices, in particular rotations.
- RLN have a wide host range and can multiply on cereals, oilseeds, pulses and pastures as well as on broadleaf and grass weeds.
- A PreDicta B test (SARDI Diagnostic Services) prior to sowing can identify the number and species of nematodes present in the soil, and therefore inform management practices.
- Crop rotations using resistant crops are recommended to reduce RLN density to below threshold levels.
- 25 Stem nematode (1998). GRDC Ground Cover Issue 22, 01 January 1998, <u>https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover/Stem-nematode</u>
- 26 Stem nematode PestFacts south eastern Issue 6 15 July 2011, <u>http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2011/pestfacts-issue-no-6-15th-july-2011/stem-nematode/</u>
- 27 Stem nematode (1998). GRDC Ground Cover Issue 22, 01 January 1998, <u>https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover/Sourd-Co</u>
- Stem nematode PestFacts south eastern Issue 6 15 July 2011, <u>http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2011/pestfacts-issue-no-6-15th-july-2011/stem-nematode/</u>
 Stem nematode Fact Sheet. Plant Health Australia, <u>http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-</u>
- Stem nematode Fact Sheet. Plant Health Australia, <u>http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf</u>
- 30 Stem nematode (1998). GRDC Ground Cover Issue 22, 01 January 1998, <u>https://qrdc.com.au/Media-Centre/Ground-Cover/Ground-Cover/Ground-Cover/Stem-nematode</u>
- 31 CropPro (2014) Root lesion nematode (RLN), <u>http://www.croppro.com.au/crop_disease_manual/ch03s07.php</u>





Reducing RLN densities can lead to higher yields in subsequent cereal crops. ³²

Pratylenchus nematodes are microscopic, worm-like organisms, less than 1 mm in length. They feed on and in root tissues using a syringe-like stylet to enter the roots and extract nutrients. Many species of RLN are found in Australia. At least 20% of cropping paddocks in south-eastern Australia have populations of RLN high enough to reduce yield. ³³ In South Australia and Victoria, the main species are *P. neglectus* and *P. thornei*; however, *P. penetrans* and *P. crenatus* have also been reported, albeit at a very low frequency. Species identification is important for effective RLN management. Some crops, varieties and plant types have different levels of resistance to different species of the *Pratylenchus* family. Pastures vary in their susceptibility to RLN, and under some pastures, nematode levels could increase and become damaging to subsequent cereals. Pastures should therefore be monitored for RLN as other crops are, and their place in the rotation should be considered for RLN management. ³⁴

The extent of RLN occurrence across Australia has recently been estimated (Figure 2).



Figure 2: The distribution and risk of causing yield loss of samples submitted to PreDictaB, SARDI in autumn 2015 for (top) Pratylenchus thornei and (bottom) *P. neglectus.*

Maps are reproduced with permission from <u>SARDI</u>. Source: <u>GRDC</u>

RLN emerged as potential problems in cereals (and other crops) after management strategies were implemented to control CCN and take-all. Yield losses in the

- 32 GRDC Tips and Tactics Root-Lesion Nematodes Southern Region (2015). <u>https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes</u>
- 33 Agriculture Victoria (2013) Cereal root diseases, <u>http://agriculture.ic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases</u>
- 34 GRDC Tips and Tactics Root-Lesion Nematodes Southern Region (2015), <u>https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes</u>





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WATCH: <u>Root-Lesion Nematodes.</u> <u>Resistant cereal varieties have</u> <u>surprising impacts on RLN numbers.</u>



southern region are variable and currently under investigation, but present estimates for intolerant varieties indicate a 1% yield loss per 2 nematodes per gram soil. *Pratylenchus thornei* (Figure 2) occurs throughout the root zone and is often more damaging than *P. Neglectus*, which tends to be concentrated in the top 15 cm of the soil.

8.3.1 Varietal resistance or tolerance

In the Southern growing region oats are rated as having *low risk* hosting ability for *P. thornei* and *medium to high risk* host ability of *P. neglectus*. ³⁵

8.3.2 Damage caused by RLN

In the Southern Region, high densities of RLN generally cause yield losses of 10–20% in susceptible crops. The extent of damage, and subsequent grain yield loss, depend on seasonal conditions, the tolerance of the crop and the numbers of nematodes present at sowing. In field trials carried out by the Victorian and South Australian state departments from 2011 to 2013, *P. thornei* reduced grain yield in intolerant varieties by 2–12%, and *P. neglectus* reduced grain yield by 2–8%. ³⁶

RLN are more likely to be a problem when:

- Susceptible varieties are grown sequentially increasing nematode numbers.
- An intolerant crop is sown.
- Sowing is delayed. ³⁷

During recent years the Department of Economic Development and SARDI have conducted field studies to quantify losses caused by RLN in the southern cropping region. This work measured grain yield in the presence of high and low numbers of the target nematode. Table 6 shows the average yield loss caused by RLN in the five most intolerant cereal cultivars in Victorian field trials. There was large seasonal effects observed. The yield losses caused by *P. neglectus* were less than those caused by *P. thornei*.

Table 6: Average yield loss due to root lesion nematodes in the five most intolerant

 cereal cultivars across five growing seasons along with average rainfall.

<i>P. thornei</i> (Banyena, Victoria)			<i>P. neglectu</i> Victo	vs (Dooen, oria)
Year	Yield Loss (%)	Rainfall (mm)	Yield Loss (%)	Rainfall (mm)
2011	12.2	241	2.0	256
2012	9.9	268	6.7	254
2013	1.9	353	2.5	326
2014	4.3	253	6.7	215

Source: <u>GRDC</u>

8.3.3 Symptoms

What to look for

Paddock:

- Crops appear patchy with uneven growth, and may appear nutrient deficient (Photo 10).
- Double sown and more fertile areas are often less affected.

35 GRDC Tips and Tactics Root-Lesion Nematodes – Southern Region (2015), <u>https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes</u>

36 GRDC Tips and Tactics Root-Lesion Nematodes – Southern Region (2015), <u>https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes</u>

37 G Hollaway (2013) Cereal root diseases, <u>http://agriculturevic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases</u>





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• Affected plants are stunted and poorly tillered and can wilt despite moist soil.

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- Roots can have indistinct brown lesions or, more often, generalised root browning.
- Badly affected roots are thin and poorly branched with fewer and shorter laterals (Photo 11).
- Roots may appear withered with crown roots often less affected than primary roots.
 - Roots can assume a 'noodle-like' root thickening appearance. ³⁸



Photo 10: Above-ground symptoms of RLN, primarily in the form of moisture stress and nutrient deficiency.

Photo: Doug Sawkins









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Photo 11: Oat plants with roots damaged by RLN. Note lack of root hairs and darkened areas. The shoots show phosphate deficiency, a result of damaged roots having poor uptake of nutrients.

Photo: Doug Sawkins

Table 7: What else it could be. 39

Condition	Similarities	Differences
Diagnosing rhizoctonia root rot in cereals	Patches of stunted plants	Rhizoctonia root rot patches are more distinct with spear tip roots.
Trifluralin and no-till sowing with tynes	Cause 'spaghetti root' symptoms	However symptoms are worse on shallower sown plants in more sandy low-organic-matter soils, and seriously damaged plants have very stubby thickened roots.
Nutrient deficiencies	Pale plants	Root-lesion nematodes cause the characteristic 'spaghetti roots'.









Pratylenchus thornei, in the Southern Region at 10 nematodes/g soil can cause grain yield losses of 10–15% in intolerant varieties, depending on seasonal conditions. ⁴⁰ The damage threshold has been estimated at 2,000 nematodes/kg soil (or 2/g soil). Control is warranted for paddocks with populations over this density threshold. ⁴¹

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8.3.5 Conditions favouring development

Root-lesion nematodes are migratory plant parasites that move freely between roots and soil if the soil is moist. In the Southern Region, the life cycle of RLN begins after the opening rains in autumn. Juvenile and adult nematodes rehydrate, become active and invade plant roots, where they feed and multiply as they move through the root. The optimum temperature for nematode reproduction is 20°–25°C. The life cycle is generally completed in 40–45 days (~6 weeks) depending on temperature. As plants and soil dry out in late spring, RLN enter a dehydrated survival state called anhydrobiosis. In this state, nematodes can survive high soil temperatures of up to 40°C and desiccation over summer. RLN can survive many years in this dehydrated state if the soil remains dry. Nematodes can also survive in root pieces.

Intensive cropping of susceptible crops—particularly wheat and chickpeas—can lead to an increase in nematode populations and greater yield loss in subsequent crops. ⁴²

8.3.6 Management

Key points

- Know your enemy—soil test to determine whether RLN are an issue and which species are present.
- Select oat varieties with high tolerance ratings to minimise yield losses in RLN infected paddocks.
- To manage RLN populations, it is important to increase the frequency of RLN resistant crops in the rotation.
- Multiple resistant crops in a rotation will be necessary for long term management of RLN populations.
- Avoid crops or varieties that allow the build-up of large populations of RLN in infected paddocks.
- Monitor the impact of your rotation.

There are four key strategies in reducing the risk of RLN:

- 1. Have soil tested for nematodes in a laboratory.
- 2. Protect paddocks that are free of nematodes by controlling soil and water runoff and cleaning machinery; plant nematode-free paddocks first.

Choose tolerant wheat varieties to maximise yields (go to <u>nvtonline.com.au</u>). Tolerant varieties grow and yield well when RLN are present.

Rotate with resistant crops to prevent increases in root-lesion nematodes (Figure 1, Table 2). When high populations of RLN are detected, you may need to grow at least two resistant crops consecutively to decrease populations. In addition, ensure that fertiliser is applied at the recommended rate to ensure that the yield potential of tolerant varieties is achieved.

Control strategies:

Manage RLN by maintaining nematode numbers below threshold levels by growing resistant crops and varieties.

41 GRDC (2015) Tips and tactics: Root lesion nematodes southern region, <u>www.grdc.com.au/TT-RootLesionNematodes</u>



⁴⁰ GRDC Tips and Tactics Root-Lesion Nematodes – Southern Region (2015), <u>https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes</u>

⁴² GRDC Tips and Tactics Root-Lesion Nematodes – Southern Region (2015), <u>https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes</u>



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WATCH: <u>What lies beneath –</u> managing RLNs to combat yield loss.

What lies beneath...



managing nematodes to combat yield loss

WATCH : <u>Root lesion nematodes</u> <u>What can I do?</u>



WATCH : <u>Crop variety effect on</u> <u>nematode.</u>



 In heavily infested paddocks, resistant crops or varieties should be grown for 1 or 2 years to decrease RLN populations.

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- Weeds can play an important role in the increase and/or persistence of nematodes in crops and pastures. Therefore, poor control of susceptible weeds will compromise the use of resistant crop rotations for RLN management.
- Healthier plants recover more readily from infestation. Providing adequate nutrition (especially nitrogen, phosphorus and zinc) will allow plants to better tolerate plant parasitic nematodes, although this does not lead to lower nematode reproduction.
- Nematodes cannot move large distances unaided. However, they can be spread by surface water, and in soil adhering to vehicles and farm machinery. In uninfested areas, good hygiene should be adopted. They can also be spread in dust when they are in a dehydrated state over summer. ⁴³

There are four major control strategies against RLN:

- Nematicides (control in a drum): There are no registered nematicides for RLN in broadacre cropping in Australia. Screening of potential candidates continues to be conducted but RLN are a very difficult target with populations frequently deep in the soil profile.
- Nutrition: Damage from RLN reduces the ability of cereal roots to access nutrients and soil moisture and can induce nutrient deficiencies. Under fertilising is likely to exacerbate RLN yield impacts however over-fertilising is still unlikely to compensate for a poor variety choice.
- 3. Variety choice and crop rotation: These are currently our most effective management tools for RLN. However, the focus is on two different characteristics—Tolerance (ability of the variety to yield under RLN pressure) and Resistance (impact of the variety on the buildup of RLN populations). NB varieties and crops often have varied tolerance and resistance levels to *Pratylenchus neglectus* and *P. thornei*.
- Fallow: RLN populations will generally decrease during a "clean" fallow, but the process is slow and expensive in lost "potential" income. Additionally long fallows may decrease Mycorrhizal (VAM) levels and create more cropping issues than they solve. 44

Cultural control

Testing for Root-lesion nematodes

On-farm

Growers are advised to check the roots of the host crops if they suspect RLN infestations. Carefully dig up roots, then wash the soil from the roots of an infected plant and inspect for symptoms (as above). If evidence of infestation in the roots is observed, then a laboratory analysis or a <u>PreDicta B</u> test can be used to determine species and density.

Commercial

A DNA test, <u>PreDicta B</u>, is commercially available around Australia and growers should contact their state department of agriculture for advice.

Grain producers can access PreDicta B via agronomists accredited by SARDI to interpret the results and provide advice on management options to reduce the risk of yield loss.

PreDicta B samples are processed weekly from February to mid-May (prior to crops being sown) to assist with planning the cropping program.



⁴³ GRDC Tips and Tactics Root-Lesion Nematodes – Southern Region (2015), <u>https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes</u>

⁴⁴ B Burton, R Norton, R Daniel (2015) GRDC Update Paper: Root-lesion nematode; importance, impact and management. NGA, <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management</u>



Crop diagnosis is best achieved by sending samples of affected plants to your local plant pathology laboratory. $^{\rm 45}$

⁴⁵ GRDC Tips and Tactics Root-Lesion Nematodes – Southern Region (2015). <u>https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes</u>



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Key messages:

- The major diseases that affect oats are stem rust, leaf rust, Barley yellow dwarf virus (BYDV) and Septoria avenae blotch, with the severity changing with seasons (Table 1).
- Oats are more at risk of disease in high rainfall areas.



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It is important that growers understand the resistance ratings of their varieties to the diseases of importance in their region and plan management strategies accordingly.

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 General management strategies for preventing disease are ensuring hygienic use of all equipment and clothing, optimizing crop rotation, minimising weed and insect infiltration, monitoring for disease and timely spraying.

Table 1: Oat disease guide. The major diseases that impact oats: leaf rust, stem rust, Septoria blotch and Barley yellow dwarf virus (BYDV).

Disease	Organism	Symptoms	Occurrence	Hosts	Control
Foliar					
Leaf rust	Puccinia coronata f.sp.avenae	Small circular orange pustules on upper leaf surface.	More severe during moist conditions with temperatures between 15–22°C.	Volunteer oats and wild oats.	Resistant varieties. Control volunteer and wild oats over the summer.
Stem rust	Puccinia graminis f.sp.avenae	Large red-brown pustules, rupture in leaf and stem surface.	Infection requires warm (15–30C) moist conditions.	Volunteer oats and wild oats.	Resistant varieties. Control volunteer and wild oats over summer.
Septoria blotch	Phaeosphaeria avenaria	Dark brown purple spots on leaves, sheaths and stems. Head and grain may become infected.	Prefers cool rainy weather, especially coastal districts.	Spores spread in autumn by raindrop splashes from oat residues.	Resistant varieties. Crop rotation, bury or graze infected stubble. Avoid early sowing in high rainfall areas.
BYDV	Barley yellow dwarf virus	Leaf tip and margins turn red with interveinal chlorosis, mottling and stunting.	Transmitted by aphids.	Hosts include all cereals and grasses, including pastures.	Resistant varieties. Chemical control of insects may be suitable for high value crops.
Halo blight	Pseudomonas syringae pv. coronafaciens	Light green, yellow or brown halo spot on leaves and sheaths. Leaves may wither and die.	Moist weather provides ideal conditions.	Bacteria on seed and crop debris are spread by rain splash, direct leaf contact, or aphids.	Avoid susceptible varieties, use clean seed in clean paddocks. Destroy infected oat stubble.
Stripe blight	Pseudomonas syringae pv striafaciens	Spots on leaves lengthen to form brown stripes on leaves and sheaths. Leaves may wither and die.	Moist weather provides ideal conditions.	Bacteria on seed and crop debris are spread by rain splash, direct leaf contact, or aphids.	Avoid susceptible varieties, use clean seed in clean paddocks, and destroy infected oat stubble.
Red leather leaf	Spermospora avenae	Long reddish lesions with buff centres. Leaves may look and feel leathery.	High rainfall provides ideal conditions.	Stubble and rain splash.	Avoid susceptible varieties and rotate crops. Remove infected oat stubble.
Grain					
Smut	Ustilage segetum var. hordei. and Ustilage avenae	Grain replaced with dark brown-black powdery spores.	Moist conditions at flowering and temperatures between 15–25°C.	Air-borne spores lodge in hulls, glumes or seed coats.	Clean seed and use seed treatment. Avoid susceptible varieties.
Root/crown					
Cereal cyst nematode (CCN)	Heterodera avenae	Yellow or pale green patches in crop. Stunted, weak plants with knotted root systems	Can survive in soil between susceptible cereal crops for up to 2 years.	Cereals and some grasses, especially wild oats.	Resistant or tolerant varieties, crop rotation, weed control.





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Disease	Organism	Symptoms	Occurrence	Hosts	Control
Foliar					
Stem nematode	Ditylenchus dipsaci	Swollen base of plant, stunted and numerous tillers.	Encouraged by moist conditions and can reproduce 4–5 times per season.	Wide host range including peas, beans, wild oats and many weeds. Nematode spread in infected hay.	Crop rotation and weed control. Avoid susceptible varieties.
Root lesion nematode	Pratylenchus thornei and Pratylenchus neglectus	Reduced tillering, ill thrift; lack of branching of root system, lesions on roots.	Favoured by wheat in rotation with wheat chickpea, medic and vetch.	Survives as dormant nematodes in the soil.	Crop rotation using resistant crops.

Source: AqVic

This table has been developed from information in the publications Wallwork H (2000) (Ed) Cereal Root and Crown Diseases (Grains Research and Development Corporation, SARDI) and Wallwork H (2000) (Ed) Cereal Leaf and Stem Diseases (Grains Research and Development Corporation, SARDI).

General disease management strategies

- Use resistant or partially resistant varieties.
- Use disease-free seed.
- Use fungicidal seed treatments to kill fungi carried on the seed coat or in the seed.
- Have a planned in-crop fungicide regime.
- Conduct in-crop disease audits to determine the severity of the disease. This can be used as a tool to determine what crop is grown in what paddock the following year.
- Conduct in-fallow disease audits to determine the severity of the disease, e.g. crown rot. This can also be used as a tool to determine what crop is grown in what paddock the following year.
- Send plant or stubble samples away for analysis to determine the pathogen or strain you are dealing with or the severity of the disease
- Keep the farm free from weeds, which may carry over some diseases. This
 includes cereals over summer that may act as a green bridge.
- Rotate crops.¹

Stay up to date with local disease guides: <u>Cereal disease guide 2016–SA</u> and <u>Cereal disease guide 2016–Vic</u>

9.1 Tools for diagnosing cereal disease

Crop Disease Au App



The Australian Field Crop Disease Guide app allows the user to quickly identify crop diseases, compare disease-resistance ratings for cereal, pulse and oilseed varieties and, potentially facilitate the early detection of exotic crop diseases.

The app brings together disease resistance ratings, disease information and also features an extensive library of quality images that make it easier for growers to diagnose crop diseases and implement timely management strategies. Live feeds from the Australian National Variety Trials (NVT) database means the app is always up to date with the latest varieties.





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If a disease cannot be identified, there is also a function that allows the user to take a photo of their crop and email it to a friend or an advisor.

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The precursor for this app was the Victorian DEDJTR Crop Disease app developed by a team of grains pathologists. The new Crop Disease Au app functions similarly to the previous DEDJTR app, but provides information for all Australian grain growing regions.

MyCrop



Released by DAFWA and funded by the GRDC, MyCrop is a collection of interactive tools that can be accessed online or via apps that enable users to diagnose cereal production constraints while in the field.

The main feature is an intuitive diagnostic key, which quickly diagnoses a range of possible constraints based on real-time crop and paddock symptoms. Covering a broad range of disease, pest and other agronomic issues, MyCrop can help users to accurately identify constraints and determine possible management solutions.

Key features include:

- Extensive image library and constraint factsheets.
- Selecting paddock and plant clues to easily identify the likely cause of cropping problems.
- Over 150 constraints ranging from pests and diseases to soil deficiencies, environmental and management factors.
- Online diagnostic tools.

CropPro Web-based

DEDJTR and GRDC's newly released online tool CropPro has diagnostic and economic features that allow growers to efficiently identify and manage constraints to both crop productivity and profitability. The core functions of CropPro are to diagnose the cause of wheat and canola crop problems, support risk analysis and provide evidence-based information for management of crop constraints. It combines paddock and crop symptoms in one resource, enabling users to work through a simple process of elimination. CropPro also has an economic feature allowing growers to compare return-on-investment outcomes for different management options and an Agronomist Toolkit that includes an extensive list of resources, online decision support tools and apps. For the first time the Field Crop Diseases Manual is available online! This provides an all-in-one resource for disease identification, biology and management information for cereal, pulse and oilseed crops. The manual is written and maintained by leading subject experts from DEPI and Marcroft Grains Pathology, and provides a detailed exploration of diseases and the influence of pest and abiotic factor. A series of economic videos also feature on CropPro, providing growers with clear information about how management decisions might influence their profitability.

9.2 Varietal resistance or tolerance

The major diseases that affect oats are stem rust, leaf rust, BYDV and Septoria, with the severity changing with seasons. In the medium and low rainfall areas, diseases of oats are usually of reduced significance. Bannister and Williams offer advantages in their rust resistance profiles over other varieties (Table 2 and 3). Although still showing susceptibility to septoria, the susceptible and moderately susceptible



) MORE INFORMATION

<u>MyCrop</u>

GRDC Cereal root and crown diseases: Back pocket guide.



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ratings these varieties carry should show visible improvements in the field over very susceptible lines. $^{\rm 2}$

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Table 2:	Oat variety agronomic guide and disease reactions in south eastern
Australia	. Oat disease reactions provided by Pamela Zwer, SARDI.

	End use	Height	Maturity	Hectolitre weight	Stem Rust	Leaf Rust	CCN		BYDV	Septoria	Bacterial	Red
							Res	Tol			blight	Leather Leaf
Milling Oats												
Bannister	Μ	TD	М	Н	S	R	VS	T	MS	S	S	MS
Mitika	Μ	D	Е	Н	S	S	VS	I	S	S	MR	S
Durack	Μ	Т	E	Н	S	R-S	R	MI- MT	MS-S	S	MR-S	MS
Possum*	М	D	EM	Н	-	-	-	-	-	-	-	-
Williams	Μ	MT	E	Н	S	R	S	I	MS	MS	R	MS
Wombat	Μ	D	EM	Н	S	MS	R	Т	MR	MS	MS	MS
Yallara	М	MT	EM	Н	S	MS	R	I	MS	MS	MS	MS
Hay/Grazing/Feed												
Brusher	H/G/F	Т	EM	М	S	S	R	MI	MS	MS	MS	MS
Forester	Н	MT	VL	L	S	MS	MS	MI	S	MR	S	RMR
Kangaroo	Н	MT	ML	М	S	S	R	MT	S	MS	MS	MS
Mulgara	Н	Т	EM	М	MS	MS	R	MT	MS	MS	MR	MSS
Tammar	Н	MT	LM	L	S	MS	MR	MT	MS	MR	MR	R-MS
Tungoo	Н	MT	ML	L	S	MS	R	MT	MS	MR	MR	R
Wintaroo	H/G	Т	FM	М	S	S	R	MT	MRMS	MS	MS	MS

End use: M = milling, F = feed grain, G = grazing, H = hay Hectolitre weight: H = heavy, M = medium, L = light

Plant height: D = dwarf, TD = tall dwarf, T = tall, ST = short tall, MT = moderate tall

Maturity: E = early, EM = early mid, M = mid-season, ML = mid-late season, LM = late mid-season, L = late, VL=very late

Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS.

p = provisional ratings - treat with caution. R = resistant, M = moderately, S = susceptible, V = very.

Disease tolerance: T = tolerant, MT = moderately tolerant, MI = moderately intolerant, I = intolerant

* Disease ratings on these older varieties are not current and have not been included.

Source: Cereal Disease Guide

It is important that growers understand the resistance ratings of their varieties to the diseases of importance in their region and plan management strategies accordingly (Table 3). Managing the green bridge will be important after summer rain events.

9.3 Barley yellow dwarf virus (BYDV)

Key points:

- The virus is spread by aphids which transmits the disease from infected plants and grasses onto crop plants within 15 minutes of feeding.
- Wet summers and autumns promote growth of host grasses and build-up of aphid vectors resulting in early crop infection, severe symptoms and yield losses.
- BYDV tends to be more serious in the high rainfall cropping regions in Victoria and South Australia, but can occur in all cropping regions.
- The virus only survives in living tissues. It does not survive in stubbles or soils and is not air-borne.
- The virus is best controlled by more resistant varieties and monitoring and spraying for aphids early in the season.

2 G Troup (2016) Oats: choosing a variety, Disease resistance. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-choosing-variety?page=0%2C2</u>





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The yellow dwarf diseases of cereals have now been divided into two groups: BYDV and cereal yellow dwarf virus (CYDV). They are the most important virus diseases of cereals worldwide. They have a wide host range including oats, wheat, barley, triticale and over 150 grass species. ³

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The virus survives between growing seasons in grasses which persist through the summer. Infection is spread from the grass reservoirs to oats and other cereals through the migration of cereal and grass aphids. Because of the role of aphids in establishing infection, BYDV is always more severe following wet summers when aphid survival and build-up has occurred. ⁴

Growers in high rainfall zones should be proactive and develop a BYDV management plan which includes crop monitoring, green bridge management, foliar pesticide sprays and pre-sowing seed treatment. These actions will control aphid populations which spread BYDV. 5

9.3.1 Varietal resistance or tolerance

See <u>Section 9.2 Varietal resistance or tolerance</u> for disease ratings for BYDV.

9.3.2 Damage caused by BYDV

Work in 1984 estimated yield losses caused by BYDV in Victoria to be 2% with up to 20% in individual crops. Trial data has shown that yield losses of between 9-79% can occur when plants are infected early in the growing season (before the end of tillering) and losses of 6-9% may occur when plants are infected late (post tillering). ⁶

9.3.3 Symptoms

Symptoms first appear three to five weeks after infection.

Paddock

Symptoms usually appear as patches of yellow or red stunted plants. The symptoms first appear where aphids have landed. Flying aphids may infect individuals or groups of plants dotted throughout the crop. If the aphids colonise the crop rings or patches develop which increase in size with time (Photo 1). If crawling aphids move into the crop from adjoining pastures or crops then symptoms will appear along the fence line first. ⁷



Photo 1: Reddening of oat leaves from the tip down and striping of young leaves is caused by Barley yellow dwarf virus (right) Barley yellow dwarf virus infection is often seen on plants at the edges of the crop (left).

Source: DAFWA

- 3 Agriculture Victoria (2003) Barley yellow dwarf virus. Ag note AG1113 August 2003 Updated June 2011, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus</u>
- 4 GJ Thomas, R Loughman (2016) Oats: leaf diseases, Barley yellow dwarf virus, DAFWA, <u>https://www.aqric.wa.gov.au/oats/oats-leafdiseases?page=0%2C3</u>
- 5 <u>GRDC Barley yellow dwarf virus Southern region Factsheet</u> (2013). GRDC 11 September 2013, <u>https://grdc.com.au/Resources/</u> Factsheets/2013/09/Barley-Yellow-Dwarf-Virus
- 6 Agriculture Victoria (2003) Barley yellow dwarf virus. Ag note AG1113 August 2003 Updated June 2011, <u>http://agriculture.vic.gov.au/</u> agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus
- 7 Agriculture Victoria (2003) Barley yellow dwarf virus. Ag note AG1113 August 2003 Updated June 2011.<u>http://agriculture.ic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus</u>







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Early infections may cause interveinal chlorosis, severe stunting, increased number of weak tillers, and abortion of florets. Late infections usually result in characteristic reddening of new leaves. Look for yellow-brown or orange-brown, diffuse blotches near the leaf tip (Photo 2). The blotches enlarge and fuse until most of the leaf is affected and appears orange-brown. Later it changes to crimson-pink which is recognised easily in the field. Oats affected as seedlings may show additional symptoms of severe stunting, increased tillering and floret abortion. Infection after tillering causes a characteristic 'reddening' of later emerging leaves and tipreddening and death of older leaves. The distribution of infection within the paddock is normally patchy but occasionally the whole crop may show symptoms. ⁸



Photo 2: Barley yellow dwarf virus in oats, showing sterility (blasting) at the stem base. 9

Photo: Terry Hahn

Symptoms of BYDV can be confused with those caused by nutrient deficiencies, waterlogging or other plant stresses that cause yellowing and interveinal chlorosis or reddening of leaves. The disease can be distinguished from nutritional deficiencies by its pattern of spread. Nutrient problems tend to be more uniform across paddocks.

9.3.4 Conditions favouring development

Early-sown crops are more at risk. The virus is usually spread by aphids from infected grasses to crops. Wet summers and autumns promote growth of host grasses and build-up of aphid vectors resulting in early crop infection, severe symptoms and yield losses.

In Victoria, perennial ryegrass is the main reservoir of CYDVs in the high rainfall areas. The virus and vectors can survive in small pockets of surviving grass even in the low rainfall areas. The aphid vectors of the viruses tend to build up in autumn and spring on the grasses, and then move into cereal crops where they often develop colonies. High rainfall areas have a greater build-up of the grasses, virus and vectors.

