Oats
Western Region
February 2016

planning/paddock preparation • pre-planting • planting •
plant growth and physiology • nutrition and fertiliser •
weed control • insect control • nematode control •
diseases • canopy management • harvest • storage •
environmental issues • marketing • current research
Start here for answers to your immediate oat crop management issues

- What grass weed control options do I have in oats?
- Can I plant the same oat variety for grain, hay and grazing?
- Is nutrition the same as other cereals?
- What diseases are an issue in oats?
- What is the grazing nutrition of oats compared to other cereals?
- Do sowing rates differ between grazing, hay and grain production?
Benefits of oats in your rotation

**Frost Tolerant**
Sow into more frost prone paddocks as oats are estimated to be 4°C more tolerant to frost at flowering than wheat.

**Early Sowing Options**

**Long Coleoptile Length**
enables deeper sowing when moisture is not close to the surface.

**More Tolerant to Waterlogging**
than wheat, barley or canola.

**Disease Break**
Provides a disease break for other cereals.

**Highly Competitive Crop Canopy**
that competes well with weeds when sown early.

**Can be**
cut for hay or harvested for grain.
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SECTION A

Introduction

Oats make up about one per cent of land use in Western Australia's eastern wheatbelt. Most are used as opportunity hay crops or for stockfeed.

There is a lack of agronomic research into growing oats in these lower-rainfall areas—but they offer diversification and profit potential.

New oat agronomy research aims to expand plantings of this crop in the lower rainfall parts of the Western Australian wheatbelt for grain and hay production, and to help manage frost risk and keep weed burdens low.

In lower rainfall areas of the eastern wheatbelt the research focus is on growing higher yielding and better performing oat varieties. ¹ Western Australia's oat deliveries into the CBH system could reach 315,000 tonnes in the 2015–16 harvest, with potential for an additional 600,000 to be grown by 2020.

The Department of Agriculture and Food, Western Australia (DAFWA) supports the oat industry through agronomic, disease and pest research and development as well as being a member of the Australian National Oat Breeding Program, which is responsible for breeding and developing new oat varieties with superior quality.

Western Australia (WA) produces up to 500,000 tonnes of oat grain and about 300,000 tonnes of export-quality hay each year. Significant amounts of hay and oat grain are also retained on-farm and traded domestically.

Typically 25% of WA's oat crop is retained on-farm as animal feed, with a further 25% being used within the domestic feed trade in compound feed rations for a range of livestock uses. Around 20% of oats are exported as premium feed grain for the high-performance Middle Eastern and Asian racehorse industries.

Oats is a traditionally early-sown winter cereal with many uses. It can be used in rotation for autumn grazing and then can be locked up for grain production, being a ‘dual-purpose crop’. It is frequently grown for grain and then stored on-farm for stock feed or for human consumption. It can also be baled for hay, with lucrative export markets available to WA growers.

Oats is adaptable to a wide range of soils and can tolerate some diseases that other cereals cannot.

A.1 Hay

Oaten hay for the domestic and export livestock markets is worth an additional $100 million per annum.

WA produces excellent-quality oaten hay and this can be attributed to some of the best hay-making conditions in Australia. WA oaten hay is highly regarded for its energy value, fibre content and palatability, which makes it an ideal feed ration for ruminants.

Good colour, a sugary taste and aroma, and fine texture are critical for good animal performance.

In WA, hay is mechanically cut and conditioned, then quickly dried in the field before it is stacked and stored locally in large sheds.

Oaten hay in the south-west of WA is usually cut from October to November to provide new season's hay.

Quality assurance programs are in place within the export hay industry to ensure quality standards are maintained. Hay processing companies in WA also apply a grading system based on nutritional value. This system is based on Australian Fodder Industry Association standards.

WA oaten hay is a preferred source of fodder for dairy cows, due to its high digestibility and palatability. High in water-soluble carbohydrates, at around 25%, it provides dairy cows with an instant source of energy that can be effectively utilised by the rumen microflora for high milk production and sustained live weight gain.  

Oaten hay is typically grown in the medium- to high-rainfall areas of the wheatbelt and export hay within a 250 km radius of Perth. The main production areas are around Moora, York, Narrogin and Wagin.

Oaten hay crops tend to be grown in the high- to medium-rainfall districts (550 mm–350 mm) and irrigated lucerne hay in the very high rainfall areas (850 mm–550 mm) of the

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south-west and supplemented by irrigation. Oaten hay yields in WA can average around 4–6 t/ha.³

Oaten hay is being used by wheatbelt growers as a profitable way to help manage herbicide-resistant weeds. It provides an ideal break crop between other cereal crops.

![Figure 2: Value of hay exports from Australia and Western Australia.](https://www.agric.wa.gov.au/grains/hay-exports)

### A.2 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), 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.⁴

### A.3 Grazing

Oats will produce more forage than other cereals and has a higher winter growth rate than pastures.⁶

This widely adaptable and reliable cereal is the major winter cereal grazing crop. 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 acid soils, use for hay and silage, use for pasture renovation, suitability for broadleaf weed control by in-crop herbicides and usefulness for grazing-out make oats a versatile crop in farming systems.⁷

### A.4 Exports

WA oats have an excellent reputation both nationally and internationally for their high quality and milling capabilities. End users recognise the aesthetic features of the grain (brightness and pulp characteristics) and the high groat levels (soft inner grain remaining when the husk is removed from harvested grain).

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Quality milling oats are exported directly from WA as grain or processed oats. The major markets for milling oats are Mexico, North Asia, South-East Asia and South Africa.

Oaten hay exports to Japan and other Asian markets are expanding, with consistent supply of first-grade hay essential to retain this market share.  

WA oaten hay is exported to more than 13 markets, with the largest being Japan, South Korea and Taiwan. 

A.5 Health benefits

Oat fibre has 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 Asian products, including oat noodles, oat milk and oat health-care products. Oat varieties grown in WA are bred specifically for their flavour and aroma when processed, as well as their high milling yield. DAFWA is a member of the National Oat Breeding Program and oversees agronomy and breeding evaluation trials across the WA wheatbelt.  

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SECTION 1
Planning/Paddock preparation

Growing winter crops profitably demands higher production per unit area while aiming to maintain a low cost per unit of production. This can only be achieved by increasing grain yields by adopting new or improved technology. The aim is not only higher total production, but also greater productivity from the resources invested in crop production, along with overall sustainability of the farm business.

Paddock selection and rotation combined with using disease-resistant varieties are the best actions to minimise disease. See the National Variety Trial website at www.nvtonline.com.au.

1.1 Paddock selection

Keys to good establishment:

- 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 (not more than one year old) and free from pests and disease.
- Seed should have a high percentage germination, free from weed seeds and inert rubbish.
- Good soil-seed contact and ‘sufficient’ soil moisture for quick germination is ideal but not always possible.
- No weeds should be present during sowing.

1.1.1 Paddock preparation

Cultural practices from paddock preparation to seeding rate and sowing date help promote plant establishment and survival. In Western Australia, with its unpredictable and erratic rainfall combined with poor soils, cultural practices are essential to help maximise oat production.

Legume-based pasture and crops provide more nitrogen (N), which increases grain yield and protein. Lower levels of applied N are needed following a good legume rotation.

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

Customers of the export hay market require that hay be free of contamination. Paddock preparation is a major part of management for export hay and requires:

- removing old crop residues (chain/rake or burning);
- removing obstructions such as sticks, tree branches, stones, carcasses and wire; and
- rolling paddocks to effectively reduce contamination and risk of machinery damage.

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Profit depends on choosing the most suitable variety for each paddock and matching this to the paddock’s limitations, such as available moisture, diseases and nutrient status.

The newer varieties do have a significant yield advantage so variety selection is a major part as well as disease resistance and milling quality.

Profitable yields largely result from good management.