The most common vectors found in Victoria are the oat aphid (Rhopalosiphum padi), the corn aphid (R. maidis), the English grain aphid (Sitobian miscanthi) and the rose grain aphid (Metopolophium dirhodum). The viruses are not transmitted by any other insects and are not transmittable through seed, soil or sap. The aphids need to feed



GJ Thomas, R Loughman (2016) Oats: leaf diseases, Barley yellow dwarf virus, DAFWA, https://www.agric.wa.gov.au/oats/oats-leafdiseases?page=0%2C3

H Wallwork (2000) Cereal leaf and stem diseases. GRDC



on an infected plant for at least 15 minutes followed by a latent period of 12 hours, before the virus will transmit to a healthy plant. Aphids remain infected for the rest of their life. $^{\rm 10}$

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Considerable BYDV spread can occur even when aphid numbers are low. Symptoms can be hard to see in winter. Consultation with an agronomist or crop pathologist is recommended. $^{\rm 11}$

9.3.5 Management of BYDV

BYDV outbreaks are likely to be worse in years when wet cool summers allow larger than normal numbers of aphids and alternate hosts to survive summer; followed by a mild winter which favours the build-up of aphid numbers. Early-sown crops or long season crops sown in high rainfall areas are particularly vulnerable to this disease.

Growers in high risk areas should treat each year as a 'BYDV year' unless there has been low rainfall over summer and autumn. Waiting until aphids or BYDV symptoms are found is too late.

Where resistant varieties (see Table 3) are not an option the management of aphid activity in crops, especially early in the season to prevent its spread, and/or delayed sowing to avoid the main aphid flights in the autumn can reduce BYDV infection.

Delayed sowing avoids the main autumn peak of aphid flights and can reduce the incidence of BYDV. However, other yield penalties associated with late sowing make this option generally considered a poor choice over using insecticides. Growers in the late sown high rainfall areas should note that late sowing may coincide with peak spring flights of aphids resulting in more severe damage.¹²

Resistant varieties

Resistant varieties when available are the preferred option for management. There are a number of oat and a couple of wheat and barley varieties with varying levels of resistance (refer to Tables 2 and 3 above). In oats, current varieties range from moderately resistant, (e.g. Wombat^(d)) to susceptible.

Chemical control

It is vital to prevent spread of the virus by aphids during the first 8–10 weeks after crop emergence using insecticides. Foliar sprays can be used early after crop emergence if aphids are easily found. There are a number of products registered for control of aphids in cereals.

Seed dressings

In situations where aphids are likely to be a problem in the first few weeks after sowing, a seed treatment containing imidacloprid could be used for protection. Imidacloprid is registered for use on cereal crops as a seed dressing for the management of aphids and BYDV spread in cereal crops. Seed dressings with imidacloprid have been shown to reduce aphids in cereal crops at the early stage of growth when cereals are most susceptible to BYDV. Do not graze treated cereal crops within nine weeks of sowing. In high risk areas, a top-up spray (see insecticides section below) is recommended at six to eight weeks after sowing. ¹³

- 10 Agriculture Victoria (2003) Barley yellow dwarf virus. Ag note AG1113 August 2003 Updated June 2011.<u>http://agriculture.vic.gov.au/</u> agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus
- 11 GRDC Barley yellow dwarf virus Southern region Factsheet (2013). GRDC 11 September 2013, <u>https://grdc.com.au/Resources/</u> Factsheets/2013/09/Barley-Yellow-Dwarf-Virus.
- 12 GRDC Barley yellow dwarf virus Southern region Factsheet (2013). GRDC 11 September 2013, <u>https://grdc.com.au/Resources/</u> Factsheets/2013/09/Barley-Yellow-Dwarf-Virus.
- 13 GRDC Barley yellow dwarf virus Southern region Factsheet (2013). GRDC 11 September 2013, <u>https://grdc.com.au/Resources/</u> Factsheets/2013/09/Barley-Yellow-Dwarf-Virus.




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Insecticides

In high risk areas, such as the long season areas of South Australia and Victoria, which have received high summer rainfall, growers can apply insecticides before aphids and/or BYDV symptoms are evident. This is considered a risk-based application. The insecticides will help kill and repel the aphids, leading to increased yields, particularly when plants are young and small. Growers can utilise a range of approved insecticides to manage the aphids. As well as pyrethroids, there are spray options which can have less impact on non-target insects. These may suit farmers trying to incorporate integrated pest management into their system. Advice prior to spraying is essential. Trial results indicate that spraying the crop in its early stages with synthetic pyrethroid to prevent aphid establishment can provide good protection and is feasible in high risk areas. ¹⁴ Synthetic pyrethroids will have a detrimental effect on many beneficial insects. The active ingredient pirimicarb only effects aphids and will have less effect on any beneficial insects present at the time of spraying. You will need to discuss with your agronomist the insecticide best suited to your situation.

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Trial results have led to the recommendation that sprays are applied three and seven weeks after crop emergence. This is because BYDV symptoms are usually not obvious until three weeks after the aphids have fed on plants. These applications will enable aphid populations to be managed before the problem has been noticed and the aphids have spread even further. In years conducive to aphid build-up, a follow-up insecticide application in spring, with both the early foliar or seed treatment strategies, may be required to limit feeding damage. The effect of late BYDV infection by itself is generally not sufficient to warrant spraying in spring so the decision should be purely based on aphid pressure.¹⁵

Table 3: Cereal insecticide seed dressings for aphid and Barley yellow dwarf virus (BYDV) control 2015. $^{\rm 16}$

Active ingredient of insecticide and fungicide— various trade names sometimes available under these active ingredients, concentrations and formulations. See specific labels for details.	Examples of seed treatment trade name and manufacturer	Rate to apply to each 100 kg###	Approx. cost to treat 100 kg of seed (\$)##	Aphid feeding damage suppression (wheat aphid and corn aphid)	Reduces spread of BYDV	Grazing withhold- ing period (weeks)
lmidacloprid 180 g/L + tebuconazole 6.25 g/L	Hombre [®] – Bayer CropScience	400 mL	7.46	\checkmark	\checkmark	9
lmidacloprid 360 g/L + tebuconazole 12.5 g/L	Hombre [®] Ultra– Bayer CropScience	200 mL	7.70	\checkmark	\checkmark	9
lmidacloprid 180 g/L + triadimenol 56 g/L	Zorro [®] – Bayer CropScience	400 mL	8.90	\checkmark	\checkmark	9
lmidacloprid 180 g/L + flutriafol 6.25 g/L	Veteran® Plus – Crop Care	400 mL	9.70	\checkmark	\checkmark	9
lmidacloprid 180 g/L + flutriafol 25 g/L	Arrow [®] Plus – Crop Care (registered for barley only)	400 mL	10.25	✓	\checkmark	9
lmidacloprid – 350 g/L	Gaucho® 350 – Bayer CropScience	200 mL–400 mL	7.37–14.74	\checkmark	\checkmark	9
lmidacloprid – 600 g/L	Gaucho [®] 600 – Bayer CropScience	120 mL–240 mL	5.00-9.99	\checkmark	\checkmark	9
Lambda-cyhalothrin 37.5 g/L +Thiamethoxam 210 g/L	Cruiser® Opti – Syngenta	165–330 mL	22.60–45.19	\checkmark	\checkmark	8

Prices quoted are GST inclusive at February 2016 and approximate only. Prices will vary depending on pack size purchased and special marketing arrangements.

Rate of product varies for length of disease control and risk level, check label. 🗸 Affords useful suppression in early crop growth stages.

14 GJ Thomas, R Loughman (2016) Oats: leaf diseases, Barley yellow dwarf virus, DAFWA, <u>https://www.aqric.wa.gov.au/oats/oats-leafdiseases?page=0%2C3</u>

15 GRDC Barley yellow dwarf virus Southern region Factsheet (2013). GRDC 11 September 2013, <u>https://grdc.com.au/Resources/</u> Factsheets/2013/09/Barley-Yellow-Dwarf-Virus.





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<u>GRDC Barley yellow dwarf virus</u> Southern region Factsheet



Management of the green bridge (volunteer cereals and grass weeds) through appropriate herbicides is important for managing BYDV, not to mention the associated benefits of moisture/nutrient conservation. On top of summer weed control, spraying out perennial grasses near and around cereal paddocks at least three weeks before sowing may reduce aphid numbers. ¹⁷

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9.4 Septoria avenae blotch

The disease is caused by the fungus *Parastagonospora avenaria* f.sp. *avenaria* (synonym: *Phaeosphaeria or Stagonospora avenae* f.sp. *avenaria*). It is not one of the septoria diseases of wheat, which are caused by different species. It occurs throughout the cereal growing areas, and is most severe in the high rainfall areas.

9.4.1 Varietal resistance or tolerance

See section 9.2 Varietal resistance or tolerance for disease ratings for Septoria avenae blotch.

9.4.2 Damage caused by disease

Septoria avenae blotch may cause up to 50% yield loss and crop lodging in extreme cases but losses of around 10% are more common in high rainfall areas. Tall or slow maturing oats are less likely to be affected by the disease than short (dwarf) or fast maturing varieties (Photo 3).



Photo 3: Tall late maturing oat varieties (right) are less prone to Septoria avenae blotch than short, early maturing varieties (left).

Source: DAFWA

9.4.3 Symptoms

The fungus infects leaves, sheaths and stems (Photo 4) and may also infect heads. Symptoms begin as mottled light and dark brown blotches, with dark brown centres. They are restricted and distinct at first but may enlarge to cover most of the leaf.



¹⁷ GRDC Barley yellow dwarf virus Southern region Factsheet (2013). GRDC 11 September 2013, <u>https://grdc.com.au/Resources/</u> Factsheets/2013/09/Barley-Yellow-Dwarf-Virus.





Photo 4: Leaves affected by Septoria avenae blotch. Source: DAFWA



Photo 5: Stems affected by Septoria avanae blotch. Source: <u>DAFWA</u>

Lesions in the leaf sheath extend into the stem causing death and blackening (Photo 5) which may lead to lodging. The fungus sometimes causes a dark discolouration of the grain (Photo 6) when unseasonably late rain occurs.





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Photo 6: Grain showing discolouration from Septoria avanae blotch.

Source: DAFWA

What to look for

Paddock:

 Plant with blotched, yellowing and dead leaves evenly distributed across paddock.

Plant:

- Symptoms begin as small dark brown to purple, oval or elongated spots on leaves. Spots grow into larger light or dark brown blotches with surrounding yellow areas that can cover and kill the entire leaf.
- Infection may spread to leaf sheaths and through to stems, where greyish-brown or shiny black lesions may cause lodging.
- Dark brown blotches can also occur on the head and grain. ¹⁸

9.4.4 Conditions favouring development

Infected stubble is the main source of carryover infection from one season to another. The sexual stage of the fungus occurs on infested stubble and produces ascospores which are spread moderate distances by wind. Oat stubbles in paddocks rotating from oat probably contribute most of the inoculum to nearby paddocks. In multiple cropped oats where stubble is not destroyed, ascospores land on the new crop in much larger quantities, resulting in the development of earlier and more severe outbreaks.

During the season, the fungus on diseased plants produces splash-borne pycnidiospores which spread the disease onto new foliage during rain. These spores do not move between paddocks but may also be produced by infested stubble residues and contribute to the development of new disease in multiple cropped oats.¹⁹

Disease inoculum is carried between seasons on infected stubble. After rain, fungal spores are ejected from sexual fruiting bodies on stubble and may be spread considerable distances on wind. Secondary generation of asexual spores occurs in black fruiting bodies on blotched leaves which are then locally dispersed within the crop by rain splash, infecting new leaves. The disease is most active in mild



¹⁸ DAFWA (2016) Diagnosing septoria avenae blotch in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/oats/</u> diagnosing-septoria-avenae-blotch-oats

¹⁹ GJ Thomas, R Loughman (2016) Oats: leaf diseases. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/oats/oats-leaf-diseases</u>



APVMA website

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9.4.5 Management of Septoria avenae blotch

Use more resistant varieties in disease-prone areas if suitable agronomic types are available. Septoria avenae blotch can be minimised by not growing continuous oat crops. In continuous oat cropping, stubble from diseased plants should be destroyed by burning or ploughing. Burning is not advised on light soils subject to wind or water erosion. Heavy soils, that is, soils which are 50 to 60% covered with clods of 2 to 3 cm diameter, may be considered for burning. Following crops should be sown at low speeds into moist soil. Foliar sprays can control the disease but are only economic when conditions favour disease spread.²¹

9.5 Stem rust

Stem rust (*Puccinia graminis* f.sp. *avenae*) is a fungal foliar disease of oats that can cause up to 90% yield loss and also reduces grain quality in susceptible varieties. Widespread outbreaks are very damaging but rare. Regional outbreaks are more common, causing losses over limited areas. Stem rust is adapted to warmer conditions than leaf rust and is usually detected later in the season (mid-spring). Disease severity can increase rapidly once a crop is uniformly infected.²²

9.5.1 Varietal resistance or tolerance

See Section 9.2 Varietal resistance or tolerance for disease ratings for stem rust.

9.5.2 Damage caused by stem rust

In Victoria, severe stem rust infections can reduce grain yield by more than 80% in susceptible varieties, and can also reduce grain quality. $^{\rm 23}$

9.5.3 Symptoms

Typical symptoms on oat plants include:

- Large reddish-brown pustules oval or elongated in shape on stems and sometimes both sides of leaves and leaf sheaths (Photo 7).
- In severe cases heads also become infected.
- Pustules become black in colour towards the end of the season. ²⁴

- 21 GJ Thomas, R Loughman (2016) Oats: leaf diseases. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-leaf-diseases</u>
- 22 DAFWA (2016) Diagnosing stem rust in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/diagnosing-stemrust-oats</u>
- 23 G Holloway (2005) Stem rust of wheat. Agriculture Victoria Ag note AG1251 June 2005 Updated May 2014, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stem-rust-of-wheat</u>
- 24 DAFWA (2016) Diagnosing stem rust in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/diagnosing-stemrust-oats</u>



²⁰ DAFWA (2016) Diagnosing septoria avenae blotch in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/oats/</u> diagnosing-septoria-avenae-blotch-oats





Photo 7: Stem rust (Puccinia graminis var. avenae) on standing oat crop (left) and close up (right).

Source: DAFWA

9.5.4 Conditions favouring development

Conditions that favour stem rust epidemics are rare and occur on average once every 16 years in Victoria. However, when conditions are conducive, the disease can cause complete crop loss in susceptible varieties.

Historically, the most severe epidemics in Victoria occurred (in descending order of severity) in 1973, 1947, 1934 and 1955. In 1973, stem rust reduced the Victorian wheat harvest by 25%. It is unlikely that stem rust losses will ever be as severe as in 1973 in wheat due to the increased cultivation of stem rust resistant varieties, and the greater availability of effective foliar fungicides. In recent years, there have been few localised occurrences of stem rust. In 2000 there was a severe stem rust outbreak in oats.

Following the exceptionally wet January of 2011 there was a large amount of inoculum carryover that resulted in widespread stem rust in Victoria during 2011. In spite of this, the widespread use of chemicals helped minimise losses from this disease.²⁵

Rusts grow and reproduce only on living plants and must continually infect new hosts. They survive over summer by infecting volunteer or wild oats and infect crops in the next season.

Seasons are at greater risk of a rust epidemic if:

- rust was present in the previous season;
- summer and autumn rains allow wild or volunteer oats to grow over summer, harbouring and building up the rust; and
- spring conditions are suitably wet.

Stem rust requires domestic or wild oat host plants in order to survive from one season to the next. If summer rain allows a green bridge to develop, then the risk of early rust on crops can be significantly increased.



²⁵ G Holloway (2005) Stem rust of wheat. Agriculture Victoria Ag note AG1251 June 2005 Updated May 2014, <u>http://agriculture.vic.gov.au/</u> agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stem-rust-of-wheat



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A high level of stem rust in the previous season increases the chance of carryover into the next season.

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Stem rust development and spread is favoured by warm ($18-30^{\circ}$ C) humid conditions and an epidemic is more likely if the spring is suitably wet. The latent period (the approximate time taken for an infection to result in new spores) of stem rust is 7–10 days under these optimal temperature conditions.

Rust can spread rapidly within and between oat crops. Spores are readily dispersed by wind and can be carried on clothing. Thoroughly wash potentially contaminated clothes and shoes before visiting crops and consider farm biosecurity measures to minimise the likelihood of visitors introducing spores to your property. ²⁶

Oat stem rust will not attack wheat and wheat stem rust does not attack oats. Under favourable conditions, stem rust is very damaging and can destroy a crop (Photo 8). Epidemics are more frequent in the rust-prone, very high rainfall districts in northern and southern agricultural areas.²⁷



Photo 8: The red discolouration throughout this crop indicates a severe stem rust infection. Early infection and a susceptible variety, combined with seasonal conditions which favoured the disease, led to crop destruction.

9.5.5 Pre-season management of stem rust

Stem rust can be managed using an integrated approach. This includes reducing the inoculum in a district by managing the green bridge, avoiding susceptible cultivars and close monitoring to enable timely fungicide sprays.

Green bridge

Rust can only survive from one season to the next on living plant material (mainly self-sown cereals). Therefore, the removal of the green bridge is essential to reduce the amount of inoculum present to infect a new crop. This is why stem rust epidemics have been worse following wet summer/autumns that favour volunteer cereal growth.



²⁶ DAFWA (2016) Diagnosing stem rust in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/diagnosing-stemrust-oats</u>

²⁷ GJ Thomas, R Loughman (2016) Oats: leaf diseases, Stem rust. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-leaf-diseases?page=0%2C1</u>



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Variety selection

Sowing resistant varieties provides the best protection against stem rust. In most parts of Victoria stem inoculum has been controlled because of the use of resistant varieties.

Stem rust produces new pathotypes (races) which are capable of attacking resistant varieties. These new pathotypes occur when a chance mutation occurs in this asexually reproducing fungus. Use of resistant varieties minimises the amount of rust in a district, thus reducing the chance of new pathotypes occurring. It is important that growers are aware of a variety's resistance reaction to stem rust. For a comprehensive list of varieties, consult an up to date <u>Victorian Cereal Diseases</u> <u>Guide (AG1160)</u>.²⁸

9.5.6 Breeding stem rust resistant oat using wild Avena species

Stem rust is the most yield and quality limiting disease of oats in south eastern Australia. This project aimed to use cytogenetic techniques to transfer sources of stem and leaf rust resistance from wild oat species into breeding lines for use by breeders to develop new rust resistant oat varieties.

In a GRDC and SARDI project (DAS00102) a new source of leaf rust resistance from a wild diploid *Avena* species was successfully transferred to a Wintaroo⁽¹⁾ derived breeding line. Several new sources of stem rust resistance were identified in wild oat species with partial resistance to Pga 512, the most virulent strain in Australia for which there are no other known sources of resistance.

The project has successfully identified new sources of leaf rust resistance and incorporated one of these (Clav7233) into a hexaploid Wintaroot background which will be crossed into the National Oat Breeding Program in spring 2012. This line is resistant to the highly virulent leaf rust strains OLR=164 and OLR=567.²⁹

9.6 Leaf rust

Oat leaf rust is also known as crown rust. The word 'crown' refers to the shape of a type of spore produced by this fungus and is not related to the disease symptoms. The disease is caused by the fungus *Puccinia coronata* var. *avenae*. Oat leaf rust is potentially a very damaging disease, reducing both grain and forage yields. It does not infect wheat and wheat leaf rust does not infect oats.³⁰

9.6.1 Varietal resistance or tolerance

See Section 9.2 Varietal resistance or tolerance for disease ratings for leaf rust.

9.6.2 Damage caused by leaf rust

In Victoria, severe leaf rust infections can reduce grain yield by more than 20% in susceptible varieties, and can also reduce grain quality. In recent years, losses from leaf rust have been confined to districts where susceptible varieties were grown.³¹



²⁸ G Holloway (2005) Stem rust of wheat. Agriculture Victoria Ag note AG1251 June 2005 Updated May 2014, <u>http://agriculture.vic.gov.au/</u> agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stem-rust-of-wheat

²⁹ Breeding stem rust resistant oat using wild Avena species. (2012) GRDC DAS00102 30 June 2012, <u>http://finalreports.grdc.com.au/</u> DAS00102

³⁰ GJ Thomas, R Loughman (2016) Oats: leaf diseases, Leaf rust. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-leafdiseases?page=0%2C2</u>

³¹ G Holloway (2005) Leaf rust of wheat. Agriculture Victoria Ag note AG1251 June 2005 Updated May 2014 <u>http://agriculture.vic.gov.au/</u> agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/leaf-rust-of-wheat





The characteristic symptom is the development of round to oblong, orange to yellow pustules, primarily on leaves (Photo 9) but also on stems and heads. The powdery spore masses in the pustules are readily dislodged. The pustule areas turn black with age.

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Photo 9: Leaf rust (Puccinia coronata var. avenae) may first appear in crops as 'hot spots' from an initial infection (left). Hot spots in early spring allow leaf rusts to build up to very severe levels by the end of the season. Close up of leaf rust on leaves (right).

Source: DAFWA

9.6.4 Conditions favouring development

Leaf rust, like other cereal rusts, requires a living host to survive from one season to the next. The most important host for rusts in Australia are susceptible volunteer wheat plants growing during the summer/autumn. Rust cannot carry over from one season to the next on seed, stubble or in soil.

Varieties susceptible to leaf rust enable inoculum levels to build up on volunteers during the summer and autumn. This can be a problem in seasons following wet summers that favour the growth of self-sown wheat. Plants that become heavily infected with rust in the autumn provide a source of rust for the new season's wheat crop. If these conditions are followed by a mild winter and a warm wet spring, then the chances of a leaf rust epidemic are high. Therefore, the chances of a rust epidemic are greatest following a wet summer.

In Australia, due to the absence of the alternate host, leaf rust reproduces asexually. This reduces the variability of the rusts in the field and therefore increases the likelihood that resistant varieties will be effective for a long period of time.

Rust spores are wind-blown and can be spread over large areas in a short time. The establishment of leaf rust epidemics within a crop is favoured by wet conditions and temperatures of in the range of 15-22°C. ³²

9.6.5 Management

Resistant varieties

The best way to control leaf rust is to grow resistant varieties. In most parts of Victoria leaf rust has been effectively controlled because of the widespread use of wheat varieties with resistance to this disease.

However, leaf rust produces new races which are capable of attacking varieties that were resistant when they were first released. These new races occur when a chance mutation occurs in this asexually reproducing fungus. Widespread cultivation of resistant varieties minimises the levels of rust in the environment and reduces the occurrence of new races.



³² G Holloway (2005) Leaf rust of wheat. Agriculture Victoria Ag note AG1251 June 2005 Updated May 2014, <u>http://agriculture.vic.gov.au/</u> <u>agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/leaf-rust-of-wheat</u>



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It is important that growers are aware of their varieties' disease reaction to leaf rust. Variety resistance ratings are available in the <u>Victorian Cereal Disease Guide</u> (AG1160). It is important to use a current disease guide as mutations occur in rust from time to time, and resistant ratings are adjusted accordingly. ³³

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Cultural practices

Heavy grazing or the use of herbicides during autumn to remove self-sown susceptible wheat will reduce the amount of rust in following crops. However, if spring conditions are favourable for leaf rust development, then even small amounts of rust that survived the autumn can multiply to cause serious yield losses in the spring. ³⁴

When oats are grown for high quality or export hay, early cutting should be considered before the disease builds up and causes obvious damage to leaves (Photo 10).



Photo 10: Clouds of leaf rust spores were released when this infected hay crop was cut. The early harvest prevented further damage to leaves. Source: DAFWA

Seed treatments

There are seed treatments available which will suppress early infections of leaf rust. Seed treatments are important in susceptible varieties, especially if they are sown early or following a wet summer favouring growth of volunteers.

Foliar fungicides

There are a number of foliar fungicides registered for the control of leaf rust in oats. Fungicides should not be regarded as a substitute for growing resistant varieties. They are more of a back-up for when a new race of rust evolves and for use in regions where adequate resistance is not available.

A fungicide response is unlikely in resistant or moderately resistant varieties. The earlier in a season that a rust epidemic starts, then the greater the potential yield loss. Crops need to be monitored to detect rust early, as timing is critical for the effective control of rust diseases with fungicides. Rust epidemics can be explosive, and once out of control, can be difficult to contain.

Like the other rusts it is important to apply fungicides early in the epidemic. If a severe epidemic develops early in the season in a susceptible variety, then it may



³³ G Holloway (2005) Leaf rust of wheat. Agriculture Victoria Ag note AG1251 June 2005 Updated May 2014, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/leaf-rust-of-wheat</u>

³⁴ G Holloway (2005) Leaf rust of wheat. Agriculture Victoria Ag note AG1251 June 2005 Updated May 2014, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/leaf-rust-of-wheat</u>



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be necessary to make two applications of fungicide. Rust first appearing after panicle emergence is less likely to have a significant impact on grain yield. $^{\rm 35}$

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Use a registered fungicide at a registered rate and ensure that withholding periods for both hay and grain are considered in timing of application. ³⁶

Consult the <u>APVMA website</u> for up-to-date recommendations and instructions for foliar fungicide application.

IN FOCUS

Incorporating new sources of stem and leaf rust resistance from wild oat species into cultivated oat varieties

Stem rust and leaf rust both cause significant damage to oat crops. The value of milling oats in the south-eastern region alone is \$11 million per annum (farm gate). The future of oat stem rust resistance in Australia depends on identifying and introgressing new sources of resistance from related species into adapted varieties in conjunction with strategies recommended for the new Australian Cereal Rust Control Program (ACRCP).

The GRDC and SARDI project (DAS00031) aimed to identify sources of stem and leaf rust resistance in wild oat species and to use cytogenetic techniques to incorporate resistance into cultivated oat germplasm.

553 wild oat and 86 cultivated oat accessions were tested. One *Avena abyssinica* and one *Avena strigosa* accession had resistance to the most virulent strains of leaf rust but none were resistant to the most virulent stem rust strains.

Hybrids between cultivated oats and the diploid species *A. abyssinica* and *A. strigosa* are viable. These plants are very vigorous and may have potential as a new hay or forage crop. Chromosome analysis indicates that introgression of useful genes is likely to be relatively simple.

The key findings were:

- Useful sources of resistance to the most virulent strains of leaf rust have been found in one accession of *Avena abyssinica* (Clav 7233) and one accession of *Avena strigosa* (Clav 6956).
- Sources of stem rust resistance have been more difficult to find but a collection has been located at the Institute of Grassland and Environmental Research, Aberystwyth, Wales, which may possess accessions with stem rust resistance.
- It is possible to produce hybrid plants using cultivated oats (*Avena sativa*) and the diploid species *Avena abyssinica* and *Avena strigosa*. These plants are very vigorous and may be useful as hay or forage plants.
- Analysis of the chromosomes of the hybrid plants shows a high degree of chromosome pairing with the wild species and cultivated oats, meaning that introgression of useful genes from the wild species is likely to be relatively simple. ³⁷

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³⁵ G Holloway (2005) Leaf rust of wheat. Agriculture Victoria Ag note AG1251 June 2005 Updated May 2014, http://agriculture.vic.gov.au/agr

⁶ DAFWA (2016) Diagnosing stem rust in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/diagnosing-stemrust-oats</u>

³⁷ Incorporating new sources of stem and leaf rust resistance from wild oat species into cultivated oat varieties. (2006) GRDC DAS00031 30 June 2006, <u>http://finalreports.grdc.com.au/DAS00031</u>



For rust identification, send rusted plant samples in a paper envelope (do not use plastic wrapping) to: Australian Cereal Rust Survey, Plant Breeding Institute, Private Bag 4011, Narellan NSW 2567.

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9.7 Rhizoctonia

Rhizoctonia root rot is an important disease of cereals in both the southern and western regions of the Australian grain belt. This is especially the case in the lower rainfall zones and on lighter soils. Rhizoctonia disease is often a problem in low-fertility, sandy or calcareous soils of southern and western Australia. In cereals, oats are most tolerant, followed by triticale, wheat and then barley, which is the most intolerant. ³⁸

9.7.1 Damage caused by Rhizoctonia

Yield losses in crops affected by bare patches can be over 50% and crops with uneven growth (Photo 11) may lose up to 20%. The disease is caused by Rhizoctonia solani AG8, a fungus that grows on crop residues and soil organic matter and is adapted to dry conditions and lower fertility soils. The fungus causes crop damage by pruning newly emerged roots (spear-tipped roots), which can occur from emergence to crop maturity. The infection results in water and nutrient stress to the plant, as the roots have been compromised in their ability to translocate both moisture and nutrients.³⁹



Photo 11: Above-ground symptoms of crop unevenness (left) are seen when Rhizoctonia damages crown roots, even when seminal roots (right) escape the infection.

Source: GRDC Tips and Tactics Rhizoctonia Southern

9.7.2 Managing Rhizoctonia

Management of Rhizoctonia requires an integrated approach to reduce inoculum and control infection and impact on yield. Rhizoctonia inoculum levels will be greatest following cereal planting, particularly barley. Grass-free canola is the most effective but legumes can also help reduce inoculum loading. Disturbance below the seed at sowing promotes rapid root growth away from the Rhizoctonia and disrupts hyphal networks. The ideal depth is 5–10 cm. Fungicides applied through in-furrow liquid banding can provide useful suppression of Rhizoctonia disease. Herbicides that slow root growth can exacerbate the problem.⁴⁰



³⁸ GRDC (2016) Rhizoctonia tips and tactics—Southern region. Root damage causes yield loss in cereals. <u>https://grdc.com.au/Resources/</u> Factsheets/2016/02/Rhizoctonia

³⁹ GRDC (2016) Rhizoctonia tips and tactics—Southern region. Root damage causes yield loss in cereals. <u>https://grdc.com.au/Resources/</u> <u>Factsheets/2016/02/Rhizoctonia</u>

⁴⁰ GRDC (2016) Rhizoctonia tips and tactics—Southern region. Root damage causes yield loss in cereals. <u>https://grdc.com.au/Resources/</u> Factsheets/2016/02/Rhizoctonia.