**Agronomist's view**

For no-till systems before seeding, standard paddock preparation protocols, such as knocking down the weeds, should be followed. ²

### 1.2 Paddock rotation and history

Growers need to plant oats into a paddock that is very clean for grass weeds due to the very limited options for grass control in the crop, in particular for wild oats, brome grass and barley grass.

Crop sequencing is a key part of a long-term farming systems approach to tackling weed, disease and moisture challenges in the northern grains region. In Western Australia, growers are finding that early-sown oats are quick to form a canopy and outcompete weeds such as low levels of ryegrass. Sowing early is proving to be an effective weed control strategy on clean paddocks providing improved yields and less weed seedset.

#### 1.2.1 Soil pH/liming

Oats are relatively tolerant of acid soil, being more tolerant than wheat, barley or canola.

Growth will be adversely affected when soil pH is below 4.8. ³

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. Regularly testing top soil and sub soil pH levels is critical for all cropping enterprises.

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.

This can be achieved by:

- minimising leaching of nitrate N;
- using less acidifying fertilisers;
- reducing the effect of removal of product; and
- preventing erosion of the surface soil.

Application of lime sand or finely crushed limestone is the only practical way to neutralise soil acidity. Lime 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 cultivation layer, the lime will only begin to neutralise subsurface soil acidity if the pH of the surface soil is maintained above 5.5. ⁴

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1.3 Benefits of crop as a rotation crop

- Early sowing options – 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 – grain or hay can be grazed.
- Frost mitigation – sow into more frost prone paddocks as oats are estimated to be 4°C more tolerant to frost at flowering than wheat.\(^5\)
- More tolerant to waterlogging than wheat, barley or canola.
- Can be cut for hay or harvested for grain.
- Provides a disease break for other cereals.
- Highly competitive crop canopy that competes well with weeds when sown early.

1.4 Disadvantages of crop as a rotation crop

- Limited option in grass weed control.
- A smaller range of in-crop broadleaf weed control chemicals.
- Still a cereal, so offers little disease break to diseases such as Crown Rot, CCN, Take All.
- Some varieties can shed pre harvest (usually less risky than barley).
- Less drought tolerant than other cereals.
- Volatility in grain prices.
- Highly susceptible to dry finishes.

1.5 Fallow weed control

Uncontrolled heavy weed growth during the summer fallow period can reduce the yield of the subsequent crop by:

- robbing subsequent crops of available soil N
- decreasing the amount of stored soil moisture
- reducing crop emergence due to the physical and/or chemical (allelopathic) interference at seeding time

Controlling summer weeds early will conserve valuable soil N and moisture for use by the crop during the following season. A Western Australian (WA) grower at Salmon Gums can demonstrate an average farm crop yield increase of 400 kg/ha following adoption of consistent summer weed control.

A study by the Cooperative Research Centre (CRC) for Australian Weed Management found that summer weeds can lock away large amounts of N in the weedy biomass, rendering it unavailable for crop growth. Weed burdens of 2.5 t/ha can cause a net loss of available soil N, and burdens of more than 3 t/ha can reduce subsequent wheat yields by as much as 40%.

Another GRDC-funded study in South Australia found that the major impact of summer weeds was on soil moisture. Complete weed control increased available soil moisture at one site by over 11 mm. The CRC study also found that as weed biomass increased, water losses increased. However, the magnitude of the water loss and its importance to the subsequent grain yields varied from site to site.

Summer weeds can also impede crop emergence. Moderate to heavy uncontrolled weed growth can result in reduced crop emergence in minimum tillage systems due to

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the impenetrable stover layer left on the soil surface. Wireweed for example, has long tough and wiry stems which can get caught in the tines at seeding.

Weeds that are ‘allelopathic’ release toxic substances directly from plant’s roots, or during the decomposition of their residue. These toxic substances can inhibit the subsequent germination of the crop. In the CRC study, allelopathic weeds (such as caltrop) reduced subsequent wheat emergence by as much as 25% due to the chemicals that were exuded from the roots.