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Year 1 crop (Sept–Nov)	Summer (Dec–April)	Season Break (April–May)	Year 2 crop (May–August)
Check for inoculum build-up	Facilitate inoculum decline	Select appropriate crop	Manage infection and disease impact through management practices
Paddocks can often be identified in the previous spring by estimating the area of bare patches and/or zones of uneven growth during spring—verify that poor plant growth is due to Rhizoctonia disease.	In wet summers, early weed control will reduce inoculum. In dry summers,	Select a non- cereal crop (e.g. canola or pulses) if you want to reduce inoculum levels. Remove autumn 'green bridge' before seeding with good weed control.	Sow early; early-sown crops have a greater chance of escaping infection.
	Adopt practices that prolong soil moisture in the		Use soil openers that disturb soil below the seec to facilitate root growth— knife points reduce disease risk compared to discs.
	upper layers (e.g. stubble retention and no cultivation) which helps maintain higher microbial activity.		Avoid pre-sowing SU herbicides.
			Supply adequate nutrition (N, P and trace elements) to encourage healthy seedling growth
	Consider soil testing for pathogen inoculum level (PreDicta B™ test		Avoid stubble incorporatio at sowing to minimise N deficiency in seedlings.
	in Feb-March), to identify high disease risk paddocks, if disease is not		Consider seed dressings and banding fungicides to reduce yield loss.
	confirmed in the previous cereal crop. ospecially if		Remove grassy weeds early.
	planning to sow cereals back on cereals		Apply nutrient/trace elements, foliar in crop, if required.

Source: GRDC Tips and Tactics Rhizoctonia Southern

9.8 Crown rot

Oat crops are considered 'symptomless hosts' of crown rot that may contribute to the maintenance of inoculum.

Crown rot is caused primarily by the fungi Fusarium pseudograminearum and/or F. *culmorum.* It is hosted by all winter cereals and many grass weeds. The crown rot fungi can survive for many years as mycelia inside infected plant residues. Cerealon-cereal cropping programs and stubble retention can increase crown rot levels. Major yield losses occur when disease levels are high and there is moisture and/or evaporative stress during grainfilling. Yield loss can be up to 90% in durum and 50% in bread wheat or barley.

CSIRO investigated the incidence of Fusarium graminearum Group 1 (infection, stem colonisation) and crown rot in three-year crop sequences of one or two years of barley, oats or mown oats, followed by wheat, compared with three years of wheat. Seed was sown into the stubble of the previous crop and stubble production estimated for each cereal treatment. Plants of each cereal were infected by the crown rot pathogen. Oats were found to be susceptible to infection but did not express symptoms of crown rot in the two years of the trial.

The overall mean incidence of infected plants increased from 12% in 1987 to 81% in 1989. The various treatments did not significantly reduce the incidence of infected wheat plants in November of the final year. The incidence of crown rot of wheat in



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MORE INFORMATION

GRDC Crown rot Factsheet

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1989 was greatest after two prior wheat crops and lowest after one or two years of mown oats.

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The three species produced a similar amount of straw by weight; however, mown oats produced significantly less. Oat straw decomposed more rapidly than that of other cereals in controlled conditions. ⁴¹

9.8.1 Symptoms

What to look for

Paddock:

 Whiteheads will not be seen for oat as it is considered a 'symptomless host' of crown rot.

Plant:

- Infected plants will not have whiteheads, but may have honey-brown colour under the leaf sheaths. This discolouration may not always be obvious. Best to assess at grain fill when symptoms are most develope Scattered single tillers and white heads.
- Monitor levels by soil sampling and PredictaB testing.
- Infected plants will contribute to the maintenance of inoculum, as plants host the pathogen.

9.8.2 Managing crown rot:

- Rotate cereals with non-susceptible crops such as pulses, oilseed, lupin or grassfree pasture to reduce inoculum levels.
- Seed between rows the following season to reduce disease load.
- Good grass weed control. 42

9.9 Bacterial blights

Blights survive on seed and crop debris. They are spread by rain splash, leaf contact and insects, especially aphids. Moist weather conditions favour development and spread from crop debris or seed coat to seedlings and then from one leaf to the next. Symptoms often develop after frost. A period of warm, dry weather stops the spread. Heavy infection with either disease leads to withering and death of leaves, often starting from the tip. ⁴³

These diseases can reduce the appearance of hay and hence downgrade its value.

Conditions favouring development

Bacterial blight is most common in continuous oaten hay crops and is prevalent with extended periods of moist weather which facilitates splash of bacteria and provides suitable conditions for infection. The disease is favoured when crop density is high and there has been a high input of nitrogen making the plants soft. As the growing season progresses, plants generally grow away from this disease. Warm dry spring conditions will rapidly reduce spread of this disease.⁴⁴

Managing blights:

 Avoid susceptible varieties, referring to your local state variety sowing guide for resistance ratings.



⁴¹ KE Nelson, LW Burgess (1995) Effect of rotation with barley and oats on crown rot of wheat in the northern wheat belt of New South Wales, Australian Journal of Experimental Agriculture 35(6) 765–770. <u>http://www.publish.csiro.au/paper/EA9950765.htm</u>

⁴² DAFWA (2016) Diagnosing crown rot of cereals. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-crown-rot-cereals</u>

⁴³ H Wallwork (2000) Cereal leaf and stem diseases. GRDC.

⁴⁴ DAFWA (2016) Diagnosing stripe blight in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/</u> diagnosing-stripe-blight-oats



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Destroy infected oat stubbles.

9.9.1 Stripe blight (*Pseudomonas syringae* pv. *striafaciens*)

Bacterial stripe blight is the main blight disease in oats. Blight bacteria survives on seed and crop debris. They are spread by rain splash or leaf contact. Insects, particularly aphids, also spread blight bacteria.

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Symptoms

It causes spots on leaves and leaf sheaths, without the halos produced by halo blight. The spots lengthen and form water-soaked patches and then brown stripes, which often have narrow yellow margins (Photo 12). The lesions join, forming irregular blotches. If the stripe occurs in the boot, the floret inside may appear rotten and stained. Emergent florets appear mottled brown to white and may be sterile (Photo 13). ⁴⁵



Photo 12: Stripe blight (bacterial blight) in oats. Photo: Hugh Wallwork







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Photo 13: Stripe blight (bacterial blight) in oats with head sterility.

What to look for:

- Heavy infection leads to withering and death of leaves often from the tip.
- Diseased plants may occur in patches, and this is worse in wetter areas and wet seasons.
- Vehicles may spread the disease by driving through wet infected plants.
- Water-soaked then red-brown longitudinal stripes that often have narrow yellow margins. Stripes join into blotches that cause leaf collapse (blight).
- If the stripe occurs on the boot the florets inside may appear rotten and stained. emerged florets appear mottled brown to white and may be sterile. ⁴⁶

Managing stripe blight:

- Unless infection is very severe, grain losses are insignificant, but hay quality is reduced.
- There is no chemical control for this disease (fungicides are not effective against bacterial diseases).
- Avoid sowing into infected stubbles and burn or incorporate stubble if the problem is widespread.
- The disease can be seed-borne, do not re-sow seed from infected crops.
- Avoid paddock operations when leaves are wet to prevent disease spread. ⁴⁷

9.9.2 Halo blight

Halo blight bacteria survive on seed and crop debris. They are spread by rain splash or leaf contact. Insects, particularly aphids, also spread them.

What to look for

Paddock:

- Diseased plants may occur in patches, and this is worse in wetter areas and wet seasons.
- Vehicles may spread the disease by driving through wet infected plants.
- 46 DAFWA (2016) Diagnosing stripe blight in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mvcrop/ diagnosing-stripe-blight-oats</u>
- 47 DAFWA (2016) Diagnosing stripe blight in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/</u> <u>diagnosing-stripe-blight-oats</u>





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Plant:

• Initially small light green oval water-soaked spots on leaves and leaf sheaths up to 10 mm in diameter.

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- Centres of spots change to a straw or brown colour surrounded by a yellow water-soaked halo (Photo 14).
- The lesions turn brown and join together to form irregular blotches (Photo 15).
- Heavy infection leads to withering and death of leaves often from the tip. ⁴⁸



Photo 14: Straw or brown colour spots surrounded by a yellow water-soaked halo that may resemble septoria.

Photo F. Henry, 2015, Source: DAFWA



Photo 15: Lesions turn brown and join together to form irregular blotches. Source: <u>DAFWA 2014</u>

48 DAFWA (2016) Diagnosing halo blight in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/ diagnosing-halo-blight-oats</u>





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- Unless infection is very severe, grain losses are insignificant, but hay quality is reduced.
- Fungicides are not registered or effective against bacterial diseases.
- Avoid sowing into infected stubbles and burn or incorporate stubble if the problem is widespread.
- The disease can be seed-borne, do not re-sow seed from infected crops.
- Avoid paddock operations when leaves are wet to prevent disease spread.⁴⁹

9.10 Loose smut (Ustilago avenae)

Loose smut and covered smut in oats are both externally seed-borne diseases with similar symptoms, and are difficult to distinguish in the field. Both diseases are managed in the same way. After sowing, spores on the seed surface germinate and infect the emerging seedling. The fungus grows without symptoms within the plant and identification of infected plants is difficult prior to head emergence. The disease can be spread by air-borne spores that lodge in healthy glumes, where they remain dormant until seeding or else grow into the hulls or seed coats and remain inactive until seeding. Infection is favoured by moist conditions during flowering, with temperatures of 15–25°C. Early sowing into a warm seedbed has often been associated with smut outbreaks. ⁵⁰ Smuts have exceeded 50% incidence in susceptible varieties when no control is applied. ⁵¹

9.10.1 Conditions favouring development:

- The disease is carried as a small colony of fungus in the seed, which infects the growing point of the oat seedling following germination. Infected seed is symptomless.
- Loose smut is not carried in soil or contaminated machinery.
- Infection is favoured by rainfall and high humidity during flowering. ⁵²

9.10.2 Symptoms

Infected plants are shorter than healthy ones, but the panicles of infected plants are compact and erect compared to healthy plants. Each spikelet, including the chaff, is replaced with a spore mass that is at first covered with dark brown to black powdery spore masses. This membrane soon bursts, releasing the spores to contaminate healthy heads and leaving a bare stalk or rachis on the infected plant. ⁵³

What to look for

Paddock:

Scattered plants with black heads or bare flower stalks (Photo 16).

Plant:

- Plants flower at the same time as uninfected plants.
- Seed replaced with a compact mass of dark brown-black powdery spores.
- Bare stalks remain once fungal spores have blown away. 54



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⁴⁹ DAFWA (2016) Diagnosing halo blight in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-halo-blight-oats</u>

⁵⁰ H Wallwork (2000) Cereal leaf and stem diseases. GRDC.

⁵¹ GM Murray (2007) Review of diseases of oats for hay: current and future management, Part II: Identification and control options for the diseases of importance, Rural Industries Research and Development Corporation, Canberra, <u>https://rirdc.infoservices.com.au/</u> <u>downloads/07–122</u>

⁵² DAFWA (2015) Diagnosing wheat loose smut. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/</u> <u>diagnosing-wheat-loose-smut</u>

⁵³ Oat Science and Technology eds Marshall and Sorrels, Agronomy 33

⁵⁴ DAFWA (2015) Diagnosing wheat loose smut. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/</u> <u>diagnosing-wheat-loose-smut</u>





Photo 16: Damaged oat floret from smut infestation. Photo: Hugh Wallwork

9.10.3 Managing smut:

- Fungicidal seed dressing controls loose smut.
- Use clean seed if contamination is found.

9.11 Ergot (Claviceps purpurea)

Ergot is a fungal infection that replaces grass seeds with a fungal resting body. These can contain extremely poisonous chemicals that can kill animals. Ergot can come from oat florets or from grass weeds in the oat crop. Ergot is more a problem for grain crops than for hay production. Because ergot is similar in size to seed, they will contaminate grain harvested from crops. The causal fungus survives in and on soil for several years. These germinate in spring to produce a small fruiting body that releases air-borne spores (ascospores) that can infect nearby grass florets. Ryegrass seems to be particularly susceptible to ergot. ⁵⁵

9.11.1 Symptoms

Symptoms include honeydew (sticky exudate), which develops in heads of grasses shortly after head emergence. A dark purple to black ergot develops in some florets in place of the normal seed (Photo 17). Ergots are roughly the same shape as the seed of the host plant but are 1.5–4 times the size, usually extending prominently out of the floret. 56

55 H Wallwork (2000) Cereal leaf and stem diseases. GRDC

56 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.



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Photo 17: Ergot in oats. Photo: Ken Holden

9.11.2 Damage caused by disease

Ergot bodies contain alkaloid chemicals that can cause lameness, gangrene of the extremities and nervous convulsions (staggers). This can lead to death in both humans and animals. As these toxins accumulate in the body, symptoms can begin to occur after long periods of low-level ingestion. Crops affected by ergot generally do not experience significant yield losses, but economic losses can be quite severe when grain tendered by growers is rejected at receival. ⁵⁷

Gangrenous ergotism of man and cattle

Symptoms: blockage of circulation to the extremities, tingling in the fingers, vomiting, diarrhoea, gangrene of the toes and fingers, ulceration of the mouth. It is a dry form of gangrene and limbs may fall off. In cattle there is lameness, especially in the hindquarters, gangrene of feet, ears and tail. Pregnant cows may abort. There is a characteristic band where the gangrenous tissue ends.

Producers are encouraged to keep an eye on animals eating ergot-infected grain in hot or sunny weather (Photo 18). Signs of ergot poisoning include animals seeking shade, being reluctant to move, and panting and distress following any exercise. Animals may also drool, have an increased respiratory rate and reduced feed intake. ⁵⁸



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⁵⁷ AWB. Wheat Quality Factsheet—ERGOT, <u>https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/</u> ERGOT_factsheet.pdf

⁵⁸ DAFWA (2015) Look out for ergots when selecting stock feed, <u>https://www.agric.wa.gov.au/news/media-releases/look-out-ergots-when-selecting-stock-feed</u>





Photo 18: Producers need to be aware that even a small amount of ergot in grain can cause serious illness to their stock.

Photo: Michael Raine

Convulsive ergotism

Symptoms similar to those of gangrenous ergotism are followed by painful spasms of the limbs, epileptic convulsions and delirium in humans. Cattle become excitable and run with a swaying, uncoordinated gait. ⁵⁹

9.11.3 Management of disease

Key points

- Give contaminated paddocks a one-year break without cereals or grasses.
- Manage grass weed contamination in crops.
- Seed cleaning. 60

For grain that is contaminated with pieces of ergot, grain-cleaning equipment can be used to remove the majority of ergot bodies (Photo 19). However, the grower will need to determine whether this is an economically viable option.



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⁵⁹ HerbiGuide, http://www.herbiguide.com.au/Descriptions/hg_Rye.htm

⁶⁰ DAFWA (2015) Diagnosing Ergot, https://www.agric.wa.gov.au/mycrop/diagnosing-ergot





Photo 19: Ergot contaminated seed.

Source: DPI Vic, in <u>DAFWA</u>

To avoid the development of ergot in subsequent cereal crops, effective farm management practices are required. One option available to growers is the use of crop rotations away from cereals for at least one year to reduce the amount of viable ergot pieces in the soil to negligible levels.

During planting clean seed must be used, as there are currently no effective treatments against ergot. For growers using conventional tillage, ergot pieces need to be buried to a minimum depth of 4 cm. This prevents the fruiting bodies that are produced by the ergot from reaching the soil surface and releasing spores. This may have an effect on the usual sowing operations and guidance should be sought.

Finally, to eliminate the development of host reservoirs growers may be able to mow or spray grass pastures to prevent flowering. $^{\rm 61}$

Control of grasses within cereal crops will help prevent cross infection. This is best achieved by preventing seed set in the season before cropping, by clear fallowing, hard grazing or hay cutting, together with the use of selective herbicides. ⁶²

Strategies to reduce the risk of ergot infection

- Use ergot-free seed if possible.
- Rotate with crops resistant to ergot, such as flax, canola and legumes.
- As the source of ergot infection is often the grass in headlands or ditches, mowing this grass before flowering or seed set will greatly reduce or eliminate the chances of ergot infection.
- Ergots germinate at or near the soil surface to produce infectious spores that attack cereal flowers. To prevent them from germinating, work the field to a depth greater than two inches to bury the ergot bodies.
- Seed at a uniform depth as shallow as possible for adequate moisture to obtain a uniform early emergence.
- Separate the seed collected from the first few combine rounds to prevent contamination of the entire lot, as most of the ergot-infested grain will likely be concentrated in this region. ⁶³
- 61 AWB. Wheat Quality Factsheet—ERGOT, <u>https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/</u> ERGOT_factsheet.pdf
- 62 Agriculture Victoria (1999) Ergot of pasture grasses, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/ grains-pulses-and-cereals/ergot-of-pasture-grasses</u>
- 63 Alberta Government (2016) Fall Rye Production, http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/agdex1269/\$file/117_20-1.pdf



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Plant growth regulators and canopy management

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Key messages:

- Crop responses to the use of plant growth regulators (PGRs) can be inconsistent.
- In general, yield responses, if any, are produced by the reduction in lodging rather than as a direct effect of the PGRs.
- Plant growth regulators must be applied at the correct crop growth stage according to product directions, which can be well before any lodging issues are apparent.
- 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.
- Earlier timed 'upfront' nitrogen increases tiller numbers and in many cases final ear number but may not necessarily increase yield.

10.1 Plant growth regulators

A plant growth regulator (PGR) is an organic compound, either natural or synthetic, that modifies or controls one or more specific physiological processes within a plant. PGRs are any substance or mixture of substances intended, through physiological action, to accelerate or retard the rate of growth or maturation, or otherwise alter the behavior of plants or their produce.¹

¹ P Lemaux (1999) Plant growth regulators and biotechnology, <u>http://ucbiotech.org/resources/biotech/talks/misc/regulat.html</u>





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In grain production, PGRs are most commonly used to reduce lodging, with application leading to shorter, thicker and stronger stems. ² However, in oaten hay production, fine stems are desirable, so the effects of PGRs may be detrimental to production quality. Talk to your local agronomist about the benefits and potential disadvantages in using plant growth regulators in your crop.

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In Australia there have been mixed results in terms of PGR ability to increase yield and profits.

Take home messages

- Crop responses to the use of plant growth regulators (PGRs) can be inconsistent.
- In general, yield responses, if any, are produced by the reduction in lodging rather than as a direct effect of the PGRs.
- Plant growth regulators must be applied at the correct crop growth stage according to product directions, which can be well before any lodging issues are apparent.

Plant growth regulators include many agricultural and horticultural chemicals that influence plant growth and development. This influence can be positive, e.g. larger fruit or more pasture growth, or negative, e.g. shorter stems or smaller plant canopies. PGRs are exogenously-applied chemicals that alter plant metabolism, cell division, cell enlargement, growth and development by regulating plant hormones or other biological signals. For example, some PGRs regulate stem elongation by inhibiting biosynthesis of gibberellins or through releasing ethylene.³

Plant growth regulators may be used to minimise crop lodging and maximise yield, particularly in high-N situations that promote heavy canopies. Attempting to grow high-yielding irrigated crops requires high levels of inputs, including water and fertiliser, which can promote large vegetative crops that increase the risk of lodging. Lodging can result in reduced yields and difficult harvest. Plant growth regulators have been around for many years but results can be variable, even having negative effects on yield. Trials conducted in 2006 and 2007 by the Irrigated Cropping Council (ICC) found that yield increases in barley may be attributed to PGRs; but, generally speaking, yield responses are produced by a reduction in lodging rather than the use of PGRs. ⁴

Plant growth regulators are chemicals which are used in various crops to manipulate the production of certain hormones, in particular gibberellic acid (SYNEXP) and ethylene (Ethephon). These hormones are produced by the plant at particular growth stages. By manipulating the amount of hormone produced by the crop, we can also change the plant height. By decreasing plant height, we can reduce the amount of lodging, and also in some cases increase the Water Use Efficiency of that crop. ⁵

Currently, there are four broad groups of PGRs in use in Australian crops. The four broad groups of PGRs are as follows:

- Ethephon, e.g. Ethrel[®]:
 - » Onium types, e.g. Cycocel[®], Pix[®] (NB: Pix[®] is registered only for cotton).
 - » Triazoles, e.g. propiconazole (NB: propiconazole is registered as a fungicide not a PGR).
- Trinexapac-ethyl, e.g. Moddus^{*}, Moddus Evo (NB: Moddus^{*} is registered for ryegrass seed crops, poppies and sugar cane. Moddus^{*} Evo is an enhanced dispersion concentrate of Moddus^{*}, it is not currently registered but has been submitted to the APVMA for registration in Australian cereals).

- A Rajala (2004) Plant growth regulators to manipulate oat stands, <u>http://ojs.tsv.fi/index.php/AFS/article/view/5786</u>
- 4 D Jones (2014) Plant growth regulators. GRDC Update Papers 31 July 2014, <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators</u>
- 5 B Haskins (2007) Durum Wheat and Barley Canopy Management, Hillston. Department of Primary Industries NSW, <u>http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/winter-creals/Durum-wheat-and-barley-canopy-management-Hillston.pdf</u>



² Tripathi, SC, Sayre, KD, Kaul, JN, Narang, RS (2004) Lodging behavior and yield potential of spring wheat (Triticum aestivum L.): effects of ethephon and genotypes. *Field Crops Research* 87, 207–220.



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These PGRs act by reducing plant cell expansion, resulting in, among other things, shorter and possibly thicker stems. If the stems are stronger and shorter than the crop is less likely to lodge.

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The majority of the PGRs reduce crop height by reducing the effect of the plant hormone gibberellin. These are applied at early stem elongation (Z30-32).

Ethephon is applied from flag leaf emerging (Z37) to booting (Z45) and reduces stem elongation through the increase in concentration of ethylene gas in the expanding cells.

Other benefits claimed by the producers of the various products include:

- Better root development that allows for increased root anchorage.
- Better root development providing greater opportunity for water and nutrient scavenging.
- May offer improved grain quality.
 - Increased Harvest Index (the ratio between grain and total dry matter).
- Faster harvest speeds and reduced stress at harvest.

An alternative to the chemical PGRs is grazing. Demonstrated in the Grain and Graze project on a number of sites was the effect of grazing on the crops where the grazed treatments were regularly shorter than the non-grazed treatments and were less prone to lodging.

Conclusions

- PGRs may have a place in the management of high yielding crops. Unfortunately, their effects are not consistent and the decision on whether to apply the PGR has to be made at approximately three months before the lodging would be expected.
- Alternative PGRs are available but are not yet registered for use on all crops or at rates and timings that would have a growth regulatory effect.
- The yield improvements seen in barley in the ICC trials need further investigation, as the reason behind the increase is not clear. ⁶







MORE INFORMATION

Plant growth regulators in broad acre

PGRs and their agronomic and

economic benefits to high yield potential cereal, pulse and oilseed

Good things come in small packages:

plant growth regulators in barley

Mixed bag-dual purpose crops,

PGRs and other local research—

Plant growth regulators

crops

crops

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IN FOCUS

Plant growth regulators to manipulate oat stands

PGR effects are widely studied and reported on barley (Hordeum vulgare L.) and wheat (Triticum aestivum L.), whereas there are only a few reports addressing oat (Avena sativa L.). This is likely to be a result of smaller acreage and lower intensity of oat management and production and hence a reduced need for stem shortening by PGRs. However, this is not the case for all cereal producing regions and there exists a need to understand the potential application of PGRs to oat production. This paper represents a review of the potential of PGRs to regulate stem elongation and other biological traits governing plant stand structure and yield components, with special emphasis on oat and its responses to PGRs. Yield improvement requires more heads per unit land area, more grains per head or heavier grains. Of these yield-determining parameters, the number of head bearing tillers and grain numbers per head, compared with grain weight, is more likely to be improved by PGR application. In the absence of lodging, PGR may reduce grain yield due to potential reduction in mean grain weight and/or grain number. Cultivation systems aiming at extensive yields with intensive use of inputs likely benefit from PGR applications more often compared with low or moderate input cultivation, for which cost effectiveness of PGRs is not frequently reached.⁷

Example of increased yield from PGRs

A trial combination of two PGRs increased yield by 16% when applied at GS31. 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 nitrogen (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. ⁸

10.2 What is canopy management?

Canopy management is managing 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 determines the crop's photosynthetic capacity and therefore its overall grain productivity. ⁹

The aim of canopy management is to get the balance right between pre and postanthesis growth, to maximise grain yield, quality and harvestability in any given season. In drier environments crop canopies that produce excessive growth (tillers) by virtue of paddock fertility (soil nitrogen or applied nitrogen) use more of the water available at pre-flowering, leaving less for grainfill when the plant goes directly into the developing grain stage. This results in lower yields and poor grain size. Conversely overly thin crop canopies that have adequate water available, produce

- 7 A Rajala (2004) Plant growth regulators to manipulate oat stands, <u>http://ojs.tsv.fi/index.php/AFS/article/view/5786</u>
- 8 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, <u>http://www.grdc.com.au/Research-and-Development/ GRDC-Update-Papers/2013/03/Managing-resources-andrisk/for-8-tonne-cereal-crops</u>
- 9 GRDC (2005) Cereal Growth Stages, https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf





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insufficient crop canopy pre-flowering to fully take advantage of the water available for grainfill post-flowering. $^{\rm 10}$

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Where this management system has been developed (principally in Europe and New Zealand), it has shifted grower focus from lush, thick crop canopies to thinner, more open canopies. At its simplest, the technique could be represented by a simple comparison of crop canopies.

Overseas growers practicing canopy management have target canopy sizes for specific growth stages, and nitrogen management is tailored to adjust the crop to these targets. If the canopy is too thin, nitrogen timing is brought forward; if it is too thick nitrogen timing is delayed. Much of the change brought about by canopy management has been due to the adoption of lower plant populations and a greater proportion of nitrogen being applied later in the season.



Photo 1: Examples of controlled canopy cover. Source: <u>GRDC</u>

In Photo 1 above is an example of a thinner crop canopy (left): yield = 6.18 t/ha and 12% protein, and thicker crop canopy (right): yield = 6.20 t/ha and 10.6% protein.

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.

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. Other than sowing date, plant population is the first point at which the grower can influence the size and duration of the crop canopy ¹¹ and one of the main tools for growers to manage the crop canopy is the rate and timing of applied fertiliser N.

If the canopy becomes too big, it competes with the growing heads for resources, especially during the critical 30-day period before flowering. This is when the main yield component (grain number per unit area) is set. Increased competition from the canopy with the head may reduce yield by reducing the number of grains that survive for grainfill.

After flowering, temperature and evaporative demand increase rapidly. If there is not enough soil moisture, the canopy dies faster than the grain develops and results in small grain. Excessive N application and high seeding rates are the main causes of excessive vegetative production. Unfortunately, optimum N and seeding rates are season dependent. Under drought conditions, N application and seeding rates that would be regarded as inadequate under normal conditions may maximise yield, whereas higher input rates may result in progressively lower yields. Alternatively, in



¹⁰ N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC 07 January 2014, <u>https://grdc.com.au/Resources/</u> <u>Publications/2014/01/Advancing-the-management-of-crop-canopies</u>

GRDC (2005) Cereal Growth Stages, https://grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf



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years of above average rainfall, yield may be compromised with normal input rates. The extreme of this scenario of excessive early growth is haying-off, where a large amount of biomass is produced, using a lot of water and resources. Then, later in the season, there is insufficient moisture to keep the canopy photosynthesising and not enough stored water-soluble carbohydrates (WSCs) to fill the grain. Therefore, grain size and yield decrease.

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To attain maximum yield, it is important to achieve a balance between biomass and resources. The main factors that can be managed are:

- plant population
- row spacing
- inputs of N
- sowing date
- weed, pest and disease control
- plant growth regulation with grazing or specific plant growth regulator products

Of these, the most important to canopy management are N, row spacing and plant population. $^{\ensuremath{^{12}}}$

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.

10.3 Cereal canopy management in a nutshell

- 1. Select a target head density for your environment.
- 2. Adjust canopy management based on paddock nutrition, history and seeding time to achieve target head density.
- 3. Established plant populations for oat of between 80 and 200 plants/m² would cover most scenarios.
- 4. Lower end of range (80–100 plants/m²)—earlier sowings/high fertility and/or low yield potential low-rainfall environments.
- 5. Higher end of the range (150–200 plants/m²)—later sowings, lower fertility situations and/or higher rainfall regions.
- During stem elongation (GS30–39), provide the crop with necessary nutrition (particularly N at GS30–33 pseudostem erect—third node) matched to water supply and fungicides, to:
 - » maximise potential grain size and grain number per head
 - » maximise transpiration efficiency
 - ensure complete radiation interception from when the flag leaf has emerged (GS39)
 - » keep the canopy green for as long as possible following anthesis

Keeping the 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) 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. Much of the research on topdressing nitrogen (N) 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



¹² N Fettell, P Bowden, T McNee, N Border (2010) Barley growth & development. PROCROP Series. Industry & Investment NSW/ NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/516180/Procrop-barley-growth-anddevelopment.pdf</u>



situations, research has shown that positive responses can be achieved, especially when good rainfall is received after N application. $^{\rm 13}$

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10.3.1 Limitations of tactical nitrogen application

The main limitation to tactical N application is the ability to reliably apply N before a rain event, to enable roots to access soluble N in the root-zone. Predicted rain fronts may pass without yielding anything; therefore, dependably applying N throughout the season is risky.