Effective weed control can reduce weed numbers in subsequent years and run down the seedbank. Uncontrolled weeds contribute massively to the soil seed bank, increasing control costs and future weed burdens. This may limit crop choice and reduce flexibility in systems.

Summer weed control can be expensive but is necessary to prevent problems with excessive growth and/or moisture and N loss from the soil.  

### 1.6 Fallow chemical plant-back effects

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

Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods, for example sulfonylureas (chlorsulfuron). This is shown in Table 1 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.

Growers who use the herbicide Sakura on wheat crops need to be very careful of plant-back periods for growing oats for either grain, hay or forage. There is a 630-day plant back from using Sakura on wheat before growing a subsequent oat crop.

Table 1: Residual persistence of common pre-emergent herbicides, and noted residual persistence in broad acre trials and paddock experiences

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

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### 1.7 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.

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 expectation of rainfall to increase soil moisture levels such that germination may occur. In north-western New South Wales, it is common for soil profiles to have high levels of plant-available water in the root-zone, coupled with a dry seedbed. This scenario may require the practice of ‘moisture seeking’, that is, placing seed deeper in the soil than is generally recommended with the main aim of ensuring timely crop establishment. This generally involves using tines to open a furrow to a depth of >7.5 cm, then placing seed into it, followed by a press-wheel to close moist soil around the seed. Cox and Chapman (2007) reported that ‘moisture seeking’ increases cropping frequency and improves timeliness of crop establishment.

Soil acidity is a major constraint to farming in Western Australia. Extensive surveys of soil pH profiles across the south-west show that more than 70% of surface soils and almost half of subsurface soils are below appropriate pH levels.

Soil acidity is an economic and natural resource threat throughout the south-western agricultural area of Western Australia. Production loss and sustainability are of major concern to farmers, with more than 14.25 million hectares of wheatbelt soils currently estimated to be acidic or at risk of becoming acidic to the point of restricting production. The estimate of production loss for the wheatbelt due to acidity is $498 million (Herbert 2009), or about 9% of the annual crop.

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Herbicide | Half-life (days) | Residual persistence and prolonged weed control
--- | --- | ---
Terbyne® (terbuthylazine) | 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 reactivates 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


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Approximately 161,000 soil samples, including about 67,000 from the subsurface, collected from over 93,000 sites across the south-west agricultural area from 2005–2012 were used to assess the current soil acidity situation (Gazey et al. 2013). These samples show that 72% of topsoils and 45% of subsurface soils were below the targets pHCa of 5.5 and 4.8, respectively. Mapping of this information at the farm scale showed that the extent and severity of acidity varies geographically and with soil type (Figure 1).  

Salinity, primarily caused by excess sodium chloride (NaCl or salt) in the soil, is a concern in many agricultural areas. Excessive soil salts can reduce the performance of oats. By comparison, oats are substantially less tolerant to salt than barley. However, oats is slightly more tolerant than sorghum.  

For oats, a 10% yield reduction in yield is likely when soil salinity reaches 5 dS/m. A 50% reduction in yield is likely when soil salinity reaches 8–10 dS/m.  

A soil pHCa between 5.5 and 8.0 provides the best conditions for most agricultural plants. If the pHCa drops below 5.0, plants that are highly sensitive to acidity, such as:

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14 ‘Oat Science and Technology’ (1992) edited by Marshall and Sorrells
as canola and barley, are adversely affected. Plants that are more tolerant of acidity continue to grow normally until the pH Ca falls below 4.5. Below pH Ca 4.4 most plants, except the very highly acid tolerant plants like oats, narrow-leaf lupins and the native pasture grass *Microlaena* spp, show a significant reduction in production.\(^{15}\)

1.8 Soil moisture

1.8.1 Dryland

Water availability is a key limiting factor for oats production in the northern grainbelt of Australia. Varieties with improved adaptation to such conditions are actively sought and studies have been carried out to identify the physiology of these adaptive traits. Field experiments have been undertaken under a range of moisture availability conditions commonly encountered by winter crops grown on the deep Vertosol soils of this region.