Foliar N application is gaining popularity; however, this is only suitable for relatively low rates of N addition. Where higher N input is required, an efficient system to apply N into the wet soil profile, after a rainfall event, needs to be devised.

As technologies such as Normalized Difference Vegetation Index (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.

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 southern cropping zone would be further aided by development of efficient, in-soil N-application equipment.







Yield:

- The yield reduction in wheat was particularly significant when row width exceeded 30 centimetres.
- Crop row spacing is an important factor for weed competition.
- At yields of 2–3 t/ha the yield reduction was negligible.
- At yields of 5 t/ha the yield reduction was 5–7%, averaging about 6%.
- Data from a single site suggests that rotation position may influence the yield response in wider row spacing in wheat. In wheat, wheat-on-wheat suffered less yield reduction with wider rows than an equivalent trial at the same site which was in wheat after canola (Photo 2). ¹⁴

13 GRDC (2014), Advancing the management of crop canopies, <u>http://www.grdc.com.au/CanopyManagementGuide</u>

14 N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC 07 January 2014, <u>https://grdc.com.au/Resources/</u> <u>Publications/2014/01/Advancing-the-management-of-crop-canopies</u>







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Photo 2: Narrow row spacing (left) and wide row spacing (right). The higher the yield potential, the greater the negative impact of wider rows on crop yields.

Source: Weed Smart

Plant spacing:

- Increasing row width decreases the plant-to-plant spacing within the row, leading to more competition within the row and reduced seedling establishment (for reasons that are not clearly understood).
- Increasing plant populations when using wider rows can be counterproductive with regard to yield, particularly where plant populations exceed 100 plants/m² as a starting point.
- Limited data indicates that increasing seeding rates such that the average plantto-plant spacing in the row drops below 2.5 cm are either negative or neutral in terms of grain yield.
- Planting seed in a band (as opposed to a row) will increase plant-to-plant spacing but may increase weed germination and moisture loss through greater soil disturbance.¹⁵

Dry matter:

- Wider row (30 cm and over) spacing reduced harvest dry matter (DM) relative to narrower rows (22.5 cm and under), with differences growing steadily (kg/h) from crop emergence to harvest, by which time differences were in the order of 1–3 t/ ha depending on row width and growing season rainfall.
- The reduction in dry matter in wide rows was also significant at flowering (GS60–69), frequently 1 t/ha reduction when row spacing increased 10 cm or more over a 20 cm row spacing base. This could be important when considering harvesting for hay rather than grain. ¹⁶

Grain quality:

- The most noticeable effect of row width on grain quality was on protein—wider rows reduced yield and increased grain protein.
- Differences in grain quality were typically small in terms of test weights and screenings, with very small benefits to wider rows over narrow rows on some occasions.¹⁷

Nitrogen management

Nitrogen management has not been found to interact with row spacing. Optimum N regimes for narrow row spacing (22.5 cm or less) can be the same as for wider row spacing (30 cm or more). The greater nitrogen efficiency observed with stem

- 15 N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC 07 January 2014, <u>https://grdc.com.au/Resources/</u> <u>Publications/2014/01/Advancing-the-management-of-crop-canopies</u>
- 16 N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC 07 January 2014, <u>https://grdc.com.au/Resources/</u> <u>Publications/2014/01/Advancing-the-management-of-crop-canopies</u>
- 17 N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC 07 January 2014, <u>https://ardc.com.au/Resources/</u> Publications/2014/01/Advancing-the-management-of-crop-canopies





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elongation applied nitrogen was more important with narrow row spacing since higher yields lead to a tendency for lower protein. ¹⁸

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10.5 Plant population

Other than sowing date, this is the first point at which the grower can influence the size and duration of the crop canopy. Though optimum plant population varies with growing season rainfall, it is important to target a specific planting density. Invariably higher plant populations create larger canopies earlier in the season. This frequently results in larger canopies overall. In the high-rainfall zone higher plant populations can be useful with later sowings where sunlight can be wasted on thin crops. However, with earlier sowings excessively thick canopies increase the risk of disease and lodging, creating poor quality grain.

Table 1: Plant establishment densities (plants/m²).

Сгор	Average rainfall (mm)				
	250–350	350–450	450–550		
	Plar	nt population (plants	/m²)		
Oats	130–150	150–180	180–200		

Source: GRDC Cereal growth stages guide

10.5.1 Grazing cereal crops as a management tool

Well-managed, dual-purpose cereals provide producers with an opportunity for increased profitability and flexibility in mixed farming systems by enabling increased winter stocking rates and generating income from forage and grain. Typically, these crops are earlier sown, longer season varieties that provide greater DM production for grazing. Research has shown that to avoid grain-yield penalties, stock must be removed from cereals before the end of tillering (GS30). However, the timing and intensity of grazing during the season can incur yield penalties, particularly when grazing pressure is high and late in the grazing period. Grazing can sometimes be beneficial to grain production by reducing lodging; in seasons with dry springs, grazing can increase grain yields by reducing water use in the vegetative stages, leaving more soil water for grainfill (Photo 3). The challenge for growers is to find the balance of optimising DM removal without compromising grain production.¹⁹



Photo 3: Cattle grazing a crop paddock.



¹⁸ N Poole, J Hunt (2014) Advancing the management of crop canopies. GRDC 07 January 2014, <u>https://grdc.com.au/Resources/</u> <u>Publications/2014/01/Advancing-the-management-of-crop-canopies</u>

¹⁹ GRDC (2102) Grazing wheat and barley—impacts on crop canopy management. GRDC Update Papers 23 March 2012, <u>https://grdc. com.au/Research-and-Development/GRDC-Update-Papers/2012/03/Grazing-wheat-and-barley-impacts-on-crop-canopy-management lodging-and-grain-yield</u>



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New tools to fight leaf diseases and respond to crops' nitrogen needs have been developed for cereal growers in the high-rainfall zone (HRZ), following a three-year project by the Foundation for Arable Research.

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Thirty-nine trials across the southern grains region showed that the use of crop sensors to assess the need for topdressed nitrogen at stem elongation has the potential to save up to \$60/ha in fertiliser costs.

The trials showed a strong relationship between nitrogen uptake and sensor readings from late tillering to the third node, if appropriate test strips are used to calibrate the figures. This relationship is particularly useful to assess the degree of nitrogen available to the crop in spring. Linked with crop models in the future, it is envisaged that crop sensors could enable growers to better visualise the growth of their crops. The use of crop sensors may have a greater role where nitrogen applications are split. The sensor can be used after the first topdressing to determine whether a second application of nitrogen is warranted on parts of the paddock.²⁰







Not applicable for this crop

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Key messages:

- Australian oats are harvested from October to January by direct heading as soon as the crop is ripe.¹
- Harvesting oats occurs as soon as the crop is ripe which will help reduce grain shedding.
- This is the most economical method if the grain moisture is uniform (less than 12%).
- Delays can lead to significant lodging and shedding due to crop movement in the wind.
- Hull-less oats are susceptible to harvest damage, as such adjustment to the harvest timing is critical.
- Care must be taken in harvesting milling varieties to minimise the amount of dehulled grain. $^{\rm 2}\,$



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¹ A Rajala (2004) Plant growth regulators to manipulate oat stands, <u>http://ojs.tsv.fi/index.php/AFS/article/view/5786</u>

² G Troup (2016) Oats: harvesting, swathing and grain storage. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage</u>



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Windrowing or swathing was common with grain oats until the release of dwarf varieties. It involves cutting the crop and placing it in rows held together by interlaced straws, supported above the ground by the remaining stubble (Photo 1). It can be considered as an option where:

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- the crop is uneven in maturity, or the climate does not allow for rapid drying of the grain naturally
- there is a risk of crop losses from shedding and lodging

High yielding crops may gain more from windrowing than low yielding crops. Generally, crops expected to yield less than 2 t/ha should not be swathed. Picking up windrowed oats is significantly slower than direct heading because of the large volume of material.

If the crop is too thin or the stubble too short to support the swath above the ground, the crop should not be windrowed. Heads on the ground may sprout and attempts to pick up heads that are lying close to the soil surface will pick up soil. ³



Photo 1: Directing chaff into a narrow windrow using a custom-made chute. Source: <u>GRDC</u>

12.1.1 Timing

Windrowing can begin when grain moisture content is below 35%—when grain is at the medium dough stage, hard but can still be dented with the thumbnail.

- It is better to windrow early to prevent losses from shedding and lodging, but not when the ground is wet after rain.
- Avoid windrowing too early as the grain is not fully developed and will result in small pinched grain.
- Although it may be easier to windrow later, the windrows of a ripe crop may not interlock well enough to withstand disturbance from strong wind.⁴



³ G Troup (2016) Oats: harvesting, swathing and grain storage, Swathing. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1</u>

⁴ G Troup (2016) Oats: harvesting, swathing and grain storage, Swathing. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1</u>



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• Cut across the sowing direction, or at 45 degrees for crops with wider row spacing, so the windrow sits-up on the stubble. Windrowing is not recommended for paddocks where the crop row spacing is over 25 cm.

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- Avoid placing windrows in the same location each year so nutrients are not concentrated in one place.
- Windrow size or width of cut should match header capacity. A double-up attachment to the windrower or placing two windrows side by side requires a larger capacity header and concentrates the residue in a narrow band within the paddock.
- Cutting height should be adjusted to keep sufficient straw on the head to hold the swath together (minimum 30 cm) and sufficient stubble height to support the windrow.
- Start the cutting height at 10–20 cm above the ground (one-third crop height) and adjust to produce an even windrow with well-interlaced straws that sit above the ground. This allows good air circulation and rapid drying should rain occur. ⁵

12.1.3 Harvesting the swath

Harvesting of the windrowed crop must be completed as soon as possible, ideally within 10 days of windrowing.

- If left too long and subjected to long periods of wetting (more than 25 mm of rain over 4–8 days), grain may sprout and become stained. The windrow may also become contaminated with bronze field beetle.
- When the windrow is picked up, the reel should be rotating slightly faster than ground speed, but not fast enough to knock the heads off the stems.
- The conveyor canvas should be revolving sufficiently fast to prevent the crop material banking up.
- Rows pick up best when the header follows the direction of the windrow (heads first).

One of the major sources of contamination in windrowed oats is the stubble being torn out during the windrowing operation. This generally occurs when the windrower is operated at too high a ground speed or when trying to swath when the straw is tough due to it being cool or damp. ⁶

12.2 Harvest issues and management

In some regions there may be long periods of unsuitable weather conditions in which the harvesting of dry grain may not be possible. This may cause considerable delays to the harvesting operation and increase the risk of head loss or grain being discoloured by early summer rains. Oats can shatter or shell out more readily than any other cereal crops.

To reduce harvesting delays the grain can be direct harvested at a moisture content above 12% and then placed under aeration to maintain quality or passed through a grain dryer to reduce its moisture content to a level that can be safely stored.

- First harvest the varieties that are likely to shed or lodge. Long delays can lead to significant lodging and shedding due to crop movement in the wind.
- Care must be taken in harvesting milling oats to minimise the amount of dehulled grain.
- Harvesting oats on hots days or during the heat of the day can reduce the need to thresh the oats to hard, resulting in less dehulled oats, less trash and often heavier test weight.
- 5 G Troup (2016) Oats: harvesting, swathing and grain storage, Swathing. DAFWA.<u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1</u>
- 6 G Troup (2016) Oats: harvesting, swathing and grain storage, Swathing. DAFWA, <u>https://www.aqric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C1</u>




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 Hull-less oats are susceptible to harvest damage, adjustment to the harvest is therefore critical.⁷

12.2.1 Delaying harvest

Oats should be threshed as soon as they reach an appropriate moisture. Straight cutting should not commence until all the oats have ripened as discounts will be made to seeds with green hulls. An alternative is to cut around the less ripe areas in a field and harvest these areas at a later date. Oats that are left too long in the field can weather and result in lower quality. If oats have been left to straight cut, weather may cause the stems to break down resulting in yield loss. As well, ripe oats are highly susceptible to shattering in heavy rain storms or wind. ⁸

Every day a crop stands in the paddock it is exposed to ongoing yield loss and quality degradation. Yield is reduced by shedding, head loss and general exposure to the elements. This is measured as a loss of yield each day in dry matter (DM). Most growers have also experienced some form of grain quality loss due to delayed harvest. Oats can become discoloured or dehulled and fungal growth reduces the end-use possibilities. These factors can combine to result in heavy discounts from a crop's net return. Time increases these risks, and ongoing exposure to moisture will eventually cause yield loss and development of one or more of these quality defects. In oats delays can lead to significant lodging and shedding due to crop movement in the wind (Figure 1).



Figure 1: Yield and risk of quality loss over time.

Source: GIWA

While the direct heading of grain is the cheapest method of harvesting, the danger is that there may be long periods of high relative humidity in which the harvesting of dry grain is not possible. This may cause considerable delays to the harvesting operation and increase the risk of head loss or grain being discoloured by early summer rains.



⁷ G Troup (2016) Oats: harvesting, swathing and grain storage. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C0</u>

⁸ Prairie Oat growers Association (2016). Oat Grower Manual: Harvest Management. http://www.poga.ca/grower-manual/harvestmanagement



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Lodging of oats is a problem, particularly in tall varieties and in high rainfall zones or high nitrogen situations. The heavy mat of stems that is formed in a lodged crop can result in delayed ripening due to reduced airflow, increased shading and higher soil moisture. Lodged crops should be harvested panicles first (one direction only) to ensure maximum pickup. ⁹

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Early harvest is recommended to avoid problems with lodging, however, this is not always possible. One option is to harvest standing crops first. These may be better yielding, harvest will go faster, standing crops will field dry quicker, and you would want to get them before they begin to lodge. On the other hand, lodged plants may be more susceptible to mold/fungal rot and further deterioration when in contact with wet soil, and another option might be to harvest lodged plants first.

Salvaging lodged crops may require a combination of equipment choices and/or modifications, and technique. If the crop is planted in rows, a row crop head may lift lodged stalks enough to get them into the machine. Crop lifters can be attached to the sickle bar of most combine flex or straight heads and improve harvesting efficiency for both row planted and drilled or solid-seeded crops.

Lifting the lodged crop is preferable to shaving the ground, reducing the amount of material run through the harvester. Running less plant material through the harvester can save fuel and wear on the machine, allow faster harvesting and pose less danger of fire.

Equipment choice and/or modifications alone will not maximise harvest efficiency of lodged crops. Recommendations are to travel slow, and choose the optimum direction of travel. If wind was a significant factor in the lodging of crops, the majority of plants may be lying in one direction. This situation may allow harvesting in two directions by traveling perpendicular to the direction the plants are leaning or lying. The best results may be obtained by harvesting in one direction, likely at an angle against the direction the plants are lying, and "deadheading" back for the next pass. If the lodging is more random, as might occur with severe stalk weakness, the direction of travel may not matter.¹⁰

12.2.3 Avoiding de-hulling at harvest

Excessive dehulling needs to be avoided during harvest as oats contain fats and oils and the enzymes in dehulled oats can become unstable and more likely to become rancid during storage. Delivery specifications limit the number of dehulled oats in a sample. Harvesters should be set up according to the operator's manual and adjustments made according to crop conditions. Oats are easier to thresh when they are ripe and during hot days with low humidity. Ensuring correct rotor speed and concave clearance is important to produce a good clean sample and avoid excessive dehulling. ¹¹

Hull-less oats are highly vulnerable to cracking and damage. Care must be taken to properly set the harvester to avoid damage and produce a sample that does not contain de-hulled oats as a these may result in the sample being down-graded. This may require a further reduction in cylinder or rotor speed. ¹²

- 10 Fanning B. (2013). Harvesting lodged crops. iGrow. https://igrow.org/agronomy/corn/harvesting-lodged-crops/
- 1 G Troup (2016) Oats: harvesting, swathing and grain storage, Lodging. DAFWA, <u>https://www.aqric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C2</u>
- 12 Prairie Oat growers Association (2016). Oat Grower Manual: Harvest Management. <u>http://www.poga.ca/grower-manual/harvest-management</u>



MORE INFORMATION

Careful harvester set-up puts more

grain in the bin

⁹ G Troup (2016) Oats: harvesting, swathing and grain storage, Lodging. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C2</u>



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The cost of aeration or drying needs to be weighed up against the value of the grain. Prioritise the varieties that are likely to shed or lodge. ¹³

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12.3 Harvest equipment

Recent trials have found there is a 10% lift in header efficiency for every 10 cm increase in harvest height. The trials in the HRZ compared three harvest heights (15 cm, 30 cm and 50 cm) in wheat and barley.

Harvesting low is done to reduce stubble loads to manageable levels, and achieved by baling or burning the windrows, or simply spreading trash and straw as evenly as possible across the header swathe.

Harvesting low and treating weed seeds also has the potential to reduce the soil weed seedbank over time, which can assist with weed control and herbicide resistance management.

The work in 2014 has shown how much slower harvesting is at a 15 cm height and the additional fuel consumption required. When increasing the height to 50 cm it was found that harvesting was around 25% faster than at 30 cm. A rule of thumb is a 10% efficiency increase for every 10 cm of harvest height. If a 100 ha crop is harvested at 15 cm it will take about 20% more time to harvest than a crop cut at 30 cm, or 38% more time than if it had been harvested at 50 cm. ¹⁴

Ensure that all equipment is clean and free from potential contaminants to the harvested grain (Photo 2).



Photo 2: Cereal harvest underway. It is important to clean all equipment prior to and after harvesting.

Source: Arquivo/ABr (Agência Brasil)

Forage harvesters

Whole-crop cereals should ideally be harvested using a precision chopping forage harvester to ensure a short chop length (20–50 mm actual length). This ensures the material can be well compacted in the stack or pit, minimising the amount of air



¹³ G Troup (2016) Oats: harvesting, swathing and grain storage. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage</u>

¹⁴ A Lawson (2015) Ground Cover Issue 118: Header efficiency increases with harvest height, <u>https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-118-Sep-Oct-2015/Header-efficiency-increases-with-harvest-height</u>



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trapped and resulting in reduced losses (nutritive value and DM). Losses are due to continued plant and microbial respiration during the early phases of fermentation.

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Most other forage harvesting machines, such as self-loading wagons, cut the material to varying lengths, often over 200 mm, making adequate compaction very difficult.

The drier the crop DM content at harvest, the shorter the chop length required. Chopping the material short also ensures a thorough mixing of the high nutritive heads with the much lower nutritive stems and leaves.

Increased density also reduces the rate of aerobic spoilage at stack opening, a common although not insurmountable problem with cereal silages. Less wastage also occurs as animals cannot easily select the heads and leave the stem material when fed.

Increasingly, forage cereals are being direct-harvested at the later growth stage with forage harvesters that have a cutterbar instead of the typical rotary disc mowers, to reduce grain loss. Grain loss from the gaps in the housing of the chopping and feeding mechanisms can be minimised by fitting blanking plates.

Due to the rotary disc action of the mower, particularly if raked before harvesting, grain loss may be slightly higher in pre-mown crops. DM yield and nutritive value will also be slightly lower.

If the crop is harvested after the soft dough stage, the grain will be hardening as it matures. Forage harvesters, which are fitted with specific rollers for cracking grain (often referred to as "primary processing") will be essential.

Balers

Harvesting whole-crop using balers is not recommended, as dense compaction is often not achieved and vermin damage to the bales in storage can be a serious problem. If whole-crop cereals are to be harvested with round and square balers, the material needs to be wilted to slightly higher DM contents to ensure a lactic acid fermentation occurs.

Balers with chopping mechanisms are highly recommended to aid compaction. The fermentation process and animal intake of WCS will also benefit substantially from the chopping. Once past the ideal stage for harvesting, cereal stems become more lignified (stiffer) and the stems are hollow, i.e. they contain more air internally. These drier stems will allow increased air to be trapped within and between the stems in the bale. In this situation a chopping baler, with all knives in operation, is highly recommended. An alternative is to bale at the moister end of the DM range recommended for baling. Baling with some dew on the material will also be useful if DM levels are above those recommended.

Baling at a slower forward speed will also allow most balers to produce a denser bale. Baling material that is too dry, or not tightly compacted, results in large volumes of air being trapped in the bale thus reducing nutritive value and increased risk of puncturing by the stalks.

Anecdotal feedback from some machinery operators indicate that if a mower only is used for the later growth stages of the crop, particularly when baling, the baler should travel in the opposite direction to the mower. The heads of the crop are picked up first which results in much less trouble in the "picking up" and "feeding in" of the forage into the machine. However, one piece of research has indicated that friction from the rolling mechanisms in some balers induces heavier grain loss than that from forage harvesters. More research is needed to determine losses at all stages of WCS harvesting and storage.

Applying netwrap instead of twine will also reduce the amount of air trapped between the plastic and the bale as the twine, especially in slightly loose bales, will "pull" into the bale. This allows air to travel around the twine once plastic is applied, possibly becoming mouldy—particularly if holed. Applying netwrap will also minimise straw





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stalks protruding from the bales, which can puncture the stretchwrap plastic seal, allowing air to enter. $^{\rm 15}$

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12.4 Fire prevention

Grain growers must take precautions during the harvest season, as operating machinery in extreme fire conditions is dangerous. They should take all possible measures to minimise the risk of fire. Fires are regularly experienced during harvest in stubble as well as standing crops. The main cause is hot machinery combining with combustible material. This is exacerbated on hot, dry, windy days. Seasonal conditions can also contribute to lower moisture content in grain and therefore a greater risk of fires.

Harvester fire reduction checklist

- 1. Recognise the big four factors that contribute to fires: relative humidity, ambient temperature, wind and crop type and conditions. Stop harvest when the danger is extreme.
- 2. Focus on service, maintenance and machine hygiene at harvest on the days more hazardous for fire. Follow systematic preparation and prevention procedures.
- 3. Use every means possible to avoid the accumulation of flammable material on the manifold, turbocharger or the exhaust system. Be aware of side and tailwinds that can disrupt the radiator fan airblast that normally keeps the exhaust area clean.
- 4. Be on the lookout for places where chaffing can occur, such as fuel lines, battery cables, wiring looms, tyres and drive belts.
- Avoid overloading electrical circuits. Do not replace a blown fuse with a higher amperage fuse. It is your only protection against wiring damage from shorts and overloading.
- 6. Periodically check bearings around the harvester front and the machine. Use a hand-held digital heat-measuring gun for temperature diagnostics on bearings and brakes.
- 7. Maintain fire extinguishers on the harvester and consider adding a water-type extinguisher for residue fires. Keep a well maintained fire fighting unit close-by to the harvesting operation ready to respond.
- Static will not start a fire but may contribute to dust accumulation. Drag chains or cables may help dissipate electrical charge but are not universally successful in all conditions. There are some machine mounted fire-suppression options on the market.
- 9. If fitted, use the battery isolation switch when the harvester is parked. Use vermin deterrents in the cab and elsewhere, as vermin chew some types of electrical insulation.
- 10. Observe the Grassland Fire Danger Index (GFDI) protocol on high fire risk days.
- 11. Maintain two-way or mobile phone contact with base and others and establish a plan with the harvest team to respond to fires if one occurs. ¹⁶

Using machinery

To preventing machinery fires, it is imperative that all headers, chaser bins, tractors and augers be regularly cleaned and maintained. All machinery and vehicles must have an effective spark arrester fitted to the exhaust system. To prevent overheating of tractors, motorcycles, off-road vehicles and other mechanical equipment, all machinery needs to be properly serviced and maintained. Fire-fighting equipment



¹⁵ Agriculture Victoria (2008) Harvesting Forage Cereals, <u>http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/harvesting-forage-cereals</u>

¹⁶ Barr R. (2015). Plant of attack needed for harvester fires. <u>https://grdc.com.au/Media-Centre/Media-News/South/2015/10/Plan-of-attack-needed-for-harvester-fires</u>



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must be available and maintained—it is not just common sense, it is a legal requirement.

Take great care when using this equipment outdoors:

Be extremely careful when using cutters and welders to repair plant equipment; this includes angle grinders, welders and cutting equipment,

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Ensure that machinery components including brakes and bearings do not overheat, as these components can drop hot metal onto the ground, starting a fire.

Use machinery correctly, as incorrect usage can cause it to overheat and ignite.

Be aware that when blades of slashers, mowers and similar equipment hit rocks or metal, they can cause sparks to ignite dry grass.

Avoid using machinery during inappropriate weather conditions of high temperatures, low humidity and high wind.

Do repairs and maintenance in a hazard-free, clean working area such as on bare ground, concrete or in a workshop, rather than in the field.

Keep machinery clean and as free from fine debris as possible, as this can reduce onboard ignitions. $^{\mbox{\tiny 17}}$

With research showing an average of 12 harvesters burnt to the ground every year in Australia (Photo 3), agricultural engineers encourage care in keeping headers clean to reduce the potential for crop and machinery losses.

Key points:

- Most harvester fires start in the engine or engine bay.
- Other fires are caused by failed bearings, brakes and electricals, and rock strikes.¹⁸



Photo 3: GRDC figures show that there are 1000 combine harvester fires in Australia each year.

Source: Weekly Times

12.4.1 Harvesting in low-risk conditions

Growers can use the Grassland Fire Danger Index guide to assess the wind speed at which harvest must cease (a GFDI of 35), depending on the temperature and relative humidity (Figure 2).

- 17 NSW Rural fire Service. Farm firewise. NSW Government, <u>http://www.rfs.nsw.gov.au/dsp_content.cfm?cat_id=1161</u>
- 18 GRDC (2012) A few steps to preventing header fires. GRDC Ground Cover Issue 101, <u>http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-101/A-few-steps-to-preventing-header-fires</u>





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GRDC Podcasts: Harvester Fires.



<u>GRDC Reducing Harvester Fire Risk:</u> The Back Pocket Guide

An investigation into harvester fires

Plan of attack needed for harvester fires

Step 1: Read the temperature on the left hand side.

Step 2: Move across to the relative humidity.

Step 3: Read the wind speed at the intersection. In the worked example, the temperature is 35oC and the relative humidity is 10 per cent so the wind speed limit is 26kph.

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			U									
	TEMP °C	5	10	15	20	25	30	40	50	60	65	RH%*
	15	31	35	38	40	43	45	49	53	56	58	Ŧ
	20	29	33	36	38	40	43	46	50	53	55	D (KF
	25	27	30	33	36	38	40	44	47	50	52	PEE
	30	25	28	31	33	35	37	41	44	47	49	QN
0	35	23	26•	28	31	33	35	38	41	44	46	E M
	40	21	24	26	28	30	32	35	39	41	43	ERAG
	45	19	22	24	26	28	30	33	36	39	40	AVI
	TEMP °C	5	10	15	20	25	30	40	50	60	65	RH%*
			3					*RH% !Wind	(Relativ	e Humid verageo	ity round d over 1	ded down) 0 minutes

Figure 2: Grassland fire danger index guide.

12.5 Receival standards

Table 1: Oats standards 2015–2016. These standards are to be applied onindividual truck loads and must not be averaged over a number of loads.Segregations indicated on this chart are only available where announced.

Test Code	Binned Grade	MOAT	GSF	
VARP	Varietal Purity minimum (% by weight)	95	No Limit	
MOGR	Moisture maximum (%)	12.5	12.5	
TWT	Test Weight minimum (kg/hl)	51.0	48.0	
SCRN	Unmillable Material Below The Screen maximum (% by weight)	10	20	
	Material passing through a 2.0 mm slotted screen after 40 shakes			
UNM	Unmillable Material Above The Screen maximum (% by weight)	No Limit	No Limit	
	Material other than oats kernels remaining on top of a 2.0 mm slotted screen after 40 shakes			
Defective Grain – Maximum % by count per 200 Grain Sample unless otherwise stated (1% = 2 grains).				

Note: NIL tolerance applies to the entire load except where stated otherwise.

Defective definitions are to be read in conjunction with the photo in the Visual Recognition Standards Guide which depicts the minimum standard for a grain to be classified as defective.

DAMS	Damaged Grains maximum (% by count)	2%	No Limit
		(4	

grains)





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Test Code	Binned Grade	MOAT	GSF
STAN	Total Weather Stained Grains maximum (% by	5%	20%
	county	(10 grains)	(40 grains)
STAK	Total Weather Stained Groats maximum (% by	NIL	20%
	count)		(40 grains)
FFUN	Field Fungi maximum (% by count)	NIL	NIL
GREE	Dry Green or Sappy maximum (% by count)	5%	No Limit
		(10 grains)	
FTDG	Frost Damaged/Takeall Affected maximum (% by	1%	20%
	county	(2 grains)	(40 grains)
DAMI	Insect Damaged maximum (% by count)	1%	5%
		(2 grains)	(10 grains)
SPRE	Shot maximum (% by count)	NIL	No Limit
SPRO	Sprouted maximum (% by count)	NIL	NIL
BURN	Heat Damaged, Bin Burnt and Storage Mould (count per half litre)	NIL	1
Seed Contaminants – Tolerances apply to whole seeds or their equivalent in pie and refer to the maximum total of all seeds named in each type per half litre. Exc TYPE (1) in which the maximum applies on an individual seed basis per half litre.			
WS1	TYPE (1): Colocynth, Jute, Long Headed Poppy, Mexican Poppy, Field Poppy, Horned Poppy, Wild Poppy, New Zealand Spinach, Parthenium Weed**	5*	5*
WS2	TYPE (2): Castor Oil Plant, Coriander, Crow Garlic/Wild Garlic, Darling Pea, Double Gees/ Spiny Emex/Three Cornered Jack***, Opium Poppy, Peanut seeds and pods, Ragweed, Rattlepods, Starburr, St. John's Wort	NIL	NIL
WS3A	TYPE (3a): Bathurst Burr, Bellvine, Branched Broomrape, Bulls Head/Caltrop/Cats Head, Cape Tulip, Cottonseed, Dodder, Noogoora Burr, Thornapple/False Castor Oil	NIL	NIL
WS3B	TYPE (3b): Vetch (Commercial), Vetch (Tare)	4	4
WS3C	TYPE (3c): Heliotrope (Blue), Heliotrope (Common) Note: Included in this Type are tolerances for seeds or pode****	1 Pods / 4 Seeds	1 Pods / 4 Seeds
WS4	TYPE (4): Bindweed (Field), Cutleaf Mignonette seeds or pods, Darnel, Hexham Scent/King	10	10

	Island Melilot*****, Hoary Cress, Mintweed, Nightshades, Paddy Melon, Skeleton Weed, Variegated Thistle			
WS5	TYPE (5): Knapweed (Creeping/Russian), Patterson's Curse/Salvation Jane, Sesbania Pea	40	40	
WS6	TYPE (6): Saffron Thistle	5	10	



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Test Code	Binned Grade	MOAT	GSF	
WS7A	TYPE (7a): Broad Beans, Chickpeas, Colombus Grass, Corn (Maize), Cowpea, Faba Beans, Johnson Grass, Lentils, Lupin, Peas (Field), Safflower, Soybean, Sunflower and any other seeds or pods greater than 5 mm in diameter	1	20	
WS7B	TYPE (7b): Barley, Bindweed (Australian), Bindweed (Black), Wheat, Durum, Oats (Sand), Rice, Rye (Cereal), Sorghum (Forage), Sorghum (Grain), Triticale, Turnip Weed and any other weed seeds not specified in TYPES (1)–(7a), TYPE (8) or Small Foreign Seeds (SFS)	50	250	
WS8	TYPE (8): Oats (Black or Wild)	10	100	
SFS	Small Foreign Seeds maximum (% by weight)	0.5%	3%	
	All foreign seeds not specified in TYPES (1)–(7b) that fall below the 2.0 mm screen during the Screenings process			
* Individual seed basis ** Parthenium Weed is a NIL tolerance in NSW/VIC/SA *** Doublegees/Spiny Emex/Three Cornered Jack is a NIL tolerance in MOAT **** Heliotrope pods must be opened and the seeds counted ***** Hexham Scent is only acceptable if no tainting odour is present				
Other Conta named in ea	aminants – Tolerances refer to the maximum total of ach type per half litre unless otherwise stated.	all contam	inants	
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Note: NIL tolerance applies to the entire load except where stated otherwise.

SMUT	Smuts/Cereal Ergots maximum (entire load)	NIL	NIL
	Includes: Ball and gall smut, other smut species, cereal ergots		
ERGR	Ergot of Ryegrass max (length in cm when pieces are aligned per half litre)	2 cm	2 cm
LIVE	Stored Grain Insects and Pea Weevils: Live max (entire load)	NIL	NIL
INLG	Field Insects – Large, dead or alive (count per half litre)	3	3
	Includes Desiantha Weevil, Hairy Fungus Beetle, Pea Weevil, Sitona Weevil, Rutherglen bugs, ladybirds, grasshoppers and wood bugs, whole or parts thereof		
	These are insect contaminants of grain that do not cause damage to stored grains		
INSM	Field Insects – Small, dead or alive (count per half litre)	10	10
	Includes all species of aphid, minute mould beetle, mites and stored grain insects (dead only)		
	These are insect contaminants of grain that do not cause damage to stored grains		
SNAL	Snails – Live or Dead maximum (count per half litre)	2	3
SAND	Sand/Soil maximum (count per half litre) (Individual grains of sand)	50	50
STON	Stones (g per 2.5 L) Maximum weight of all Stones retained above a 2.0 mm screen per 2.5 L	4	4





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<u>Grain Trade Australia Oats trading</u> <u>standards</u>.



WATCH: <u>Harvest Weed Seed Control</u> for the high rainfall zone



Test Code	Binned Grade	MOAT	GSF
OBJM	Objectionable Material maximum (entire load)	NIL	NIL
	Includes: Sticks, stones, glass, concrete or any other commercially unacceptable contaminant, smell or taste		
PICK	Pickling Compounds maximum (entire load)	NIL	NIL
MLD	Odour maximum (entire load)	NIL	NIL
	Grain which has any commercially objectionable foreign odour due to tainting agents or improper storage causing mould, souring or musty odours		
CHEM	Chemicals Not Approved for Oats maximum (entire load)	NIL	NIL
	Residues of any chemical compound not approved for oats, used in contravention of the labelled instructions or chemicals in excess of the maximum residue limit (MRL)		
OFM	Other Foreign Material (% by weight) maximum	0.1	NIL
	Other material not otherwise specified, including but not limited to: fine material (<0.06 mm in diameter), minerals, Snail Shell (less than half an entire shell, Grain Insects, pieces of Stored Grain Insects (not whole), pieces of Insects Large and Small, sticks that are smaller than the dimensions specified under Objectionable Matter, and other non-vegetative material		

Source: Grain Trade Australia (GTA) Standards CSG-31 (MOAT) and CSG-32 (GSF)

12.6 Harvest weed seed management

Targeting weed seeds at harvest is a pre-emptive action against problematic populations of annual weeds. Our most damaging crop weeds—annual ryegrass, wild radish, wild oats and brome grass—are all capable of establishing large, persistent seedbanks. Thus, if annual weeds are allowed to produce seed that enters the seedbank, the cropping system will inevitably be unsustainable. Fortunately, seedbank decline is rapid for these weed species, with annual seed losses of 60–80%. Without inputs, a very large seedbank (>1000 seed/m²) can therefore be reduced to a very modest one (<100 seed/m²) in just four years. A small seedbank of weeds allows easier and more effective weed control with reduced risk of development of herbicide resistance. Effective weed management in productive cropping systems is thus reliant on preventing viable seed from entering the seedbank. Several systems developed over the past three decades target the weed-seed-bearing chaff fraction during harvest.

Techniques have been developed targeting weed seeds during harvest, and these techniques are now being adopted in the eastern states. At harvest, much of the total seed production for the dominant weed species is retained above harvester cutting height (Table 2). Additionally, for some of these species such as wild radish, high levels of seed retention are maintained over much of the harvest period (Figure 3). Therefore, the collection and management of the weed-seed-bearing chaff fraction can result in significant reductions in population densities of annual weeds.¹⁹



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M Walsh, S Powles (2012) Harvest weed seed control. GRDC Update Papers, 12 April 2012, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Harvest-weed-seed-control/</u>



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 Table 2: Proportion of total seed production retained above a low harvest cutting height (15 cm).
 Source: GRDC

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Species	Seed retention above 15 cm (%)
Annual ryegrass	88
Wild radish	99
Brome grass	73
Wild oats	85



Figure 3: Seed retention above a harvest height of 15 cm over the first 4 weeks of harvest for the major weeds of Western Australian wheat crops.

A key strategy for all harvest weed seed control operations is to maximise the percentage of weed seeds entering the header. This means harvesting as early as possible before weed seed is shed, and harvesting as low as is practical.

12.6.1 Burning of narrow windrows

During traditional, whole-paddock stubble burning, the very high temperatures needed for weed seed destruction are not sustained for long enough to kill most weed seeds, in particular wild radish. By concentrating harvest residues and weed seed into a narrow windrow, fuel load is increased and the period of high temperatures extends to several minutes, improving the kill of weed seeds (Photo 4). Stubble cover is also retained across the paddock, resulting in less erosion and greater moisture retention.

Establishing narrow windrows suitable for autumn burning is achieved by attaching chutes to the rear of the harvester to concentrate the straw and chaff residues as they exit the harvester. This concentration of residue increases the seed destruction potential of residue burning. With more fuel in these narrow windrows, the residues burn hotter than standing stubbles or even conventional windrows (Photo 5). Weed seed kill levels of 99% for both annual ryegrass and wild radish have been recorded from the burning of wheat, canola and lupin stubble windrows.²⁰



²⁰ M Walsh, S Powles (2012) Harvest weed seed control. GRDC Update Papers, 12 April 2012, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Harvest-weed-seed-control/</u>



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Photo 4: Harvest in action—producing narrow chaff rows for burning in the following autumn.

Photo: A. Storrie



Photo 5: Windrow burning. Photo: Penny Heuston

12.6.2 Chaff carts

Chaff carts are towed behind headers during harvest to collect the chaff fraction as it exits the harvester (Photo 6). Collected piles of chaff are then burnt the following autumn or used as a source of stock feed. ²¹ The weed seed collection efficiency of several commercially operating harvesters with attached chaff carts was evaluated by the Australian Herbicide Resistance Initiative (AHRI). Harvesters were found to collect 75–85% of annual ryegrass seeds and 85–95% of wild radish seeds entering the



²¹ GRDC. Section 6: Managing weeds at harvest. GRDC Integrated Weed Management Hub, <u>http://grdc.com.au/Resources/IWMhub/</u> Section-6-Managing-weeds-at-harvest



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front of the header during the harvest operation. Collected chaff must be managed to remove weed seeds from the cropping system. Typically, this material is left in piles in the paddock to be burnt in the following autumn. In some instances though, chaff is removed from the paddock and used as a source of feed for livestock. ²²

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Photo 6: Chaff cart in action. Photo: Trent Butcher, ConsultAg

12.6.3 Bale-direct systems

An alternative to the *in-situ* burning or grazing of chaff, the bale-direct system uses a baler attached to the back of the harvester to collect all chaff and straw material as it exits the harvester. As well as removing weed seeds, the baled material has an economic value as a livestock feed source. ²³ The bale-direct system was developed by the Shields family in Wongan Hills as a means of improving straw hay production (Photo 7). It consists of a large square baler directly attached to the harvester that collects and bales all harvest residues. A significant secondary benefit is the collection and removal of annual weed seeds. Studies by AHRI determined that ~95% of annual ryegrass seed entering the harvester was collected in the bales. As well as being an effective system for weed seed removal, the baled material can have a substantial economic value as a feed source. However, as with all baling systems, consideration must be given to nutrient removal. ²⁴



Photo 7: Bale-direct machine at Kellie Shield's "Gunwarrie" Frankland River. Photo: Penny Heuston

- 22 M Walsh, S Powles (2012) Harvest weed seed control. GRDC Update Papers, 12 April 2012, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Harvest-weed-seed-control/</u>
- 23 GRDC. Section 6: Managing weeds at harvest. GRDC Integrated Weed Management Hub, <u>http://grdc.com.au/Resources/IWMhub/Section-6-Managing-weeds-at-harvest</u>
- 24 M Walsh, S Powles (2012) Harvest weed seed control. GRDC Update Papers, 12 April 2012, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Harvest-weed-seed-control/</u>



Visit <u>www.glenvar.com</u> for the story of the development of header-towed bailing systems.





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12.6.4 Chaff grinding – the Harrington Seed Destructor

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Processing of chaff sufficient to destroy any weed seeds that are present during the harvest operation is the ideal system for large-scale Australian conservation cropping systems. Rendering weed seeds non-viable as they exit the harvester removes the need to collect, handle and/or burn large volumes of chaff and straw residues. Because of the importance and potential industry benefits of this process, there has been substantial interest in the development of an effective system.

Ray Harrington, a progressive farmer from Darkan, Western Australia, invented and developed the Harrington Seed Destructor (HSD), a cage-mill-based system attached to the back of the harvester that processes chaff during harvest.

The HSD system comprises a chaff-processing cage mill, and chaff and straw delivery systems. The retention of all harvest residues in the field reduces the loss and/or banding of nutrients and maintains all organic matter to protect the soil from wind and water erosion, as well as reducing evaporation loss compared with windrow burning, chaff carts and baling. ²⁵

Evaluation under commercial harvest conditions by AHRI has determined that the HSD will destroy \geq 95% of annual weed seed during harvest. With the efficacy of the HSD system well established, its development has progressed to commercial production. ²⁶

A new chaff grinder that is integrated into the back of the header is now in commercial production. It has similar principles to the HSD and it was developed at the University of South Australia.

12.6.5 Desiccation pre-hay cutting

With the registration of weedmaster[®] DST[®] for desiccating hay pre-cutting, growers now have an option which reduces weed seed set and prevents re-growth of weeds and oats.

Desiccating 1–11 days pre-mowing delivers benefits including:

- Reducing weed seed set
- Preventing hay and weed re-growth
- Preserving soil moisture
- Maintaining or improving hay quality.

For some growers wheel tracks can be an issue for mowing but this is best managed by spraying in a different direction to the hay mower. ²⁷



²⁵ GRDC. Section 6: Managing weeds at harvest. GRDC Integrated Weed Management Hub, <u>http://grdc.com.au/Resources/IWMhub/</u> Section-6-Managing-weeds-at-harvest

⁶ M Walsh, S Powles (2012) Harvest weed seed control. GRDC Update Papers, 12 April 2012, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Harvest-weed-seed-control/</u>

²⁷ NuFarm TechNOTE Control weed seed set and hay/silage re-growth with weedmaster DST, <u>http://www.nufarm.com/Assets/28377/1/</u> weedmasterDSTHay_Silage_v1.pdf



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Key messages:

- Oats contain fats unlike other cereals and require greater care when storing.
- The maximum moisture content at which oats can be safely stored is 12.5% unless the temperature is reduced below 15°C. Above the safe limit, fungi may develop and cause grain spoilage.
- Effective grain hygiene and aeration cooling can overcome 85% of pest problems.
- Chemically treated oats are not acceptable into all human consumption markets.
- The only approved fumigant for oats is phosphine.
- Growers should pressure-test sealable silos once a year to check for damaged seals on openings.
- It is important that growers monitor stored grain at least once a month.

When oats are destined for human consumption markets correct storage is of paramount importance. Grain Trade Australia (GTA) stipulates standards for heatdamaged, bin-burnt, storage-mould-affected or rotten grain, all of which can result in the discounting or rejection of grain. GTA has nil tolerance to live, stored grain insects for all grades from milling grades to feed. Effective management of stored grain can eliminate all of these risks to quality (Photo 1).







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Photo 1: Weevil on stored oat grain. Source: Walden Effect

Correct storage of oats is particularly important when destined for human consumption. Buyers of milling oats will generally require growers to have a quality management program in place. Before harvest clean all grain-handling equipment harvester, truck, silos and augers need to have residues removed. Grain stores need to be maintained and kept watertight as oats are like a sponge and very susceptible to moisture migration which can cause mould, odour and sprouting which can result in the whole silo, shed or silo bag being unsalable. There are a number of important factors to consider when maintaining oat grain quality in storage.¹

13.1 How to store product on-farm

13.1.1 Grain moisture

Keeping grain dry and free from fungal growth is the most important requirement for safe storage. The maximum moisture content at which oats can be safely stored is 12.5% unless the temperature is reduced below 15°C. Above the safe limit, fungi may develop and cause grain spoilage.²

13.1.2 Duration of storage

Storing oats at a temperature below 20°C and a moisture content of less than 12.5% should provide a shelf-life of at least 12 months.

- The initial moisture content should be lower for longer periods of storage.
- Aeration is considered necessary for long-term storage of oats to preserve the quality by keeping an even, cool temperature within the storage vessel. It is also a valuable tool for reducing the loss in grain quality caused by moisture, grain insects and mould.³



G Troup (2016) Oats: harvesting, swathing and grain storage, Lodging. DAFWA, https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C2

² G Troup (2016) Oats: harvesting, swathing and grain storage, Lodging. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-</u> swathing-and-grain-storage?page=0%2C2

³ G Troup (2016) Oats: harvesting, swathing and grain storage, Lodging. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C2</u>



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Oat millers have a preference for new crop oats that are no older than 12 months to ensure quality (taste and smell) of processed oat products.

13.1.3 On-farm investment

Growers in the Southern region are investing in on-farm storage for a range of reasons (Table 1). In the eastern states, on-farm storage gives growers options into domestic and export markets, while in South Australia – where the majority of grain goes to bulk handlers – growers tend to set up storage to improve harvest management.

Growers might only plan to store grain on-farm for a short time, but markets can change, so investing in gas-tight sealable structures means you can treat pests reliably and safely and leave your business open to a range of markets.

Growers should approach storage as they would purchasing machinery: Growers spend a lot of time researching a header purchase to make sure it is fit-for-purpose. Grain storage can also be a significant investment, and a permanent one, so it pays to have a plan that adds value to your enterprise into the future.

Decide what you want to achieve with storage, critique any existing infrastructure and be prepared for future changes: A good storage plan can remove a lot of stress at harvest – growers need a system that works so they capture a better return in their system.⁴



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 Table 1: Advantages and disadvantages of grain storage options.

Storage type	Advantages	Disadvantages		
Gas-tight sealable	Gas-tight sealable status allows phosphine and controlled	Requires foundation to be constructed		
silo	atmosphere options to control insects	Relatively high initial investment required		
	Easily aerated with fans	Seals must be regularly maintained		
	Fabricated on-site or off-site and transported	Access requires safety equipment and infrastructure		
	Capacity from 15 tonnes up to 3,000 tonnes	Requires an annual test to check gas-tight sealing		
	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			



GRDC. (2015). Ground cover issue 119 – Grain storage. Extension tailored for regional challenges. https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-119-Grain-storage/Extension-tailored-for-regional-challenges



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Storage type	Advantages	Disadvantages			
Non- sealed silo	Easily aerated with fans	Requires foundation to be constructed Silo cannot be used for fumigation—see phosphine label			
	7–10% cheaper than sealed silos				
	Capacity from 15 tonnes up to 3,000 tonnes				
	Up to 25 year plus service life	Insect control options limited to protectants in eastern states and Dryacide™ in WA			
	Can be used multiple times in-				
	season	Access requires safety equipment and infrastructure			
Grain	Low initial cost	Requires purchase or lease of			
storage baas	Can be laid on a prepared pad in a	loader and unloader			
		short-term storage (typically three			
	Provide narvest logistics support	months)			
	Are all ground operated	Limited insect control options.			
	Can accommodate high violding	specific protocols			
	seasons	Requires regular inspection and			
	Grain is untreated for wider market access.	maintenance, which need 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	Can be used for dual purposes	Aeration systems require specific			
storage sheds	30 year plus service life	aesign			
	Low cost per stored tonne	purpose use			
		Difficult to seal for fumigation			
		Vermin control is difficult			
		Limited insect control options without sealing			
		Difficult to unload			

Source: Kondinin Group

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13.1.4 Silos

An on-farm storage system designed for good hygiene that includes aeration and sealable silos for fumigation is essential for growers who wish to supply these markets and local oat mills to maximise their returns (Photo 2). Without sealable silos, growers could also 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 oat 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



(i) MORE INFORMATION

Benefits flow from on-farm storage in

the Mallee.

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operated provides the best insurance a grower can have on the quality of grain to be out-turned.



Photo 2: When using on-farm silos it is important to pressure test all silos, even those that are labeled as 'sealed'.

Source: <u>GRDC</u>

Sealed silos offer a more permanent grain storage option than grain storage bags. Depending on the amount of storage required, they will have a higher initial capital cost than grain storage bags and are depreciated over a longer time frame than the machinery required for the grain bags. In a silo grain storage system as stored tonnage increases the capital cost of storage increases.

Potential advantages of using sealed grain silos as a method for grain storage include improved harvest management, reduced harvest stress, reduced harvest freight requirements, minimal insecticide exposure and the opportunity to segregate and blend grain.

Potential disadvantages of using sealed grain silos as a method for grain storage include the initial capital outlay, the outlay required to meet occupational health and safety requirements, the additional on farm handling required and the additional site maintenance requirements. ⁵

Pressure testing

- A silo sold as a 'sealed silo' needs to be pressure tested to be sure it's gas-tight.
- It is strongly recommended that growers ask the manufacturer or reseller to quote the AS2628 on the invoice as a means of legal reference to the quality of the silo being paid for.
- Pressure test sealed silos upon erection, annually and before fumigating with a five-minute half-life pressure test.
- Maintenance is the key to ensuring a silo purchased as sealable can be sealed and gas-tight.

A silo is only truly sealed if it passes a five-minute half-life pressure test according to the Australian Standard AS2628. Often silos are sold as sealed but are not gas-tight — rendering them unsuitable for fumigation.

Even if a silo is sold as 'sealed' it is not sealed until it is proven gas-tight with a pressure test.



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⁵ Francis J. (2006). An analysis of grain storage bags, sealed grain silos and warehousing for storing grain. <u>https://grdc.com.au/uploads/</u> documents/Final%20report%20Grain%20Storage%20Bags%2021%20Jul%20061.pdf





MORE INFORMATION

FEEDBACK

<u>GRDC Pressure testing sealable silos</u> factsheet.

GRDC Silo buyer's guide

Eumigating with phosphine, other fumigants and controlled atmospheres'



WATCH : <u>Pressure testing sealed</u> silos.



WATCH : <u>Stored grain: Managing</u> sealed and unsealed storage.



The term 'sealed' has been used loosely during the past and in fact some silos may not have been gas-tight from the day they were constructed.

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However, even a silo that was gas-tight to the Australian Standard on construction will deteriorate over time so needs annual maintenance to remain gas-tight.

Why do I need to do a pressure test?

In order to kill grain pests at all stages of their life cycle (egg, larvae, pupae, adult), phosphine gas concentration levels need to reach and remain at 300 parts per million (ppm) for seven days or 200ppm for 10 days.

The importance of a gas-tight silo

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. ⁶

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. Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3 ppm close to the leaks. The rest of the silo also suffers from reduced gas levels.⁷

It is recommended to pressure-test silos that are sealable once a year to check for damaged seals on openings. Storages must be able to be sealed properly to ensure effective fumigation.

There is no compulsory manufacturing standard for sealed silos in Australia. A voluntary industry standard was adopted in 2010. Watch this <u>GRDC Ground Cover TV</u> clip to find out more.

13.1.5 Grain bags

Grain storage bags are relatively new technology offering a low cost alternative for temporary storage of grain to permanent grain storage structures on farm such as silos. Grain storage bags are made of multilayer polyethylene material similar to that used in silage fodder systems. Bags typically store between 200 and 220 tonnes of cereal grain and are filled and emptied using specialised machinery (Photo 3). The bags are sealed after filling producing a relatively airtight environment which, under favourable storage conditions, protects grain from insect damage without the use of insecticides.

Potential advantages of using grain storage bags as a method for grain storage include the low capital set up costs, improved harvest management, less harvest stress, reduced harvest freight requirements, minimal cost in occupational health and safety (OH&S) requirements, reduced grain insecticide requirements and the opportunity to segregate and blend grain.

Potential disadvantages of using grain storage bags as a method for grain storage include the requirement for disposal of used bags, the period of storage before bag deterioration and the management necessary to ensure bag integrity. Another potential disadvantage of this system, when compared to permanent structures,



⁶ 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), <u>https://grdc.com.au/uploads/documents/GRDC-Fumigating-with-Phosphine-other-fumigants-and-controlled-atmospheres.pdf?shortcut=1</u>

⁷ P Botta, P Burrill, C Newman (2010) Pressure testing sealable silos. GRDC Grain Storage Fact Sheet, September 2010 Revised July 2014. <u>http://storedgrain.com.au/wp-content/uploads/2014/09/GSFS-3_PressureTest-July14.pdf</u>









WATCH: <u>Extension Files: Grain</u> bags—a grower's perspective



is that once the storage period is complete there is no asset value in the storage system other than the bagging machinery. $^{\rm 8}$

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Photo 3: A 100m bag can be filled in 30 minutes with a constant supply of grain.

13.1.6 Monitoring stored grain

Check the grain regularly during storage for signs if grain insect activity and be prepared to deal with an infestation if it occurs. ⁹

Monitoring grain temperature and moisture content:

- Pests and grain moulds thrive in warm, moist conditions. Monitor grain moisture content and temperature to prevent storage problems.
- Use a grain temperature probe to check storage conditions and aeration performance (Photo 4).
- When checking grain, smell air at the top of storages for signs of high grain moisture or mould problems.
- Check germination and vigour of planting seed in storage.
- Aeration fans can be used to cool and dry grain to reduce storage environment problems.

It is vital to monitor grain moisture content to prevent pests and grain moulds from thriving. $^{\rm 10}$



⁸ Francis J. (2006). An analysis of grain storage bags, sealed grain silos and warehousing for storing grain. <u>https://qrdc.com.au/uploads/</u> documents/Final%20report%20Grain%20Storage%20Bags%2021%20Jul%20061.pdf

Waratah Seed Co. Ltd. (2010) Triticale: planting guide. <u>http://www.porkcrc.com.au/IA-102_Triticale_Guide_Final_Fact_Sheets.pdf</u>
 Plant Health Australia. (2015). Monitoring stored grain on farm. <u>http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/</u> Monitoring-stored-grain-on-farm.pdf





Photo 4: Monitor moisture and temperature using a digital probe from both the top and the bottom of silos, if safe to do so.

Source: Plant Health Australia.

13.1.7 Grain storage – get the economics right

As growers continue to expand their on-farm grain storage, the question of economic viability gains significance. There are many examples of growers investing in on-farm grain storage and paying for it in one or two years because they struck the market at the right time, but are these examples enough to justify greater expansion of on-farm grain storage?

The grain storage extension team conduct approximately 100 grower workshops every year, Australia wide and it's evident that no two growers use on-farm storage in the exact same way. Like many economic comparisons in farming, the viability of grain storage is different for each grower. Depending on the business's operating style, the location, the resources and the most limiting factor to increase profit; grain storage may or may not be the next best investment. For this reason, everyone needs to do a simple cost benefit analysis for their own operation.

Comparing on-farm grain storage

To make a sound financial decision, we need to compare the expected returns from grain storage versus expected returns from other farm business investments, such as more land, a chaser bin, a wider boomspray, a second truck or paying off debt. The other comparison is to determine if we can store grain on-farm cheaper than paying a bulk handler to store it for us.

Calculating the costs and benefits of on-farm storage will enable a return-on investment (ROI) figure, which can be compared with other investment choices and a total cost of storage to compare to the bulk handlers.

Cheapest form of storage

The key to a useful cost–benefit analysis is identifying which financial benefits to plan for and costing an appropriate storage to suit that plan. People often ask, "what's the cheapest form of storage?" The answer is the storage that suits the planned benefits. Short term storage for harvest logistics or freight advantages can be suited to grain





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bags or bunkers. If flexibility is required for longer term storage, gas-tight, sealable silos with aeration cooling allow quality control and insect control.

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Benefits

To compare the benefits and costs in the same form, work everything out on a basis of dollars per tonne. On the benefit side, the majority of growers will require multiple financial gains for storing grain to make money out of it. These might include harvest logistics or timeliness, market premiums, freight savings or cleaning, blending, or drying grain to add value.

Costs

The costs of grain storage can be broken down into fixed and variable. The fixed costs are those that don't change from year to year and have to be covered over the life of the storage. Examples are depreciation and the opportunity or interest cost on the capital. The variable costs are all those that vary with the amount of grain stored and the length of time it's stored for. Interestingly, the costs of good hygiene, aeration cooling and monitoring are relatively low compared to the potential impact they can have on maintaining grain quality. One of the most significant variable cost, and one that is often overlooked is the opportunity cost of the stored grain. That is the cost of having grain in storage rather than having the money in the bank paying off an overdraft or a term loan.

The result

While it's difficult to put an exact dollar value on each of the potential benefits and costs, a calculated estimate will determine if it's worth a more thorough investigation. If we compare the investment of on-farm grain storage to other investments and the result is similar, then we can revisit the numbers and work on increasing their accuracy. If the return is not even in the ball park, we've potentially avoided a costly mistake. On the contrary, if after checking our numbers the return is favourable, we can proceed with the investment confidently.

Summary

Unlike a machinery purchase, grain storage is a long term investment that cannot be easily changed or sold. Based on what the grain storage extension team are seeing around Australia, the growers who are taking a planned approach to on-farm grain storage and doing it well are being rewarded for it. Grain buyers are seeking out growers who have a well-designed storage system that can deliver insect free, quality grain without delay.

Table 2 is a tool that can be used to figure out the likely economic result of on-farm grain storage for each individual business. Each column can be used to compare various storage options including type of storage, length of time held or paying a bulk handler. ⁿ







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Table 2: Cost-benefit template for grain storage.