**Technologies to support decision-making:**

Several technologies provide information useful in decision-support without requiring excessive investment.

**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, using a portable electromagnetic induction (EMI) device to measure bulk electrical conductivity and calculate soil water has a number of advantages. The EMI is quick, 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 saline soils and does not apportion soil water to particular layers within the soil profile.\(^{16}\)

**New thoughts on soil moisture monitoring**

Despite 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 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


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.\(^{17}\)

**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 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. To calculate the availability of soil moisture for crop use (in mm of available water) requires further processing of the data and knowledge of a soil's PAW capacity (PAWC). A suitable characteristic may be identified from the APSoil database or SoilMapp, or electronic sensor output may be used to identify the soil's water content operating range, to make reasonable assumptions on values for drained upper limit and crop lower limit. An alternative is to use Soil Water Express (Burk and Dalgliesh 2012), a tool which uses the soil's texture, salinity and bulk density to predict PAWC and to convert electronic sensor output to meaningful soil water information (mm of available water).

**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 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 (Freebairn 2012).\(^{18}\)

### 1.9 Yield and targets

#### 1.9.1 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.\(^{19}\)

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?

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• Avoiding a failed crop saves money now and saves stored water for future crops. 20

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 regularly becoming available. For more information, download the GRDC Update paper, Managing data on the modern farm.

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 by 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
• assess the effect of changed sowing dates or varieties
• 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.

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

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 at: https://itunes.apple.com/au/app/cropmate-varietychooser/id476014848?mt=8

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 Apple iTunes store at: https://itunes.apple.com/au/app/australianclimate/id582572607?mt=8 or visit http://www.australianclimate.net.au

One of the CliMate tools, ‘Season’s progress?’, uses long-term (1949 to present) weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years. 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 HowWet–N?), should I adjust inputs?

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

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire risk chart as the departure from the average in units of standard deviation. 21

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. 22

1.9.2 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 SOI can

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21 Australian CliMate—Climate tools for decision makers, www.australianclimate.net.au

indicate the likelihood of the season being wet or dry; however, they cannot guarantee that rain will fall when you need it.23

**HowWet?**

HowWet? 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. HowWet? tracks soil moisture, evaporation, run-off 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.

HowWet?:
- 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.

Many grain growers are in regions where stored soil water and nitrate at planting are important in crop management decisions. This is of particular importance to northern Australian grain growers with clay soils where stored soil water at planting can constitute a large part of a crop’s water supply.

**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? 24

**Inputs**

- A selected soil type and weather station
- An estimate of soil cover and starting soil moisture
- Rainfall data input by the user for the stand-alone version of HowOften?

**Outputs**

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

**Reliability**

HowWet? uses standard water-balance algorithms from HowLeaky? and a simplified nitrate mineralisation based on the original version of HowWet? 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. 25

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1.9.3 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 using 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 run-off, drainage and evaporation from the soil surface and to weeds.

Rainfall is more summer-dominant in the northern region, and both summer and winter crops are grown. However, 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.

Storing water in fallows between crops is the grower’s most effective tool to manage the risk of rainfall variability, as in-season rainfall alone, in either summer or winter, is rarely enough to produce a profitable crop, especially with high levels of plant transpiration and evaporation.

Fortunately, many cropping soils in the northern region have the capacity to store large amounts of water during the fallow. 26

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

Fallow efficiency (%) = change in plant available water during the fallow x 100

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)

Ways to increase yield

In areas such as western New South Wales where yield is limited by water availability, there are four ways of increasing yield (Passioura and Angus 2010):

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).
2. 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).

3. Increase the efficiency with which crops exchange water for carbon dioxide to grow dry matter, that is, transpiration efficiency (e.g. early sowing, good nutrition, high transpiration efficiency varieties).

4. Increase the total proportion of dry matter that is grain, that is, improve harvest index (e.g. early-flowering varieties, delayed N, wider row spacing, low plant densities, minimising losses to disease, high harvest index varieties).