Financial gains fro	Example \$/t	\$/t	
Harvest logistics/ timeliness	Grain price x reduction in value after damage % x probability of damage %	\$16	
Marketing	Post harvest grain price - harvest grain price		
Freight	Peak rate \$/t - post harvest rate \$/t	\$20	
Cleaning to improve grade	Clean grain price - original grain price - cleaning costs - shrinkage		
Blending to lift average grade	Blended price - ((low grade price x %mix) + (high grade price x %mix))		
Total benefits	Sum of benefits	\$36.20	
Capital cost	Infrastructure cost / storage capacity	\$155	
Fixed costs			
Annualised depreciation cost	Capital cost \$/t / expected life storage eg 25yrs	\$6.20	
Opportunity cost on capital	Capital cost \$/t x opportunity or interest rate eg 8% / 2	\$6.20	
Total fixed costs	Sum of fixed costs	\$12.40	
Variable costs			
Storage hygiene	(Labour rate \$/hr x time to clean hrs / storage capacity) + structural treatment	\$0.23	
Aeration cooling	Indicatively 23c for the first 8 days then 18c per month / \ensuremath{t}	\$0.91	
Repairs and maintenance	Estimate e.g. capital cost \$/t x 1%	\$1.51	
Inload/outload time and fuel	Labour rate \$/hr / 60 minutes / auger rate t/m x 3	\$0.88	
Time to monitor and manage	Labour rate \$/hr x total time to manage hrs / storage capacity	\$0.24	
Opportunity cost of stored grain	Grain price x opportunity interest rate e.g. 8% / 12 x No. months stored	\$7.20	
Insect treatment cost	Treatment cost $/t \times No.$ of treatments	\$0.35	
Cost of bags or bunker trap	Price of bag / bag capacity tonne		
Total variable costs	Sum of variable costs	\$11.32	
Total cost of storage	Total fixed costs + total variable costs	\$23.72	
Profit/Loss on storage	Total benefits - total costs of storage	\$12.48	
Return on investment	Profit or loss / capital cost x 100	8.1%	

Source: GRDC.



(i) MORE INFORMATION

<u>GRDC Economics of on-farm grain</u> storage, cost benefit analysis.

Economics of on-farm grain storage:

a grains industry guide

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WATCH: <u>On-farm storage in the SA</u> <u>Mallee with Corey Blacksell.</u>



WATCH: On-farm storage in SA— Linden Price



WATCH: <u>Over the Fence: On-farm</u> storage delivers harvest flexibility and profit



WATCH: <u>Stay safe around grain</u> storage



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13.2 Stored grain pests

Key points:

- Effective grain hygiene and aeration cooling can overcome 85% of pest problems.
- When fumigation is needed it must be carried out in pressure-tested, sealed silos.
- Monitor stored grain monthly for moisture, temperature and pests.

The combination of meticulous grain hygiene plus well-managed aeration cooling generally overcomes 85% of storage pest problems. For grain storage, three key factors provide significant gains for both grain storage pest control and grain quality: hygiene, aeration cooling and correct fumigation.

In one year, one 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 (Photo 5).

Stored grain needs to be protected from insect infestation.

- Serious infestation will occur within three months, even in situations where risk is minimised by cleaning harvesting equipment, grain store and the surrounding area.
- With poor hygiene, this interval is reduced to 6–8 weeks, and there is a greater risk of secondary effects such as moisture problems and fungal growth.



Photo 5: Insect damage to oat grain. Source: <u>USDA</u>

Common species

The most common insect pests of stored cereal grains in Australia are (Figure 1):

- Weevils (*Sitophilus spp.*). Rice weevil is the most common weevil in cereals in Australia
- Lesser Grain Borer (Rhyzopertha dominica)
- Rust Red Flour Beetle (Tribolium spp.)





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- Flat Grain Beetle (Cryptolestes spp.)
- Indian Meal Moth (Plodia interpunctella)
- Angoumois Grain Moth (Sitotroga cerealella).

Another dozen or so beetles, psocids (booklice) and mites are sometimes present as pests in stored cereal grain.

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Figure 1: Identification of common pests of stored grain. Source: <u>GRDC</u>.

13.2.1 Monitoring grain for pests

Damage by grain insect pests often goes unnoticed until the grain is removed from the storage. Regular monitoring will help to ensure that grain quality is maintained.

- Sample each grain storage at least monthly. During warmer periods of the year fortnightly sampling is recommended.
- Take samples from the top and bottom of grain stores and sieve (using 2 mm mesh) onto a white tray to separate any insects (Photo 6).
- Hold tray in the sunlight for 10–20 seconds to trigger movement of any insects, making them easier to see. Use a magnifying glass to identify pests.
- Grain probes or pitfall traps should also be used to check for insects. These traps are left in the grain during storage and are often able to detect the start of an infestation.
- Push probe/trap into the grain surface and pull up for inspection fortnightly/ monthly. Place 1–2 traps in the top of a silo or several traps in a grain shed.
- Be sure to check grain 3 weeks prior to sale to allow time for treatment if required. ¹²

12 Plant Health Australia. (2015). Monitoring stored grain on farm. <u>http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/</u> Monitoring-stored-grain-on-farm.pdf









<u>GRDC Stored grain pests; the back</u> pocket guide

Monitoring stored grain on farm.







Photo 6: A 2 mm mesh sieve will separate insects from grain. Source: <u>Plant Health Australia.</u>

13.2.2 Hygiene

Key points:

- Effective grain hygiene requires complete removal of all waste grain from storages and equipment.
- Be meticulous with grain hygiene pests only need a small amount of grain for survival.

Effective grain hygiene and aeration cooling can overcome 75% of pest problems in stored grain. The first grain harvested is often at the greatest risk of early insect infestation due to contamination. Remove grain residues from empty storages and grain-handling equipment, including harvesters, field bins, augers and silos, to ensure an uncontaminated start for new-season grain. Clean equipment by blowing or hosing out residues and dust and then consider a structural treatment. Remove and discard any grain left in hoppers and bags from the grain storage site so it does not provide a habitat for pests during the off season. 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 (Photo 7).



Photo 7: Poor grain hygiene undermines effective stored grain insect control.





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Hygienic storage of grain 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 grain 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.

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.

Where to clean

Removing an environment for pests to live and breed in is the basis of grain hygiene, which includes all grain handling equipment and storages. Grain pests live in dark, sheltered areas and breed best in warm conditions.

Common places where pests are found include:

- Empty silos and grain storages
- Aeration ducts, augers and conveyers
- Harvesters, field bins and chaser bins
- Left-over bags of grain trucks
- Spilt grain around grain storages
- Equipment and rubbish around storages
- Seed grain
- Stockfeed grain

Successful grain hygiene involves cleaning all areas where grain gets trapped in storages and equipment (Photo 8). Grain pests can survive in a tiny amount of grain, so any parcel of fresh grain through the machine or storage becomes infested.



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Photo 8: Grain left in trucks is an ideal place for grain pests to breed. Keep trucks, field bins and chaser bins clean.

Source: <u>GRDC</u>.

When to clean

Straight after harvest is the best time to clean grain handling equipment and storages, before they become infested with pests. One trial revealed more than 1000 lesser grain borers in the first 40 litres of grain through a harvester at the start of harvest, which was considered reasonably clean at the end of the previous season. Discarding the first few bags of grain at the start of the next harvest is also a good idea. Further studies revealed insects are least mobile during the colder months of the year. Cleaning around silos in July – August can reduce insect numbers before they become mobile.

How to clean

The better the cleaning job, the less chance of pests harbouring. The best ways to get rid of all grain residues use a combination of:

- Sweeping
- Vacuuming
- Compressed air
- Blow/vacuum guns
- Pressure washers
- Fire-fighting hoses

Using a broom or compressed air gets rid of most grain residues, a follow-up washdown removes grain and dust left in crevices and hard-to-reach spots (Photo 9). Choose a warm, dry day to wash storages and equipment so it dries out quickly to prevent rusting. When inspecting empty storages, look for ways to make the structures easier to keep clean. Seal or fill any cracks and crevices to prevent grain lodging and insects harbouring. Bags of left-over grain lying around storages and in sheds create a perfect harbour and breeding ground for storage pests. After collecting spilt grain and residues, dispose of them well away from any grain storage areas.





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Photo 9: Clean silos, including the silo wall, with air or water to provide a residue-free surface to apply structural treatments.

Source: <u>GRDC</u>.

The process of cleaning on-farm storages and handling equipment should start with the physical removal, blowing and/or hosing out of all residues. Once the structure is clean and dry, consider the application of DE as a structural treatment.

For more information on structural treatments, see section 1.2.4 below.

TIP: A concrete slab underneath silos makes cleaning much easier (Photo 10).



Photo 10: Concrete slab under silo makes cleaning up spilled grain much easier. Source: <u>GRDC</u>.

13.2.3 Aeration cooling for pest control

Freshly-harvested grain usually has a temperature around 30°C, which is an ideal breeding temperature for storage pests. Studies have shown that rust-red flour beetles stop breeding at 20°C, lesser grain borer at 18°C, and below 15°C all storage pests stop breeding. Aim for grain temperatures of less than 23°C during summer and less than 15°C during winter. When placing grain into storage, run aeration fans

i) MORE INFORMATION

<u>GRDC's Grain Storage Fact Sheet:</u> <u>Hygiene and structural treatment for</u> <u>grain storages</u>.









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continuously for the first 2–3 days to push the first cooling front through the grain and to create uniform moisture conditions. Then run the fans during the coolest 9–12 hours per day for the next 3–5 days. This will push a second cooling front through the grain bulk.

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While adult insects can still survive at low temperatures, most young storage pests stop developing at temperatures below 18–20°C (see Table 3).

At temperatures below 15°C the common rice weevil stops developing.

At low temperatures insect pest life cycles (egg, larvae, pupae and adult) are lengthened from the typical four weeks at warm temperatures $(30-35^{\circ}C)$ to 12-17 weeks at cooler temperatures $(20-23^{\circ}C)$.

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

Grain temp (°C)	Insect and mould development	Grain moisture content (%)
40–55	Seed damage occurs, reducing viability	
30–40	Mould and insects are prolific	>18
25–30	Mould and insects are active	13–18
20–25	Mould development is limited	10–13
18–20	Young insects stop developing	9
<15	Most insects stop reproducing, mould stops developing	<8

Source: Kondinin Group in GRDC.

For more information, see Section 13.4.2 Aeration cooling below

13.2.4 Structural treatments

Key points:

- Structural treatments, such as diatomaceous earth (DE), can be used on storages and equipment to protect against grain pests.
- Check delivery requirements before using chemical treatments.

Chemicals used for structural treatments do not list the specific use before storing pulses on their labels and MRLs in pulses for those products are either extremely low or nil. Using chemicals even as structural treatments risks exceeding the MRL so is not recommended.

Using diatomaceous earth (DE) as a structural treatment is possible but wash and dry the storage and equipment before using for pulses. This will ensure the DE doesn't discolour the grain surface. Diatomaceous earth is an amorphous silica commercially known as Dryacide[®] and acts by absorbing the insect's cuticle or protective waxy exterior, causing death by desiccation. If applied correctly with complete coverage in a dry environment, DE can provide up to 12 months of protection for storages and equipment.

If unsure, check with the grain buyer before using any product that will come in contact with the stored grain. $^{\rm 13}$

Application

Inert dust requires a moving air-stream to direct it onto the surface being treated; alternatively, it can be mixed into a slurry with water and sprayed onto surface. See label directions. Throwing dust into silos by hand will not achieve an even coverage, so will not be effective. For very small grain silos and bins, a hand-operated duster, such as a bellows duster, is suitable. Larger silos and storages require a powered duster operated by compressed air or a fan. If compressed air is available, it is the



i) MORE INFORMATION

GRDC fact sheet, Aeration cooling for pest control

<u>Hygiene and structural treatments for</u> <u>grain storages</u>.

¹³ GRDC Stored Grain information hub. Storing Pulses. www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses



most economical and suitable option for on- farm use, connected to a venturi duster such as the Blovac BV-22 gun (Photo 11).

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MORE INFORMATION

GRDC Grain Storage Fact Sheet: Hygiene and Structural Treatment for Grain Storages.



WATCH: Applying diatomaceous earth dust.



Photo 11: A blow/vac or air venture gun is the best applicator for inert dusts. Aim for an event coat of diatomaceous earth across the roof, walls and base. Photo: C. Warrick, Proadvice,

The application rate is calculated at 2 g/m² surface area treated. Although inert, breathing in excessive amounts of dust is not ideal, so use a disposable dust mask and goggles during application (Table 4).

Silo application

Apply inert dust in silos, starting at the top (if safe), by coating the inside of the roof then working your way down the silo walls, finishing by pointing the stream at the bottom of the silo (Table 4). If silos are fitted with aeration systems, distribute the inert dust into the ducting without getting it into the motor, where it could cause damage.¹⁴

Table 4: Inert dust (diatomaceous earth) application guide.

Storage capacity (t)	Dust quantity (kg)
20	0.12
56	0.25
112	0.42
224	0.60
450	1.00
900	1.70
1800	2.60



¹⁴ Pulse Australia (2013) Northern chickpea best management practices training course manual —2013. Pulse Australia Limited.



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13.2.5 Fumigation

Fumigants are eradicants that clean up infested grain. They can also be regarded as a protectant in a sealed silo. The only approved fumigant for oats is phosphine. When applying a phosphine-releasing fumigant, the silo must be sealed otherwise the success of the treatment will be limited. ¹⁵

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There are a number of chemical control options for the control of grain pests in stored cereals (Table 5).

Table 5: Resistance and efficacy guide for stored grain insects.

Treatment and example product	WHP	Lesser grain borer	Rust-red flour beetle	Rice weevil	Saw- toothed grain beetle	Flat grain beetle	Psocids (booklice)	Structural treatments
Grain disinfestants—used on infested	grain to	control full	life cycle (a	adults, eggs	s, larvae, pupa	e)		
Phosphine (Fumitoxin®) ^{1.3} when used in gas-tight, sealable stores	2							
Sulfuryl fluoride (ProFume®)10	1							
Grain protectants—applied postharve	st. Poor	adult contro	ol if applied	to infested	l grain			
Pirimiphos-methyl (Actellic 900°)	rimiphos-methyl (Actellic 900°) nil ²							
Fenitrothion (Fenitrothion $1000^{\circ})^{4,7}$	1–90							
Chlorpyrifos-methyl (Reldan Grain Protector®) ⁵	Nil ²							
'Combined products' (Reldan Plus IGR Grain Protector)	Nil ²							
Deltamethrin (K-Obiol®)10	Nil ²							
Spinosad and Chlorpyrifos-methyl (eg Conserve On-Form^ $\ensuremath{^{\text{TM}}}\xspace)^9$								
Diatomaceous earth, amorphous silic Specific-use grain treatments	a—effect	ive internal	structural	treatment f	or storages and	d equipmer	nt.	
Diatomaceous earth, amorphous silica (Dryacide®) ⁸	Nil ²							
		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 (e.g. Fenitrothion at label rate) 8 Do not use on stored maize destined for export, or on grain delivered to bulk-handling authorities 9 Dichlorvos 500 g/L registration only 10 Restricted to licensed fumigators or approved users 11 Restriced to use under permit 14075 only. Unlikely to be practical for use on farm Source: Registration information courtesy of Pestgenie, APVMA and InfoPest (DEEDI) websites Source: http://storedgrain.com.au/pest-control-guide-ns/						
		Fumigation with phosphine is a common component of many integrated pest control strategies (Photo 12).						
		Taking fumigation shortcuts may kill enough adult insects in grain so it passes delivery standards, but the repercussions of such practices are detrimental to the grains industry.						
		Poor fum	igation tech	niques fail t	to kill pests at a	III life cycle :	stages, so wl	nile

Poor fumigation techniques fail to kill pests at all life cycle stages, so while some adults may die, grain will soon be reinfested again as soon as larvae and eggs develop.

15 G Troup (2016) Oats: harvesting, swathing and grain storage, Lodging. DAFWA, <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C2</u>







What's worse, every time a poor fumigation is carried out, insects with some resistance survive, making the chemical less effective in the future.

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Photo 12: Phosphine is widely accepted as having no residue issues.

While phosphine has some resistance issues, it is widely accepted as having no residue issues for grain or pulses. 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.¹⁶

Phosphine application

For effective phosphine fumigation, a minimum of 300 parts per million (ppm) gas concentration for seven days or 200ppm for 10 days is required. Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3ppm close to the leaks. The rest of the silo also suffers from reduced gas levels.

Achieve effective fumigation by placing the correct phosphine rates (as directed on the label) onto a tray and hanging it in the top of a pressure-tested, sealed silo or into a ground level application system if the silo is fitted with recirculation.

After fumigation, ventilate grain for a minimum of one day with aeration fans running, or five days if no fans are fitted.

A minimum withholding period of two days is required after ventilation before grain can be used for human consumption or stock feed.

The total time needed for fumigating is 10-17 days.

As a general rule, only keep a silo sealed while carrying out the fumigation (for example, one to two weeks).

After fumigation has been completed, return to aeration cooling to hold the stored grain at a suitable temperature level. ¹⁷



WATCH: <u>GCTV Stored Grain.</u> Fumigation recirculation.



WATCH: <u>GCTV Stored Grain:</u> <u>Phosphine Dose Rates.</u>



i MORE INFORMATION

Eumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once: A Grains Industry Guide



¹⁶ P Collins (2009) Strategy to manage resistance to phosphine in the Australian grain industry. Cooperative Research Centre for National Plant Biosecurity Technical Report, <u>http://www.graintrade.org.au/sites/default/files/file/NWPGP/Phosphine%20Resistance%20Strategy.pdf</u>

¹⁷ GRDC Northern and southern region stored pest control guide. Revised July 2014, http://storedgrain.com.au/pest-control-guide-ns/



MORE INFORMATION

Grain fumigation – a guide.

Fumigating with phosphine, other fumigants and controlled

A Grains Industry Guide'

atmospheres: Do it right-do it once.

GRDC Grain Storage Fact Sheet:

Grain Protectants Prevent Pests.

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Handle with care

Phosphine is a highly toxic gas with potentially fatal consequences if handled incorrectly. As a minimum requirement, the label directs the use of cotton overalls buttoned at the neck and wrist, eye protection, elbow-length PVC gloves and a breathing respirator with combined dust and gas cartridge.

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Where to apply

Arrange the tablets where as much surface area as possible is exposed to air, so the gas can disperse freely throughout the grain stack. Spread phosphine tablets evenly across trays before hanging them in the head space or placing them level on the grain surface inside a gas-tight, sealed silo. Hang bag chains in the head space or roll out flat on the top of the grain so air can freely pass around them as the gas dissipates. Bottom-application facilities must have a passive or active air circulation system to carry the phosphine gas out of the confined space as it evolves. Without air movement, phosphine can reach explosive levels if left to evolve in a confined space.

Time to kill

To control pests at all life stages and prevent insect resistance, phosphine gas concentration needs to reach 300 parts per million (ppm) for seven days (when grain is above 25°C) or 200ppm for 10 days (between 15–25°C). Insect activity is slower in cooler grain temperatures so require longer exposer to the gas to receive a lethal dose. ¹⁸

Phosphine application in silo bags

Silo bags as well as silos can be fumigated. 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.

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. In previous trials when spears were spaced 12 m apart, the phosphine gas took too long to diffused throughout the whole bag.¹⁹



media/Documents/R-and-D/Update-Newsletters/Northern/Northern/Update-Issue-66.pdf




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Fighting phosphine resistance

Table 6: Resistance and efficacy guide for stored grain insects (northern and southern regions) in cereal grains.

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Treatment and example product	WHP	Lesser grain borer	Rust-red flour beetle	Rice weevil	Saw- toothed grain beetle	Flat grain beetle	Psocids (booklice)	Structural treatments
Grain disinfestants—used on infested	grain to co	ontrol full lif	e cycle (ad	ults, eggs,	larvae, pupa	ae)		
Phospine (Fumitoxin $^{\mbox{\tiny D}}$) $^{\mbox{\tiny 1.3}}$ when used in gas-tight sealable stores	2							
Sulfuryl fluoride (ProFume [©]) ³	1							
Dichlorvos (e.g. Dichlorvos 1140°) 10	7–28							9
Grain protectants—applied postharve	st. Poor ad	ult control i	f applied to	infested g	rain			
Pirimiphos-methyl (Actellic 900©)	nil 2							
Fenitrothion (Fenitrothion 1000°) 4	1–90							
Chlorpyrifos-methyl (Reldan Grain Protector®) ⁵	nil 2							
Methoprene (Grain Star 50©)	nil6		7		7			
'Combined products' (Reldan Plus IGR Grain Protector)	nil 2							
Deltamethrin (K-Obiol®) 10	nil 2							
Diatomaceous earth, amorphous silica Specific-use grain treatments	a—effective	e internal st	ructural tre	atment for	storages a	nd equipme	ent.	
Diatomaceous earth, amorphous silica (Drya Dryacide™) 8	nil 2							
		Not registered High-level resis Resistant speci Effective contra Unlikely to be effe 2 When used as dir 3 Total of (exposure 4 Nufarm label only 5 Stored grains exc 3 When applied as 7 Periods of 6–9 m 3 Do not use on st 9 Dichlorvos 500 g 10 Restricted to lice 11 Restricted to use Source: Registration	for this pest stance in flat grain ies likely to survive lespread (unlikely to ected on label e + ventilation + witi rept malting barley directed, do not m onths storage inclu ored maize destine // registration only under permit 1407 n information court	beetle has been id this structural tree o be effective) sites, causing resis hholding) = 10 to 2 and rice/stored lu ove treated grain n uding mixture in ad d for export, or on r approved users 5 only. Unlikely to l esy of Pestgenie, <i>i</i>	dentified, send inse tment for storage a tance. See label for 7 days oins registration for or 24 hours ulticide (e.g. Fenith grain delivered to l grain delivered to l pe practical for use APVMA and InfoPes	cts for testing if fur and equipment r definitions Victoria only/not o rothion at label rate bulk-handling autho on farm st (DEEDI) websites	nigation failures occur n stored maize destine e) orities	d for export
		Reduce sel	lection:					
		 Limit th 	e number c	of applicatio	ns of phosp	ohine.		
		 Use no hygiene 	n-chemical e, to minimi	methods si se insect po	uch as cooli opulations.	ng and stor	age, and equi	oment
		• At a site	e, reduce re	e-colonisatio	on by comp	lete emptyi	ng of all storag	jes.
		Destroy res	sistant inse	ects:				
		 Make e exposu 	every fumiga ire periods	ation count are achieve	by ensuring d througho	recommer ut the stora	ided gas conc ge.	entrations and
		• Replace	e phosphine	e with alterr	native fumig	ants or con	trolled atmosp	heres.
		Use alt	ernative ch	emicals and	I physical tre	eatments to	replace fumic	jation.
		Monitor an	d test:					

Monitor gas concentrations during fumigations.

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Test insects for resistance to phosphine and other chemicals. ²⁰

Sulfuryl fluoride (SF) has excellent potential as an alternative fumigant to control phosphine-resistant grain storage pests. 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 phosphineresistant 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 resistancemonitoring 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 southern and northern 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.²¹

Non-chemical treatment options include:

- Carbon dioxide: Treatment with CO, involves displacing the oxygen inside a gastight silo with CO₂, which creates a toxic atmosphere to grain pests. To achieve a complete kill of all the main grain pests at all life stages, CO₂ must be retained at a minimum concentration of 35% for 15 days.
- Nitrogen: Grain stored under N₂ provides insect control and quality preservation without chemicals. It is safe to use and environmentally acceptable, and the main operating cost is the capital cost of equipment and electricity. It also produces no residues, so grains can be traded at any time, unlike chemical fumigants that have withholding periods. Insect control with N₂ involves a process using pressure swinging adsorption (PSA) technology, modifying the atmosphere within the grain storage to remove everything except N_2 , starving the pests of oxygen. 22

13.3 Grain protectants for storage

Key points:

- Consider using grain protectants when gas-tight sealable storage is not available and to ensure security of planting seed.
- Grain protectants work best when combined with meticulous storage hygiene and aeration cooling.
- Stringent maximum residue limits (MRLs) leave no margin for error in application. Always check with your grain buyer before applying.
- Even coverage is required to reliably manage stored grain insects. ²³

Grain Trade Australia has found 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 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

C Warrick (2012) Fumigating with phosphine, other fumigants and controlled atmospheres: Do It right—do it once. A Grains Industry Guide. January 2011. Reprinted June 2012, <u>http://www.grdc.com.au/~/media/5EC5D830E7BF4976AD591D2C03797906.pdf</u>



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²⁰ P Collins (2009) Strategy to manage resistance to phosphine in the Australian grain industry. Cooperative Research Centre for National Plant Biosecurity Technical Report, http://www.graintrade.org.au/sites/default/fi es/file/NWPGP/Phosphine%20Re pdf

²¹ M Nayak (2012) Sulfuryl fluoride—A solution to phosphine resistance? GRDC Research Update Northern Region, Spring 2012, Issue 66, https://grdc.com.au/^/media/Documents/R-and-D/Update-Newsletters/Northern/Northern-Update-Issue-66.pdf

²³ GRDC (2015) Grain protectants prevent pests Fact Sheet. GRDC 23 April 2015, https://grdc.com.au/Resources/Factsheets/2015/04/ Grain-protectants-prevent-pests



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grain protectant or fumigant, growers need to check with prospective buyers, as the use of some chemicals may exclude grain from certain markets. ²⁴

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Grain protectants are designed to prevent pest infestations and not to control existing infestations. Grain must be clean and free of pests before applying a protectant. A common misunderstanding is that grain protectants kill insects already infesting the grain, but those types of products (contact disinfestants) are no longer available for on-farm use. In order to give protectants the best chance to defend stored grain, combine their use with meticulous storage hygiene practices before and after harvest. Cleaning up the storage site and the harvesting equipment removes harbours where pests can survive, ready to infest the new season's grain. The addition of aeration cooling also provides an unattractive environment for pests in stored grain.

Table 7: Southern and Northern region stored grain protectants guide.

Protectant	Lesser grain borer	Rust-red flour beetle	Rice weevil	Saw- toothed grain beetle	Flat grain beetle
Pirimiphos-methyl e.g. Actellic 900©					
Fenitrothion e.g. Fenitrothion 1000 [©]					
Chlorpyrifos-methyl e.g. Reldan Grain Protector®					
Chlorpyrifos-methyl + S-methoprene e.g Reldan Plus IGR®					
Deltamethrin + Piperonyl Butoxide e.g. K-Obiol ^{© 1}					
Spinosad + Chlorpyrifos- methyl + S-methoprene e.g. Conserve On-Farm™					

Not registered for this pest
 Resistance widespread (unlikely to be effective)
 Effective control
 Approved user ID card required for purchase - contact Bayer to obtain ID

 $Source: GRDC \ Grain \ protectants \ prevent \ pests. \ \underline{https://grdc.com.au/Resources/Factsheets/2015/04/Grain-protectants-prevent-pests}$

K-Obiol Combi

<u>K-Obiol</u>[®] (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.²⁵

K-Obiol is a synergised grain protectant for use on cereal grains, malting barley and sorghum. It can be used in any type of storage, sealed or unsealed. It is suitable for use by grain growers and grain accumulators. Like all protectants it is a liquid and must be evenly applied as a dilution to the grain as it is fed into the storage. It is not suitable for oil seeds or pulses. It is for use on un-infested grain and is not recommended for eradicating insect pests when they have infested grain.

The active constituent is deltamethrin. Piperonyl butoxide is added as a synergist; meaning it increases the effectiveness of the deltamethrin. As K-Obiol is based on



²⁴ P Collins (2009) Strategy to manage resistance to phosphine in the Australian grain industry. Cooperative Research Centre for National Plant Biosecurity Technical Report, <u>http://www.graintrade.org.au/sites/default/files/file/NWPGP/Phosphine%20Resistance%20Strategy.</u> pdf

²⁵ P Burrill (2013) Grain Storage Future pest control options and storage systems 2013–2014. GRDC Update Papers, July 2013, <u>https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Grain-Storage-Future-pest-control-options-and-storage-systems-2013-2014</u>



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deltamethrin there are none of the insect resistance problems being experienced with other protectants.

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Because protectants are residual there can be concern by grain users that the grain does not contain excessive levels. This may come about from incorrect treatment or double treatment as the grain moves along the supply chain. To protect the end user of the grain, and ultimately the Australian grain growers, a Product Stewardship program has been developed to ensure correct use of the product. The Program will also ensure the product is used in the way that minimises the development of insect resistance and increase it usable life. ²⁶

Conserve On-farm

<u>Conserve™ On-Farm</u>: 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.

Conserve On-Farm is a grain protectant from DOW that has three active ingredients to control most major insect pests of stored grain, including the resistant lesser grain borer (LGB).

Conserve On-Farm provides six to nine months of control and has a nil withholding period (WHP).

Maximum residue limits (MRLs) have been established with key trading partners and there are no meat residue bioaccumulation issues.

Conserve On-Farm is a combination of two parts that are applied together. Using Part A and Part B together is very important to get control of the complete spectrum of insects.

Part A: $1 \times 5 L$ of chlorpyrifos-methyl and S-methoprene – controls all stored grain insect pests other than the resistant lesser grain borer (Rhyzopertha dominica)

Part B: $2 \times 1 L$ of spinosad – is very effective on the lesser grain borer, including resistant strains, but has little to no activity on other key species. ²⁷

13.4 Aeration during storage

13.4.1 Dealing with high moisture grain

Key points:

- Deal with high-moisture grain promptly.
- Monitoring grain moisture and temperature regularly (daily) will enable early detection of mould and insect development.
 - Aeration drying requires airflow rates in excess of 15 litres per second per tonne.
- Dedicated batch or continuous flow dryers are a more reliable way to dry grain than aeration drying in less-than-ideal ambient conditions.