The last three of these all improve WUE. 27

Knowledge of evaporation for the northern growing region soils is limited yet it is the largest part of the water balance. Since 2010, Queensland Department of Natural Resources and Mines researchers have been measuring evaporation directly for a range of soils using lysimetry techniques. They found most, but not all, soils evaporate at a similar rate. There are significant interactions between soil water, climate and rainfall that influence this rate of evaporation. This data has been used to test current modelling assumptions, better parameterise models, and is now directly contributing to improving predictions of the soil water balance component of models such as APSIM, APSIM-SWIM, HowLeaky, and HowWet (via CLiMate), by providing more realistic responses for our soils and climates.


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, that is, 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 that something is 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. 29

Challenging the French–Schultz model

Application of the French–Schultz model for the northern region has been challenged in recent times.

In the wheatbelt of eastern Australia, rainfall shifts from winter-dominated in the south (South Australia, Victoria) to summer-dominated in the north (northern New South Wales


and Queensland). The seasonality of rainfall, together with frost risk, drives the choice of cultivar and sowing date, resulting in a flowering time between October in the south and August in the north.

In eastern Australia, wheat crops are therefore exposed to contrasting climatic conditions during the critical period for grain formation, that is, a window of about 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 north to south 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, that is, $/ha.mm.

### 1.9.4 Nitrogen-use efficiency

Soil type, rainfall intensity and the timing of fertiliser application largely determine N losses from dryland cropping soils.

In cracking clay soils of the northern grains region, saturated soil conditions between fertiliser application and crop growth can lead to significant losses of N from the soil through denitrification. The gases lost in this case are nitric oxide, nitrous oxide and dinitrogen (N\(_2\)). Isotope studies in the northern region have found these losses can be >30% of the N applied. Direct measurements of nitrous oxide highlight the rapidity of loss in this process.

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 exception occurred with the application of ammonium sulfate to soils with free lime at the surface, where losses were >25% of the N applied. Recovery of N applied in-crop requires sufficient in-crop rainfall for plant uptake from otherwise dry surface soil.\(^{30}\)

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.

### 1.10 Disease status of paddock

#### 1.10.1 Soil testing for disease

**Stubble testing**

Some of the current strategies for managing crown rot are to control grass hosts prior to cropping, rotate susceptible cereals with non-host break crops, inter-row sowing, and grow tolerant wheat 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. This is the only way to accurately test for the disease. Results are provided to the grower and consultant within about four weeks of receiving the sample.  

Check your cereal crops for crown rot between grain-fill 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
- medium, if 10–25% of plants infected
- high, if >25% of plants infected

**Soil testing**

PreDicta B (B = broadacre) is a DNA-based soil-testing service to identify which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding.

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

- cereal cyst nematode
- take-all (Gaemaniomyces graminis var. tritici (Ggt) and G. graminis var. avenae (Gga))
- rhizoctonia barepatch (Rhizoctonia solani AG8)
- crown rot (Fusarium pseudograminearum)
- root lesion nematode (Pratylenchus neglectus and P. thornei)
- stem nematode (Ditylenchus dipsaci)

Northern region grain producers can access PreDicta B via Crown Analytical Services or agronomists accredited by the South Australian Research and Development Institute 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.

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.

**1.10.2 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.

Stubble burning is not recommended as a control for crown rot, and cultivation can increase incidence of seed–stubble contact. Inter-row sowing is a recommended strategy. High cereal intensity and including durum wheat in cropping programs are factors that increase crown rot levels.

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31 Crown Analytical Services, [https://sites.google.com/site/crownanalyticalservices/](https://sites.google.com/site/crownanalyticalservices/)


1.11 Insect status of paddock

1.11.1 Insect sampling of soil

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

Soil insects include:

- cockroaches
- crickets
- earwigs
- black scarab beetles
- cutworms
- false wireworm
- true wireworm
- Desiantha weevil larvae
- slugs
- snails

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

- 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.
SECTION 2

Pre-planting

2.1 Varietal performance and ratings yield

Identifying the option that will lead to the greatest returns for a grower is a complex problem. Yield will be one of the key determinants of returns, but grain quality is also a consideration. Two recently released varieties for Western Australia, Bannister and Williams, have shown significant yield and disease resistance improvements over other varieties and should be considered by growers.