A Department of Employment, Economic Development and Innovation (DEEDI) trial revealed that high-moisture grain generates heat when put into a confined storage, such as a silo.

Wheat at 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 two days reached 46°C providing ideal conditions for mould growth and grain damage (Figure 2). Grain that is over the standard safe storage moisture content of 12.5% can be dealt with by:

Blending — mixing high-moisture grain with low-moisture grain, then aerate.



²⁶ GRDC Stored Grain information hub. K-Obiol Combi. http://storedgrain.com.au/k-obiol-combi/

²⁷ GRDC Stored Grain information hub. Conserve On-farm. <u>http://storedgrain.com.au/conserve-farm/</u>



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 Aeration cooling — grain of moderate moisture, up to 15% moisture content, can be held for a short term under aeration cooling until drying equipment is available.

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- Aeration drying large volumes of air force a drying front through the grain in storage and slowly removes moisture. Supplementary heating can be added.
- Continuous flow drying grain is transferred through a dryer, which uses a high volume of heated air to pass through the continual flow of grain.
- Batch drying usually a transportable trailer drying 10–20 tonnes of grain at a time with a high volume of heated air, which passes through the grain and out perforated walls.





13.4.2 Aeration cooling

Key points:

- Grain temperatures below 20°C significantly reduce mould and insect development.
- Reducing grain temperature with aeration cooling protects seed viability.
- Controlling aeration cooling is a three-stage process continual, rapid and then maintenance.
- Stop aeration if ambient, relative humidity exceeds 85%.
- Automatic grain aeration controllers that select optimum fan run times provide the most reliable results.

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





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High-moisture grain generates heat when put into a confined storage, such as a silo. In one study, oats with 16.5% moisture content at a temperature of 28°C were put into a silo with no aeration. Within hours, the grain temperature reached 39°C and within two days reached 46°C, providing ideal conditions for mould growth and grain damage. ²⁸

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As soon as grain is harvested and put in storage, run the aeration system 24 hours per day for the first five days to reduce grain temperatures and produce uniform moisture conditions in the grain bulk. Without aeration, grain holds its heat as it is an effective insulator and will maintain its warm harvest temperature for a long time. Cereals at typical harvest temperatures of 28–35°C and moisture content greater than 13–14% provide ideal conditions for mould and insect growth.²⁹

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%. $^{\rm 30}$

Aeration cooling can be used to reduce the risk of mould and insect development for a month or two until drying equipment is available to dry grain down to a safe level for long-term storage or deliver. In most circumstances, grain can be stored at up to 14–15% moisture content safely with aeration cooling fans running continuously, delivering at least 2–3 litres per second per tonne. It is important to keep fans running continuously for the entire period, only stopping them if the ambient relative humidity is above 85% for more than about 12 hours, to avoid wetting the grain further.

Blending

Blending is the principle of mixing slightly over-moist grain with lower-moisture grain to achieve an average moisture content below the ideal 12.5% moisture content. Successful for grain moisture content levels up to 13.5%, blending can be an inexpensive way of dealing with wet grain, providing the infrastructure is available. Aeration cooling does allow blending in layers but if aeration cooling is not available blending must be evenly distributed (Figure 3). ³¹



Figure 3: *Diagram demonstrating the correct practices for blending.* Source: Kondinin Group in <u>GRDC.</u>

- 28 P Burrill, P Botta, C Newman, B White, C Warrick (2013) Dealing with high-moisture grain. GRDC Grain Storage Fact Sheet, June 2013, http://storedgrain.com.au/wp-content/uploads/2013/07/GSFS-7_HighMoistureGrain_2013_LR_Final.pdf
- 29 P Burrill, P Botta, C Newman, B White, C Warrick (2013) Dealing with high-moisture grain. GRDC Grain Storage Fact Sheet, June 2013, http://storedgrain.com.au/wp-content/uploads/2013/07/GSFS-7_HighMoistureGrain_2013_LR_Final.pdf
- 30 NSW Department of Primary Industries District Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf</u>
- 31 GRDC Stored Grain Information Hub: Dealing with high moisture grain. http://storedgrain.com.au/dealing-with-high-moisture-grain/









<u>GRDC Aerating Stored Grain –</u> Industry Guide.



WATCH: <u>Grain Storage Cooling</u> <u>Aeration</u>



Seed viability

Research trials reveal that cereal grain at 12% moisture content stored for six months at $30-35^{\circ}$ C (unaerated grain temperature) will have reduced germination percentage and seedling vigour.

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13.4.3 Aeration drying

Aeration drying relies on a high air volume and is usually done in a purpose-built drying silo or a partly filled silo with high-capacity aeration fans. Aeration drying is a slow process and relies on four keys:

- High airflow rates.
- Well-designed ducting for even airflow through the grain.
- Exhaust vents in the silo roof.
- Warm, dry weather conditions.

It is important to seek reliable advice on equipment requirements and correct management of fan run times, otherwise there is a high risk of damaging grain quality.

High airflow for drying

Unlike aeration cooling, aeration drying requires high airflow, in excess of 15 L/s/t, to move drying fronts quickly through the whole grain profile and depth and carry moisture out of the grain bulk. As air passes through the grain, it collects moisture and forms a drying front. If airflow is too low, the drying front will take too long to reach the top of the grain stack – often referred to as a 'stalled drying front.' Providing the storage has sufficient aeration ducting, a drying front can pass through a shallow stack of grain much faster than a deep stack of grain. As air will take the path of least resistance, make sure the grain is spread out to an even depth.

Ducting for drying

The way to avoid hot spots is with adequate ducting to deliver an evenly distributed flow of air through the entire grain stack (Photo 13). A flat-bottom silo with a full floor aeration plenum is ideal providing it can deliver at least 15 L/s/t of airflow. The silo may only be able to be part filled, which in many cases is better than trying to dry grain in a cone-bottom silo with insufficient ducting.





Photo 13: Aeration drying requires careful management, high airflow rates, well designed ducting, exhaust vents and warm, dry weather conditions.

Venting for drying

Adequate ventilation maximises airflow and allows moisture to escape rather than forming condensation on the underside of the roof and wetting the grain on the top of the stack. The amount of moisture that has to escape with the exhaust air is 10 L for every one per cent moisture content removed per tonne of grain.

Weather conditions for drying

For moisture transfer to occur and drying to happen, air with a lower relative humidity than the grain's equilibrium moisture content must be used. For example, Table 8 shows that grain at 25°C and 14% moisture content has an equilibrium point of the air around it at 70% relative humidity. In order to dry this grain from its current state, the aeration drying fans would need to be turned on when the ambient air was below 70% relative humidity.

Phase one of drying

Aeration drying fans can be turned on as soon as the aeration ducting is covered with grain and left running continuously until the air coming out of the top of the storage has a clean fresh smell. The only time drying fans are to be turned off during this initial, continuous phase is if ambient air exceeds 85% relative humidity for more than a few hours.

Phase two of drying

By monitoring the temperature and moisture content of the grain in storage and referring to an equilibrium moisture table, such as Table 8, a suitable relative humidity trigger point can be set. As the grain is dried down the equilibrium point will also fall,



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MORE INFORMATION

Dealing with high moisture grain.

VIDEOS

right

WATCH: Aeration drying—getting it

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so the relative humidity trigger point will need to be reduced to dry down the grain further. Reducing the relative humidity trigger point slowly during phase two of the drying process will help keep the difference in grain moisture from the bottom to the top of the stack to a minimum, by ensuring the fans get adequate run time to push each drying front right through the grain stack.

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Table 8: Equilibrium moisture content for wheat. NOTE: values may be different fortriticale grain.

Relative		Temperature		
humidity (%)	15	25	35	
30	9.8	9.0	8.5	G
40	11.0	10.3	9.7	cor
50	12.1	11.4	10.7	mo Iten:
60	13.4	12.8	12.0	t %)
70	15.0	14.0	13.5	Ø

Source: GRDC

Supplementary heating

Heat can be added to aeration drying in proportion to the airflow rate. Higher airflow rates allow more heat to be added as it will push each drying front through the storage quick enough to avoid over heating the grain close to the aeration ducting. As a general guide, inlet air shouldn't exceed 35°C to avoid over heating grain closest to the aeration ducting.

Cooling after drying

Regardless of whether supplementary heat is added to the aeration drying process or not, the grain should be cooled immediately after it has been dried to the desired level. ³²

13.4.4 Aeration controllers

Aeration controllers manage both aeration drying, cooling and maintenance functions in up to ten separate storages (Photo 14). The unit it takes into account the moisture content and temperature of grain at loading, the desired grain condition after time in storage and selects air accordingly to achieve safe storage levels.

A single controller has had the ability to control the diverse functions of aeration: cooling, drying and maintenance. The controller can not only combine the ability to control all three functions, but automatically selects the correct type of aeration strategy to obtain the desired grain moisture and temperature.³³

Research has shown that with the support of an aeration controller, aeration can rapidly reduce stored grain temperatures to a level that helps maintain grain quality and inhibits insect development.

During trials where grain was harvested at 30°C and 15.5% moisture, grain temperatures rose to 40°C within hours of being put into storage.

An aeration controller was used to rapidly cool grain to 20°C and then hold the grain between 17–24°C during November through to March.

Before replicating similar results on farm, growers need to:

- Know the capacity of their existing aeration system.
- Determine whether grain requires drying before cooling can be carried out.



³² GRDC Stored Grain Information Hub: Dealing with high moisture grain. http://storedgrain.com.au/dealing-with-high-moisture-grain/

³³ GRDC. (2007). Ground Cover Issue 57 – New Generation in aeration controller. <u>https://ground-Cover-Supplements/Ground-Cover-Issue-57-Grain-Storage-Supplement/New-generation-aeration-controller</u>



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Philip Burrill

WATCH: Aeration controllers with

• Understand the effects of relative humidity and temperature when aerating stored grain.

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Determine the target conditions for the stored grain.



Photo 14: Automatic aeration controllers are the most effective way to cool grain and are designed to manage many storages, from one central control unit. Source: <u>GRDC</u>.

13.5 Storing forage oats

Although the preferred method for harvesting forage cereals is by precision chopping into bulk storage, many farmers will use balers.

The material stored in any storage system must be compacted as densely as possible in its storage package, sealed airtight as soon as possible after harvesting is completed, and be regularly inspected for holes and repairing damage with specific silage plastic film tape as soon as possible.

Whole-crop cereal silage storage systems:

- Forage harvested as bulk storage
- Stacks above ground
- Concrete bunkers
- Pits in the ground
- Stretchable bags

Baled silage storage:

- Individually wrapped bales
- Continuously wrapped in-line 'sausage'
- Stretchable tubes or 'socks'
- Above ground storage under plastic sheets
- Pits below ground

13.5.1 Forage harvested as bulk storage

Precision chopped material can be stored in stacks or walled bunkers above ground or in pits in hillsides, along bank walls, etc. It can also be stored in stretchable sausage bags.





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Precision chopped forage, being very short in length but ideal for compaction, will not bind in a stack compared to longer material. In particular, material harvested at the soft dough stage may tend to 'move' when rolled by the compacting machinery. To minimise this and the danger it may present to operators, stacks with some type of side constraint, such as in ground pit, dirt walls or cement walled bunkers, are preferable to rectangular or circular bun stacks above ground.

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13.5.3 Compacting the stack

The stack should be continuously rolled with a very heavy and preferably a wheeled tractor. However some contractors are now using dual-wheeled tractors or very heavy excavators (tracks) for safety reasons.

Spread the material in layers of about 15 cm to allow for improved compaction (air exclusion) compared to thicker layers. Rolling slowly rather than quickly is essential to allow the weight of the rolling machine to exert downward pressure. Aim for a packing density of about 250 kg dry matter (DM) per cubic metre although this may be lower with longer chopped and/or drier material. Density is influenced by DM content, chop length, stack depth, weight of compacting machine and period of compaction.

A general rule of thumb for ensuring maximum compaction based on the weight of the packing or rolling tractor is:

Weight of packing tractor (kg) \div 300 = Delivery rate (tonnes of fresh crop per hour).

E.g. 18,000 kg tractor ÷ 300 = 60 tonnes/hour.

A stack being filled over several days should be covered overnight with a plastic sheet to minimise plant respiration and heating. Each new day's harvested material should, ideally, cover yesterday's material by a depth of at least one metre to prevent continued respiration of the earlier harvested material. If on the second or third day of filling a stack, a hand pushed into the face up to the wrist feels very warm or hot, then aerobic deterioration is occurring at a rapid rate, i.e. lost DM and nutritive value plus rapid increases of yeast and moulds. This could be caused by inadequate compaction due to the material being cut too long, too dry, the rolling machine is too light or rolling speed may be too fast. Keep silage free of contaminants. Mud, dead animal carcasses, decaying plants, etc. must not enter the storage as the bacteria they contain will be deleterious to the fermentation process. Ensiled carcasses can cause animal deaths due to botulism. ³⁴



³⁴ Agriculture Victoria (2006) Storing forage cereals. Ag note AG1245 July 2006 Updated August 2008, <u>http://agriculture.vic.gov.au/</u> agriculture/grains-and-other-crops/crop-production/storing-forage-cereals



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i) MORE INFORMATION

Agronomist's guide to information for managing weather and climate

Tools to reduce impact of climate variability – Southern region

Key messages:

- Oats are regarded as the cereal crop least susceptible to frost damage and are thought to be about 4°C more tolerant than wheat.
- Frost occurs on clear nights when the air temperature drops to 2°C or less.
- Oats are seen as more tolerant of waterlogging than other cereals, particularly prior to germination.
- Oats can be sensitive to heat and drought stress.

Due to the effects of climate change, both heat stress and frost are likely to play an increasing role in the future and will require growers to take steps to manage the risks. ¹ A survey conducted in 2015 found that South East Australian grain growers and advisors rate grain filling heat as a greater risk than frost. ²



Barr R. (2016). Diversity the key to balancing frost-heat risks. <u>https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks</u>

² Grey D, Nuttal J, Barlow K. (2015). South East Australian grain growers and advisors rate grain filling heat as a greater risk than frost. http://www.agronomy2015.com.au/1031



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Key points:

Crop susceptibility to frost from most to least susceptible is triticale > wheat > barley > cereal rye > oats. ³

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- Frost is estimated to cost south-east Australia at least \$100 million a year in unfulfilled or lost yield potential.⁴
- Frost events can have major and sudden impacts on cereal yields.
- Frost is a relatively rare occurrence but some areas are more prone to it.
- There has been an increase in frost frequency in many areas in the last 20 years.
- Minor agronomic tweaks might be necessary in some frost prone areas but most growers should be steady as she goes.
- In the event of severe frost, monitoring needs to occur up to two weeks after the event to detect all the damage.⁵

Frost occurs on clear nights when the air temperature drops to 2°C or less. Damage to crops from frost may occur at any stage of development but is most damaging at and around flowering. Symptoms of frost damage can occur as sterility and stem damage. Physical damage to the plant occurs when ice forms inside the plant tissue, as expanding ice bursts membranes, resulting in mechanical damage and dehydration injury. Frost damage can reduce both grain yield and quality.

Oats are regarded as the cereal crop least susceptible to frost damage and are thought to be about 4°C more tolerant than wheat. Frost events can have quite a large social impact as they happen so suddenly, unlike drought which one can adapt to mentally and financially by reducing further inputs as it unfolds.

Spring radiation frost is of significant importance in Australia causing large yield and revenue losses to the national economy. Winter cereals are most susceptible to low temperatures during reproductive stage as reproductive parts are not protected by the leaf sheaths and ice can nucleate directly on them. As a result of these circumstances, complete or serious yield losses are felt when frost occurs between the booting and grain ripening stages (Photo 1). Identification of winter cereals with reproductive frost tolerance is a priority for frost research in Australia.



Photo 1: Frost on cereal crop.

Source: Farm Online

- 3 GRDC. (2009). Frost risk Factsheet https://grdc.com.au/uploads/documents/GRDC_FS_Frost.pdf
- 4 Barr R. (2016). Diversity the key to balancing frost-heat risks. <u>https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks</u>
- 5 Grey D. (2014). GRDC Update Papers: Frost damage in crops where to from here? <u>https://grdc.com.au/Research-and-Development/</u> <u>GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</u>





Once heads and grain have been frosted, small discoloured grain may be produced. In addition to direct yield loss, frost also causes economic losses by downgrading crop quality through lower organic matter digestibility and metabolizable energy. Frost can cause reductions in grain size, decrease flour extraction, decrease dough strength and baking quality, and an increase in flour ash and α-amylase activity. It is estimated that frost causes a monetary loss of AU\$1.9 million from quality downgrading in Victoria and SA.⁶

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14.1.1 Conditions leading to frost

Clear, calm and dry nights following cold days are the precursor conditions for a radiation frost (or hoar frost). These conditions are most often met during winter and spring where high pressures follow a cold front, bringing cold air from the Southern Ocean but settled cloudless weather (Figure 1). When the loss of heat from the earth during the night decreases the temperature at ground level to zero, a frost occurs. Wind and cloud reduce the likelihood of frost by decreasing the loss of heat to the atmosphere. The extent of frost damage is determined by how quickly the temperature takes to get to zero, the length of time its stays below zero and the how far below zero it gets.



Figure 1: A cold front passes through injecting cold air in from the Southern Ocean the day before frost (left). Overnight the high pressure system stabilises over SE Australia meaning clear skies and no wind leading to a frost event (right).

Though temperatures (particularly those in winter and spring), are getting warmer, frost is still a major issue. CSIRO researchers have found that there are areas of Australia where the number of frost events are increasing (greatest in August), with Central West NSW, Eyre Peninsula, Esperance and Northern Vic Mallee, the only major crop growing areas to be less affected by frost in the period 1961–2010 (Figure 2). This increase is thought to be caused by the latitude of the Sub Tropical Ridge of high pressure drifting south (causing more stable pressure systems) and the existence of more El Nino conditions during this period. ⁷

6 Tshewang S. (2011). Frost tolerance in Triticale and other winter cereals at flowering. <u>https://e-publications.une.edu.au/vital/access/</u> manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm_contributor%3A%22Birchall+C%22

7 Grey D. (2014). GRDC Update Papers: Frost damage in crops – where to from here? <u>https://grdc.com.au/Research-and-Development/</u> <u>GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</u>







WATCH: <u>GCTV20: Frost's emotional</u> <u>impact, is it greater than its economic</u> <u>impact?</u>



WATCH: GCTV15: Frost Ratings.



WATCH: <u>GCTV15: The frost ranking</u> challenge.



WATCH: GCTV12: Frost susceptibility ranked.



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Figure 2: Region of increasing August-November frost events. Source: Steven Crimp in <u>GRDC</u>.

Cost of frost

The real cost of frost is a combination of the actual cost due to both reduced yield and quality, along with the hidden cost of management tactics used to try and minimise frost risk. The hidden costs associated with conservative management to minimise frost risk include:

- delayed sowing and its associated yield reduction
- avoiding cropping on the valley floors which also contain some of the most productive parts of the landscape. ⁸

14.1.2 Diagnosing frost

What to look for

Paddock:

- Symptoms may not be obvious until 5–7 days after the frost.
- Heads on affected areas have a dull appearance that becomes paler as frosted tissue dies.
- At crop maturity severely frosted areas remain green longer.
- Severely frosted crops have a dirty appearance at harvest due to blackened heads and stems and discoloured leaves.

Plant:

Before flowering:

- Freezing of the emerging head by cold air or water is caught next to the flag leaf or travelling down the awns into the boot. Individual florets or the whole head can be bleached and shrivelled stopping grain formation. Surviving florets will form normally.
- Stem frost by a small amount of water that has settled in the boot and frozen around the peduncle. Symptoms include paleness or discolouration and roughness at the affected point on the peduncle, and blistering or cracking of nodes and leaf sheath. Stems may be distorted.

Flowering head:

- The ovary in frosted flowers is 'spongy' when squeezed and turns dark in colour.
- Anthers are dull coloured and are often banana shaped. In normal flowers the ovary is bright white and 'crisp' when squeezed. As the grain develops it turns green in colour. Anthers are green to yellow before flowering or yellow turning white after flowering (Photo 2).



⁸ G Troup (2016) Oats: harvesting, swathing and grain storage. DAFWA <u>https://www.agric.wa.gov.au/oats/oats-harvesting-swathing-and-grain-storage?page=0%2C2</u>



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Grain:

Frosted grain at the milk stage is white, turning brown, with a crimped appearance. It is usually spongy when squeezed and does not exude milk/ dough. Healthy grain is light to dark green and plump, and exudes white milk/ dough when squeezed.

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Frosted grain at the dough stage is shrivelled and creased along the long axis, rather like a pair of pliers has crimped the grain. ⁹



Photo 2: Oat grain heads showing damage from frost. Photo: Sarah Jackson.

Monitoring for frost:

- Inspect cereal crops between ear emergence and late grain filling if night air temperature falls below 2°C (recorded 1.2 metres above ground).
- Check low lying, light coloured soil types and known frost-prone areas first. Then check other areas.
- To identify frost damage open florets and peel back leaves on plants.

Growing oaten hay in frost-prone paddocks

Growing oaten hay on frost-prone paddocks minimises the frost risk as it is cut soon after flowering, avoiding the frost-sensitive period (Photo 3). If severe frost damage does occur to other crops, baling them for hay may reduce economic loss. Oats are much more tolerant than other cereals to frost events that occur during vegetative growth and flowering. Sow oats in frost-prone paddocks with the expectation that frost damage will occur if a severe frost event is experienced after ear emergence.

Costs:

- Growing hay is a capital-intensive enterprise.
- Hay is a high-risk enterprise as time of cutting and baling is critical for maintaining hay quality.
- Late spring rains, which benefit grain crops, can be detrimental to hay quality and ultimately returns.
- Transport can be expensive, depending on your location.
- The price of hay is highly volatile and depends on supply and quality each season.
- Hay removes large quantities of nutrients, particularly potassium, that need to be replenished for the following crop, increasing input costs. Hay crops remove
- 9 DAFWA (2015) Diagnosing stem and head frost damage in cereals. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.</u> au/mycrop/diagnosing-stem-and-head-frost-damage-cereals





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greater amounts of potassium (about 10 kilograms per tonne) than other cereals harvested for grain. If potassium deficiency is diagnosed in a crop, applying 40–80 kilograms per hectare as muriate of potash near seeding may give an economic yield increase if applied early enough.

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Benefits:

- Oats are generally more frost-tolerant than wheat and barley so the likelihood of frost damage is reduced.
- Farm enterprises (and risk) become more diversified.
- Frost-prone paddocks usually have highly productive soils in frost-free seasons and growing hay capitalises on the production potential while minimising frost risk.
- Oaten hay provides a break crop to manage weeds.¹⁰



Photo 3: Growing hay on frost-prone paddocks can benefit farming systems and whole farm profitability.

Photo: DAFWA

Sowing rate and spacing

Lower sowing rates may result in a less dense canopy that increases crop tillering and may allow more heating of the ground during the day, transferring this heat to the canopy at night. Note that there is no hard evidence lower sowing rates will reduce frost damage. The main disadvantage of this practice is that in the absence of frost, lower grain yield and/or protein may be the result during favourable seasons, contributing to the hidden cost of frost. Less-vigorous crops can also result in the crop being less competitive with weeds. Sowing wider row spacings on heavy soils may allow more airflow through crops, thus allowing soil heat to rise up to canopy height during frosts. Previous trial work has shown that wide-row sowing has debatable



¹⁰ DAFWA (2016) Growing oaten hay on frost-prone paddocks. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/frost/growing-oaten-hay-frost-prone-paddocks</u>



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effectiveness on both sandy and heavy-texture soil. There is also a 1% yield loss per inch increase in row spacing and compromised weed control. $^{\rm 11}$

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Sowing varieties

Sow a mixture of long season and short season varieties. This practice broadens the period of flowering and different canopy heights may create a more undulating crop that could assist the emission of warm air from the soil to reach and buffer cold temperatures around the crop heads on frost nights. Blending varieties is not usually recommended due to higher cost of seed, extra time required for sowing and the potential contamination of non-frosted grain from one variety with frosted grain from the other resulting in quality downgrading at delivery. To achieve the highest grade, grain from both varieties must be suitable for delivery to the same grade.

Stubble removal

Remove stubbles and maintain bare soil. This may increase the temperature of the crop at canopy height as stubbles can act as an insulator by reflecting light during the day. Removing stubbles is not usually recommended but as there is debatable effectiveness it is more valuable to retain stubble to retain moisture.

Rolling

Roll sandy and loamy clay soil after seeding. This practice consolidates moist soil providing a reduced surface area. This enables more radiant heat to be trapped and stored during the day compared with dry, loose soil. Moist and firm soil is a better conductor of heat and will cool slowly because heat removed at the surface by radiation is replaced in part by heat conducted upwards from the warmer soil below. A roller is usually towed behind the seeder machinery or it can be done postemergent. Rolling is not usually recommended due to the extra expense, extra time required, debatable effectiveness, inter-row weed germination and increased wind erosion risk on susceptible soil types.¹²

Managing a frosted crop

There are a number of options available for managing crops that have been frosted (Table 1). The following table highlights these options and the pros and cons of each. The suitability of each option will be dependent on the severity of the frost and analysis costs versus returns.

Table 1: Options for managing frosted crops.

Option	Advantages	Disadvantages		
Harvest	No damage estimates required.	Costs may be greater than returns.		
	Salvage remaining grain.			
	Condition stubble for seeding.	Need to implement weed control.		
	j.	Threshing problems.		
		Need to remove organic matter.		
Hay/Silage	Stubble removed.	Cost per hectare.		
	Weed control.	Quality may be poor (especially wheat).		
Chain/Rake	Retains some stubble and	Cost per hectare.		
	reduces erosion risk.	Time taken.		
	Allows better stubble handling.			

11 DAFWA (2016) Frost and cropping. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/frost/frost-andcropping?page=0%2C1</u>

12 DAFWA (2016) Frost and cropping. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/frost/frost-and-cropping?page=0%2C2</u>





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<u>Managing frost risk – a guide for</u> southern Australian growers.

Ranking cereals for frost susceptibility using frost values – southern region.

GRDC Managing frost risk Factsheet.

VIDEOS

WATCH: GCTV3: Frost R&D.



WATCH: <u>GCTV16: National Frost</u> Initiative.



Option	Advantages	Disadvantages		
Graze	Feed value.	Inadequate stock to utilise feed.		
	Weed control.	Remaining grain may cause acidosis.		
		Stubble may be difficult to sow into.		
Spray	Stops weed seed set. Preserves feed quality for	Difficulty getting chemicals onto all of the weeds with a thick crop.		
	grazing.	May not be as effective as burning.		
	Retains feed	Boom height limitation.		
	Retains organic matter	Cost per hectare.		
	Retains organie matter.	Some grain still in crop.		
Plough	Recycles nutrients and retains	Requires offset discs to cut straw.		
	organic matter. Stops weed seed set. Green manure effect.	Soil moisture needed for breakdown and incorporation of stubble.		
Swath	Stops weed seed set.	Relocation of nutrients to windrow.		
	Windrow can be baled.	Low market value for straw.		
	Regrowin can be grazed.	Poor weed control under swath.		
	weed regrowth can be sprayed.	Cost per hectare.		
Burn	Recycles some nutrients.	Potential soil and nutrient losses.		
	Controls surface weed seeds.	Fire hazard.		
	Permits recropping with disease control.	Organic matter loss.		
	Can be done after rain.			

Source: DAFWA

14.2 Waterlogging/flooding issues for oats

Key points:

- Waterlogging occurs when roots cannot respire due to excess water in the soil profile.
- Water does not have to appear on the surface for waterlogging to be a potential problem.
- Improving drainage from the inundated paddock can decrease the period at which the crop roots are subjected to anaerobic conditions.
- While raised beds are the most intensive management strategy, they are also the most effective at improving drainage.
- Waterlogged soils release increased amounts of nitrous oxide (N_2O), a particularly damaging greenhouse gas.

Under waterlogged conditions, soil and crop environment is affected by the depletion of oxygen, leading to reduced root respiration and other vital plant physiological processes. Root-harming gases such as carbon dioxide and ethylene also accumulate in the root zone and affect the plants. This results in impaired plant growth and yield loss, as well as increasing susceptibility to disease, reducing plant vigour and potentially causing plant death. Plants are particularly vulnerable from seeding to tillering with seminal roots being more affected than later forming nodal roots.



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Oats are seen as more tolerant of waterlogging than other cereals, particularly prior to germination. When growing in waterlogged conditions they tend to maintain green leaves while wheat and barley often become chlorotic. ¹³

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Where does waterlogging occur?

- Waterlogging occurs when there is insufficient oxygen in the soil pore space for plant roots to adequately respire.
- Root-harming gases such as carbon dioxide and ethylene also accumulate in the root zone and affect the plants.
- Waterlogging damage is worse in the following situations:
- Deeper sown crops
- Water-accumulating or poorly drained areas such as valleys, at the change of slope or below rocks Duplex soils, particularly sandy duplexes with less than 30 cm sand over clay
- Low nitrogen status crops
- In very warm conditions when oxygen is more rapidly depleted in the soil.
- Salinity affects growth by reducing plant root ability to extract water from the soil, and chloride toxicity.
- Primary salinity occurs naturally in heavy textured, highly alkaline and usually well-drained soils with high levels of salt in the subsoil. Most common are morrell-blackbutt loams on the edge of major valleys or greenstone soil and Dowak clay in the Esperance Mallee. Oats yield poorly on these soils.
- Secondary salinity has been caused by salt accumulation from saline water tables or seepages that have increased after land clearing.
- Salinity is frequently accompanied by waterlogging in autumn and winter, which greatly increases plant damage.¹⁴

14.2.1 Identifying waterlogged areas

The best way to identify problem areas is to dig holes about 40 cm deep in winter and see if water flows into them (Photo 4). If it does, the soil is waterlogged. Digging holes for fence posts often reveals waterlogging.

Some farmers put slotted PVC pipe into augered holes. They can then monitor the water levels in their paddocks.

Symptoms in the crop of waterlogging include:

- Yellowing of crops and pastures.
- Presence of weeds such as toad rush, cotula, dock and Yorkshire fog grass. ¹⁵

- 14 DAFWA (2016) Diagnosing waterlogging and salinity in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/</u> mycrop/diagnosing-waterlogging-and-salinity-oats
- 15 Soilquality.org. Waterlogging Factsheet. http://soilquality.org.au/factsheets/waterlogging



¹³ Troup G. (2016). Oats: paddock selection. https://www.agric.wa.gov.au/oats/oats-paddock-selection?page=0%2C1





Photo 4: Water fills hole while digging in waterlogged soil.

Water levels can be monitored with bores or observation pits, but water tables can vary greatly over short distances. Plants can be waterlogged if there is a water table within 30 cm of the surface and no indication of waterlogging at the surface. Observe plant symptoms and paddock clues and verify by digging a hole. ¹⁶

14.2.2 Waterlogging symptoms

Waterlogged seed will be swollen and may have burst. Seedlings may die before emergence or be pale and weak. Waterlogged plants appear to be nitrogen deficient with pale plants, poor tillering, and older leaf death. If waterlogging persists, roots (particularly root tips) cease growing, become brown and then die. Seminal roots are important for accessing deep subsoil moisture. If damaged by waterlogging the plants may be more sensitive to spring drought.

What to look for

Paddock:

- Poor germination or pale plants, in water collecting areas, particularly on shallow duplex soils.
- Wet soil and/or water-loving weeds present.
- Early plant senescence in waterlogging prone areas.

Plant:

- Plants are particularly vulnerable from seeding to tillering with seminal roots being more affected than later forming nodal roots.
- Waterlogged seed will be swollen and may have burst.
- Seedlings may die before emergence or be pale and weak.
- Waterlogged plants appear to be nitrogen deficient with pale plants, poor tillering, and older leaf death (Photo 5).
- If waterlogging persists, roots (particularly root tips) cease growing, become brown and then die.
- 16 DAFWA (2016) Diagnosing waterlogging and salinity in oats. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/</u> mycrop/diagnosing-waterlogging-and-salinity-oats





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Seminal roots are important for accessing deep subsoil moisture. If damaged by waterlogging the plants may be more sensitive to spring drought. ¹⁷

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Photo 5: Pale plants in waterlogged areas. Source: DAFWA

14.2.3 Waterlogging and salinity

Waterlogging and salinity often occur together. Oats are very waterlogging tolerant.

What to look for

Paddock:

- Poor germination or pale plants, in water collecting areas, particularly on shallow duplex soils.
- Wet soil and/or water-loving weeds or salt tolerant plants only as salinity increases.
- Nitrogen-deficient plants with more leaf necrosis and premature death in more saline areas (Photo 6).

Plant:

- Salinity symptoms:
- Plants have a harsh droughted appearance, and may be smaller with smaller dull leaves.
- Old leaves develop dull yellow tips and die back from the tips and edge (Photo 7).
- Premature death.



¹⁷ DAFWA (2015) Diagnosing waterlogging in cereals. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/mycrop/</u> diagnosing-waterlogging-cereals



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Photo 6: Old leaf browning, necrosis from waterlogging and mild salinity. Source: DAFWA 2015



Photo 7: Water stressed plant in saline patch. Source: DAFWA



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WATCH : Over the Fence: Raised beds boost yields at Winchelsea.



14.2.4 Management strategies

Key points:

- Sow waterlogging tolerant crops such as oats and faba beans.
- Sow as early as possible with a higher cereal seeding rate.
- Drainage may be appropriate on sandy duplex soils on sloping sites.

Raised beds are more effective on relatively flat areas and on heavier textured soils, but areas need to be large enough to justify machinery costs. ¹⁸ (For more information on raised beds see <u>Cropping on raised beds in southern NSW</u>).

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Drainage is usually the best way of reducing waterlogging. Other management options to reduce the impact of waterlogging include: choice of crop, seeding, fertiliser and weed control.

Drain waterlogged soils as quickly as possible, and cultivate between rows to aerate the soil.

Good drainage is essential for maintaining crop health. Wet weather provides a good opportunity to improve the drainage of your crop land, as it allows you to identify and address any problem areas.

There are several things you can do to improve crop drainage, immediately and in the longer term.

Agronomic management strategies for growing oats in waterlogged areas include:

- sowing as early as possible in waterlogged conditions. Delayed sowing results in a greater yield reduction and loss of quality
- delaying sowing if a significant rainfall event is forecast
- planting the seed at a shallow depth
- using long season varieties so crops are established before waterlogging occurs
 and still flower at their optimum time
- ensuring adequate crop nutrition—a healthy plant will be better equipped to grow away from a stressed situation
- ensuring adequate nitrogen is available to the crop before and after waterlogging. Supplementing nitrogen fertiliser can offset a portion of the yield loss because nitrate can act as a secondary source of oxygen for the plant
- minimising weed competition ¹⁹

Caution should be taken when combining waterlogging and salinity. Under these conditions, low oxygen concentrations around the roots limit energy available to the plants and they are not able to exclude salts from their tissues.²⁰

Nitrogen fertiliser

Crops tolerate waterlogging better with a good nitrogen status before waterlogging occurs. Applying nitrogen at the end of a waterlogging period can be an advantage if nitrogen was applied at or shortly after seeding because it avaoids loss by leaching or denitrification. However, nitrogen cannot usually be applied from vehicles when soils are wet, so consider aerial applications.

If waterlogging is moderate (7–30 days waterlogging to the soil surface), then nitrogen application after waterlogging events when the crop is actively growing is recommended where basal nitrogen applications were 0–50 kg N/ha. However, if waterlogging is severe (greater than 30 days to the soil surface), then the benefits of nitrogen application after waterlogging are questionable. But this recommendation requires verification in the field at a range of basal nitrogen applications using a selection of varieties.

- 18 DAFWA. (2015). Diagnosing waterlogging in cereals. <u>https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-cereals</u>
- 19 G Troup (2016) Paddock selection, Soil type. Department of Agriculture and Food WA, <u>https://www.agric.wa.gov.au/oats/oats-paddock selection?page=0%2C1</u>
- 20 G Troup (2016) Paddock selection, Soil type. Department of Agriculture and Food WA,<u>https://www.agric.wa.gov.au/oats/oats-paddock-selection?page=0%2C1</u>







i) MORE INFORMATION

Should waterlogged crop be topdresses with N fertiliser?



WATCH : <u>The 2012 N story and</u> planning for 2013.



Weed density affect a crop's ability to recover from waterlogging. Weeds compete for water and the small amount of remaining nitrogen, hence the waterlogged parts of a paddock are often weedy and require special attention if the yield potential is to be reached. ²¹

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14.3 Other environmental issues

14.3.1 Drought and heat stress

Drought is one of the major environmental factors reducing grain production in rainfed and semiarid regions of Australia. The direct effects of heat stress are estimated to cost grain growers in south-east Australia almost \$600 million per year and about \$1.1 billion nation-wide. Due to the effects of climate change, both heat stress and frost are likely to play an increasing role in the future and will require growers to take steps to manage the risks.²²

Oats are claimed to be sensitive to drought, particularly during anthesis and grain fill. ²³ A quantitative knowledge of the response of crops to drought and heat stress is important for the management of both irrigated and dryland crops. Heat stress is caused by high temperatures and hot dry winds before or during flowering. Drought has been found to affect the yield of oats reducing panicle and grain number; effects on grain weight were small. Early drought through late irrigation has been found to lead to more late tillers, more panicles, heavier grains, and later maturity and full and late drought has been found to increase screenings. ²⁴

What to look for:

- Tips of leaves turn brown to grey (Photo 8).
- Some or all grains fail to develop in a panicle.



Photo 8: Withered and split leaf tips. Source: SARDI Oat breeding unit (2015)

23 J Brouwer, RG Flood (1995) In: The Oat Crop. (Ed. RW Welch) (Chapman and Hall, London)

24 RJ Martin, PD Jamieson, RN Gillespie, S Maley (2001) Effect of timing and intensity of drought on the yield of oats (Avena sativa L). Screening, 1(5.0), 7–90, <u>http://agronomyaustraliaproceedings.org/images/sampledata/2001/l/b/martin.pdf</u>



²¹ DAFWA. (2015). Management to reduce the impact of waterlogging in crops. <u>https://www.agric.wa.gov.au/waterlogging/management-reduce-impact-waterlogging-crops</u>

²² Barr R. (2016). Diversity the key to balancing frost-heat risks. <u>https://grdc.com.au/Media-Centre/Media-News/South/2016/01/Diversity-the-key-to-balancing-frost-heat-risks</u>



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Effect of timing and intensity of drought on the yield of Oats (Avena sativa L.)

The response of oats (*Avena sativa L*.) to timing and intensity of drought was determined in a mobile rainshelter, which excluded rainfall during crop growth. Ten irrigation treatments subjected the crops to drought of varying duration at different stages during plant growth; the crops were otherwise fully irrigated. Oat grain yield generally increased linearly with cumulative water use, and decreased linearly as the maximum potential soil moisture deficit experienced during crop growth increased, regardless of the timing of drought. The exception to this was the no drought (fully irrigated) treatment, where lodging reduced panicle number and grain weight compared to early drought treatments. Drought affected yield mainly by reducing panicle and grain number, effects on grain weight were small. Relieving early drought through late irrigation led to more late tillers, more panicles, heavier grains, and later maturity. Full and late drought increased screenings.²⁵

) MORE INFORMATION

Make sure to consider the impacts of herbicide residues following drought.

Winter cropping following drought.

Soil management following drought.

DPI NSW Drought Hub.

Drought Planning

Managing Drought

Managing heat and drought stress

Key points:

- Heat stress is a key yield limiting factor in crop production.
- Heat stress has been shown to adversely affect yield as early as growth stage 45.
- Post flowering heat stress is most common in southern Australia.
- Delayed sowing increases the chance of the crop being exposed to heat stress, particularly at the vulnerable pre-flowering growth stages.

Research in SA suggests that variety selection and early sowing are still the most effective means to reduce the risk of a crop being damaged by excessive heat. A later sown crop will have an increased likelihood of being exposed to the heat stress at more sensitive growth stages, particularly pre-flowering, and will have greater consequences to the potential grain yield. ²⁶

Drought events can be unpredictable and can last extended periods of unknown lengths, therefore it is difficult to prepare for drought conditions. See the links below for some tips on managing drought.



²⁵ RJ Martin, PD Jamieson, RN Gillespie, S Maley (2001) Effect of timing and intensity of drought on the yield of oats (Avena sativa L). Screening, 1(5.0), 7–90, <u>http://agronomyaustraliaproceedings.org/images/sampledata/2001/l/b/martin.pdf</u>

²⁶ Telfer P, Edwards J, Bennett D, Kuchel H. (2013). Managing heat stress in wheat. <u>http://www.msfp.org.au/wp-content/uploads/Managing-heat-stress-in-wheat.pdf</u>



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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.

Figure 1 shows a grain-selling flowchart that summarises:

- The decisions to be made.
- The drivers behind the decisions.
- The guiding principles for each decision point.

The reference column refers to the section of the GrowNote where you will find details to help in making decisions.





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Figure 1: Grain-selling flowchart.

The grower will run through a decision-making process each season, because growing and harvesting conditions, and prices for grains, change all the time. For example, wheat prices in the six years to 2014 varied by as much as A\$150/t (Figure 2). Part of the price a grower receives comes down to their skill and to how well they manage marketing and its associated risks.



Note to figure: Newcastle APWI 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.





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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 a target price, and then working towards achieving the target price.

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Unknowns include the amount of grain available to sell (production variability), the final cost of producing the grain, 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 are difficult to predict.

The skills growers have developed to manage production unknowns can also be used to manage pricing unknowns. This guide will help growers manage and overcome price uncertainty.

15.1.1 Be prepared

Being prepared by having a selling plan is essential for managing uncertainty. The steps involved are forming a selling strategy, and forming a plan for effectively executing sales. The selling strategy consists of when and how to sell.

When to sell

Knowing when to sell requires an understanding of the farm's internal business factors, including:

- production risk
- a target price based on the cost of production and the desired profit margin
- business cashflow requirements

How to sell

Working out how to sell your grain is more dependent on external market factors, including:

- the time of year, which determines the pricing method
- market access, which determines where to sell
- relative value, which determines what to sell

The following diagram (Figure 3) lists the key selling principles to employ when considering sales during the growing season. Exactly when each principle comes into play is indicated in the rest of section 15.





Figure 3: *Timeline of grower commodity selling principles.*

15.1.2 Establish the business risk profile

Establishing your business risk profile helps you determine when to sell : it allows you to develop target price ranges for each commodity, and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify the risks of those during the production cycle are described below (Figure 4).



Figure 4: *Typical farm business circumstances and risk.*

Source: Profarmer Australia





Production-risk profile of the farm

Production risk is the level of certainty of producing a crop, and is influenced by location (climate, season and soil type), crop type, crop management, and the time of year.

Principle: You can't sell what you don't have.

Therefore, don't increase business risk by overcommitting production. Establish a production-risk profile (Figure 5) by:

- 1. Collating historical average yields for each crop type and a below-average and above-average range.
- 2. Assessing the likelihood of achieving the average, based on recent seasonal conditions and the seasonal outlook.
- 3. Revising production outlooks as the season progresses.



Figure 5: *Typical risk profile of a farm operation.* Source: Profarmer Australia

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, which means knowing all farm costs, both variable and fixed.

Principle: Don't lock in a loss.

If committing production ahead of harvest, ensure the price will be profitable. The steps needed to calculate an estimated profitable price is based on the total cost of production and a range of yield scenarios, as provided below (Figure 6).





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Estimating cost of production - V	Vheat
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
Receival fees	\$11 /t
Freight to Port	\$22 /t
Total per tonne costs	\$48 /t
Cost of production Port FIS equiv	\$259.20
Target profit (ie 20%)	\$52.00

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.

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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: An example of how to estimate the costs of production. <u>GRDC's manual</u> <u>Farming the Business</u> also provides a cost-of-production template and tips on grain selling vs grain marketing.

\$311.20

Income requirements

Target price (port equiv)

Understanding farm business cash-flow requirements and peak cash debt enables growers to time grain sales 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.

Typical cash flows to grow a crop are illustrated below (Figures 7 and 8). Costs are incurred up front and during the growing season, with peak working capital debt incurred at or before harvest. Patterns will vary depending on circumstance and enterprise mix. The second figure demonstrates how managing sales can change the farm's cash balance.







Figure 7: *Typical operating cash balance.* Source: Profarmer Australia



In this scenario peak cash surplus starts lower and peak cash debt is higher

Figure 8: Typical operating cash balance.

Source: Profarmer Australia

The when-to-sell steps above result in an estimated production tonnage and the risk associated with producing 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

The first part of the selling strategy answers the question about when to sell and establishes comfort around selling a portion of the harvest.





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The second part of the strategy, managing your price, addresses how to sell your crop.

Methods of price management

Pricing products provide varying levels of price risk coverage (Table 1).

Table 1: Pricing methods and how they are used for different crops.

	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	Subject to both price	Pools	Pools	Pools	Pools	Pools	Pools	Pools

Figure 9 summarises how the different methods of price management are suited for the majority of farm businesses.



harvest selling strategies.

Figure 9: Price strategy timeline, summarising the suitability for most farm businesses of different methods of price management for different phases of production.

Principle: If increasing production risk, take price risk off the table.

When committing to unknown production, price certainty should be achieved to avoid increasing overall business risk.

Principle: Separate the pricing decision from the delivery decision.

Most commodities can be sold at any time with delivery timeframes being negotiable, hence price management is not determined by delivery.



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Fixed price

A fixed price is achieved via cash sales and/or selling a futures position (swaps) (Figure 10). It provides some certainty around expected revenue from a sale, as the price is largely a known factor, except when there is a floating component in the price, e.g., a multi-grade cash contract with floating spreads or a floating-basis component on futures positions.



Figure 10: Fixed price strategy.

Source: Profarmer Australia

Floor price

Floor-price strategies (Figure 11) can be achieved by utilising options on a relevant futures exchange (if one exists), or via a managed-sales program (i.e. a pool with a defined floor price strategy) offered by a third party. This pricing method protects against potential future downside while capturing any upside. The disadvantage is that the price 'insurance' has a cost, which adds to the farm's cost of production.

This option is not available for oats.



Figure 11: Floor-price strategy. Source: Profarmer Australia





Figure 12: Floating-price strategy.

Source: Profarmer Australia

Having considered the variables of production for the crop to be sold, and how these fit against the different pricing mechanisms, the farmer may revise their selling strategy.

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 they cost more.

Floating-price strategies provide minimal price certainty, and so are best used after harvest.

15.1.4 Ensuring access to markets

Once the questions of when and how to sell are sorted out, planning moves to the storage and delivery of commodities to ensure timely access to markets and execution of sales. Planning where to store the commodity is an important component of ensuring the type of access to the market that is likely to yield the highest return (Figure 13).



Figure 13: How storage decisions affect selling time, and must be accommodated as part of the timing of all farming practices.

Source: Profarmer Australia




SECTION 15 OALS

MORE INFORMATION

For more information on on-farm

refer Section 13: Storage.

storage alternatives and economics

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Storage and logistics

The return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access so as to maximise returns as well as harvest logistics.

Storage alternatives include variations of bulk handling, private off-farm storage, and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity (Figure 14).

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Principle: Harvest is the first priority.

During harvest, getting the crop into the bin is the most critical aspect of business success; hence storage, sale and delivery of grain should be planned well ahead of harvest to allow the grower focus on the harvest itself.

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. feedlot, processor, or container packer), may be more suited to on-farm or private storage to increase delivery flexibility.

Storing commodities on the farm requires prudent quality management to ensure that the grain is delivered to the agreed specifications. If not well planned or carried out, it can expose the business to high risk. Penalties for out-of-specification grain arriving at a buyer's weighbridge can be expensive, as the buyer has no obligation to accept it. This means the grower may have to incur the cost of taking the load elsewhere, and may also have to find a new buyer.

On-farm storage also requires prudent delivery management to ensure commodities are received by the buyer on time and with appropriate weighbridge and sampling tickets.

Principle: Storage is all about market access.

Storage decisions depend on quality management and expected markets.





Figure 14: Grain storage decision-making.

Source: Profarmer Australia

Cost of carrying grain

Storing grain to access sales opportunities post-harvest invokes a cost to 'carry', or hold, the grain (Figure 15). Price targets for carried grain need to account for the cost of carrying it. Carrying costs are typically \$3–4/t per month and consist of:

- Monthly storage fee charged by a commercial provider (typically $^{150-2.00/t}$).
- Monthly interest associated with having wealth tied up in grain rather than available as cash or for paying off debt (~\$1.50-\$2.00/t, 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 the price offered at harvest.





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The cost of carrying also applies to grain stored on the farm, as there is the cost of the capital invested in the farm storage, plus the interest component. A reasonable assumption is a cost of 3-4/t per month for on-farm storage.

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Principle: Carrying grain is not free.

The cost of carrying grain needs to be accounted for if holding it for sale after harvest is part of the selling strategy.

If selling a cash contract with deferred delivery, a carrying charge can be negotiated into the contract. For example, a March sale of canola for March–June delivery on the buyer's call, at a price of 200/t + 3/t carrying per month, would generate revenue of 200/t delivered.



Figure 15: Cash value v. value adjusted for the cost of carrying.

Source: Profarmer Australia

Optimising farm-gate returns involves planning the appropriate storage strategy for each commodity to improve market access and ensure that carrying costs are covered in pricing decisions.

15.1.5 Converting tonnes into cash

This section provides guidelines for converting the selling and storage strategy into cash by effective execution of sales.

Set up the toolbox

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox for converting tonnes of grain into cash includes the following.

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 interests first by not having conflicts of interest and by investing time in the relationship. A better return on investment for the farm business is achieved through higher farm-gate prices that are obtained by accessing timely information, and the seller's greater market knowledge and greater market access.

3. Futures account and a bank-swap facility





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Access to buyers, brokers, agents, products and banks through <u>Grain</u> <u>Trade Australia</u>

Commodity futures brokers

ASX's Find a futures broker

These accounts provide access to global futures markets. Hedging futures markets is not for everyone; however, strategies which utilise exchanges such as the Chicago Board of Trade (CBOT) can add significant value.

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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 (Figure 16):

- Price—future price is largely unpredictable, so devising a selling plan to put current prices into the context of the farm business is critical to manage price risk.
- Quantity and quality—when entering a cash contract, you are committing to deliver the nominated amount of grain at the quality specified, so production and quality risks must be managed.
- Delivery terms—the timing of the 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 the title on the grain to be transferred ahead of payment, so counterparty risk must be managed.





Figure 16: Typical terms of a cash contract. Source: Grain Trade Australia

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. Figure 17 shows the terminology used to describe these points and the associated costs to come out of each price before growers receive their net return.









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<u>Grain Trade Australia, A guide to</u> taking out grain contracts

Grain Trade Australia, Trading standards

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Emerald Grain

Clear Grain Exchange, Getting started

<u>Clear Grain Exchange, Terms and</u> <u>conditions</u>

i) MORE INFORMATION

GTA, Managing counterparty risk

<u>Clear Grain Exchange's title transfer</u> <u>model</u>

<u>GrainGrowers, Managing risk in grain</u> <u>contracts</u>

Leo Delahunty, Counterparty risk: A producer's perspective

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 is 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 option depends on location and commodity.

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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 offer and the bid match, the particulars of the transaction are sent to a secure settlement facility, although the title on the grain does not transfer from the grower until they receive funds from the buyer. The availability of this option 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.

Counterparty risk

Most sales involve transferring the title on the grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

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.
- Conducting a credit check (banks will do this) before dealing with a buyer you are unsure of.
- Selling only a small amount of grain to unknown counterparties.
- Considering credit insurance or a letter of credit from the buyer.
- Never delivering a second load of grain if payment has not been received for the first.
- Not parting with the title before payment, or requesting and receiving a cash deposit of part of the value ahead of delivery. Payment terms are negotiated at time of contracting. Alternatively the Clear Grain Exchange provides secure settlement whereby the grower maintains title until the receive payment, and then title and payment are settled simultaneously.

Above all, act commercially to ensure the time invested in implementing a selling strategy is not wasted by poor management of counterparty risk. Achieving \$5/t more on paper and not getting paid is a disastrous outcome.

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 to hold commodities that are not well priced at any given time. That is, give preference to the commodities with the highest relative value. This achieves price protection for the overall revenue of the farm business and enables more flexibility to a grower's selling program while achieving the business goal 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.





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An example based on a wheat and barley production system is provided below (Figure 18).



Figure 18: Brisbane prices for ASW wheat v. feed barley, showing when a farmer would ideally sell their barley.

Source: Profarmer Australia

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 19).



Note to figure:

Once the decision to take price protection has been made, choosing which pricing method to use is determined by which selling methods 'hold the greatest value' in the current market.

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Source: Profarmer Australia



Figure 19: Newcastle APWI v. CBOT wheat (A\$/t).



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Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (e.g. price, premiums-discounts, oil bonuses), and optimising your allocation reflects immediately on your bottom line.

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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 lower grades of wheat to contracts with the lowest discounts.
- Allocate higher grades of wheat to contracts with the highest premiums (Figure 20).



Note to figure:

In these two examples the only difference between acheiving an average price of \$290/t and \$295/t is which contracts each parcel was allocated to. Over 400/t that equates to \$2,000 which could be lost just in how parcels are allocated to contracts.

Figure 20: How the crop is allocated across contracts can have an impact on earnings from the crop.

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 very interested.

Principle: Sell when there is buyer appetite.

When buyers are chasing grain, growers have more market power to demand the price they want 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 that 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 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.

The selling strategy is converted to maximum business revenue by:

Ensuring timely access to information, advice and trading facilities.





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- Minimising counterparty risk by conducting effective due diligence.
- Understanding relative value and selling commodities when they are priced well.

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- Thoughtful contract allocation.
- Reading market signals to extract value from the market or to prevent selling at a discount.

15.2 Southern oats: market dynamics and execution

15.2.1 Price determinants for southern oats

The global oat crop is estimated at 20–23 Mt each year; Australia is an important player, typically producing 1–1.5 Mt annually. Australia exports about 20% of our production each season, with the bulk of the crop being consumed domestically. The large majority of exported oats are used for human consumption.

Western Australia is Australia's largest oat-production state, accounting for about onethird of the crop and 70–80% of oats exported each season. In southern markets, a very small proportion of the oat crop is exported each year (typically through containers), with the majority of milling-quality oats being processed for human consumption at local mills and the remainder of the crop consumed in animal feed.

Values for feed oats are primarily influenced by the supply and demand of other local feed sources such as wheat, barley and hay fodder. While the commodities are not necessarily substitutable, the price relativity is important in order to ensure consumer supply requirements are met each season.

Although most oats is consumed domestically, prices are influenced by relative WA values, which are tied closely to export values. Southern farm-gate prices are heavily influenced by both local and global factors.

15.2.2 Ensuring market access for southern oats

Since the large majority of the southern oat crop is consumed domestically, private commercial storage or on-farm storage are often the most effective method of accessing the domestic consumer market.

For milling-quality oats intended for human consumption, prudent quality management is required. In order to obtain premiums for this product, it is also a good idea to have relationships in place with buyers before harvesting the crop (Figure 21), so that the supply chain from the farm to the miller is more secure.





Figure 21: Australian supply-chain flow

15.2.3 Converting tonnes into cash for southern oats

Knowing where the southern Australian oat crop is likely to end up will help a grower refine their selling and logistics decisions: understanding whether the grain will be used for milling or for feed will help in determining the best path to market.

For milling-quality oats it is of the utmost importance to maintain grain quality, in light of the discounts that occur if the grain fails to meet milling standards. Milling oats are often contracted prior to production, with consumers looking to lock in supply; alternatively, milling oats are sold into the cash market after harvest. Because consumers have rigid supply requirements each season, forward selling a portion of the crop may result in a premium being paid. It is always important, however, to manage prospective pre-harvest sales against production risk. Specialist oat-milling facilities in southern Australia include;

- Blue Lake Milling, Bordertown (SA)
- Blue Lake Milling, Dimboola (Vic)
- UniGrain, Smeaton (Vic)
- Uncle Toby's, Wahgunyah (Vic)

Compared with milling oats, feed oats are more heavily influenced by domestic factors such as the relative price of other feed grains and local feed-grain supply and





demand. There may be further benefit in storing feed oats throughout the season, and executing sales based on opportunistic pricing. Oats are a sought-after feed grain due to the low-risk nature of the grain and its attractive characteristics as a feed. As a result, feed oats can price at strong premiums over other available feed grains.

Given the lack of active participants in the oat market in southern Australia, monitoring liquidity using the principles of GrowNote to Bank Note minimises the risk of being exposed to sudden price drops.





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Current and past research

Project Summaries

As part of a continuous investment cycle each year the Grains Research and Development Corporation (GRDC) invests in several hundred research, development and extension and capacity building projects. To raise awareness of these investments the GRDC has made available summaries of these projects.

These project summaries have been compiled by GRDC's research partners with the aim of raising awareness of the research activities each project investment.

The GRDC's project summaries portfolio is dynamic: presenting information on current projects, projects that have concluded and new projects which have commenced. It is updated on a regular basis.

The search function allows project summaries to be searched by keywords, project title, project number, theme or by GRDC region (i.e. Northern, Southern or Western Region).

Where a project has been completed and a final report has been submitted and approved a link to a summary of the project's final report appears at the top of the page.

The link to Project Summaries is https://grdc.com.au/research/projects

Final Report Summaries

In the interests of raising awareness of GRDC's investments among growers, advisers and other stakeholders, the GRDC has available final reports summaries of projects.

These reports are written by GRDC research partners and are intended to communicate a useful summary as well as present findings of the research activities from each project investment.

The GRDC's project portfolio is dynamic with projects concluding on a regular basis.

In the final report summaries there is a search function that allows the summaries to be searched by keywords, project title, project number, theme or GRDC Regions. The advanced options also enables a report to be searched by recently added, most popular, map or just browse by agro-ecological zones.

The link to the Final Report Summaries is http://finalreports.grdc.com.au/final_reports.grdc.com.au/final_reports.php

Online Farm Trials

The Online Farm Trials project brings national grains research data and information directly to the grower, agronomist, researcher and grain industry community through innovative online technology. Online Farm Trials is designed to provide growers with the information they need to improve the productivity and sustainability of their farming enterprises.

Using specifically developed research applications, users are able to search the Online Farm Trials database to find a wide range of individual trial reports, project summary reports and other relevant trial research documents produced and supplied by Online Farm Trials contributors.

The Online Farm Trials website collaborates closely with grower groups, regional farming networks, research organisations and industry to bring a wide range of crop research datasets and literature into a fully accessible and open online digital repository.

Individual trial reports can also be accessed in the trial project information via the Trial Explorer.

The link to the Online Farm Trials is http://www.farmtrials.com.au/





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