Yield will be the main determinant of returns but grain quality is also an important consideration.

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.
- The rotational benefits or costs of each crop such as weed control from a hay crop.

Choose a range of two or more varieties to suit likely sowing opportunities in your area. Assess risk factors such as disease susceptibilities, herbicide sensitivities, dockages for downgraded samples, susceptibility to weather damage, coleoptile length, tolerance to acid soil and boron toxicity.

Traditionally, only tall oats were accepted for use in the milling industry in WA as those carrying the dwarfing genes generally did not produce suitable grain. The National Oat Breeding Program has now released a number of dwarf varieties suitable for milling (Table 1). In Western Australia these have been Williams, Kojonup, Bannister and Mitika. This means the benefits dwarf varieties offer growers in terms of higher grain yields, less lodging and less head loss are now widely available.

### Table 1: List of milling oat varieties for Western Australia, provided by GIWA Oat Council

<table>
<thead>
<tr>
<th>2015-16 Oat varieties</th>
<th>Classification</th>
<th>Oat1</th>
<th>Oat2</th>
<th>OWAN1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Premium Milling</td>
<td>Standard Milling</td>
<td>Oats Wandering</td>
</tr>
<tr>
<td>Bannister (new 2012)</td>
<td>Milling</td>
<td>*</td>
<td></td>
<td></td>
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<tr>
<td>Carrollup</td>
<td>Milling</td>
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<tr>
<td>Coomallo</td>
<td>Milling</td>
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<tr>
<td>Hotham</td>
<td>Milling</td>
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<td></td>
</tr>
<tr>
<td>Kojonup</td>
<td>Milling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitika</td>
<td>Milling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortlock</td>
<td>Milling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pallinup</td>
<td>Milling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wandering</td>
<td>Wandering</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams (new 2013)</td>
<td>Milling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yallara</td>
<td>Milling</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


The choice to grow oats compared to other crops is as important as the selection of an appropriate variety. Oats are often thought of as an “easy” crop to grow but attention to detail is required to produce high yields and quality. Weed control options remain limited compared to other cereal crops and timely grain harvest is important as most varieties shed their grain easily.2

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)

#### 2.1.1 Yielding ability

Bannister and Williams have excellent grain yields and are consistently the highest yielding lines in all AgZones of Western Australia. They are over 20% better yielding than Carrollup and have a more than 10% yield improvement over Wandering. Nationally, Williams is the highest yielding potential milling oat variety in National Variety Testing (NVT) trials (Table 2). 3

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Table 2: Average grain yield (t/ha) in Western Australia - 2005 to 2012. The number in brackets is the number of trials. (Data courtesy National Oat Breeding Program and NVT. Analysis by SAGI)

<table>
<thead>
<tr>
<th>Variety</th>
<th>AgZone 2 (45)</th>
<th>Agzone 3 (3.5)</th>
<th>AgZone 4 (3.6)</th>
<th>AgZone 6 (3.6)</th>
<th>WA Overall (3.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bannister</td>
<td>3.0</td>
<td>3.5 (49)</td>
<td>1.8 (3)</td>
<td>4.3 (9)</td>
<td>3.2 (106)</td>
</tr>
<tr>
<td>Williams</td>
<td>3.1 (40)</td>
<td>3.6 (45)</td>
<td>1.8 (3)</td>
<td>4.3 (8)</td>
<td>3.2 (96)</td>
</tr>
<tr>
<td>Carrolup</td>
<td>2.6 (71)</td>
<td>2.9 (77)</td>
<td>1.5 (3)</td>
<td>3.4 (14)</td>
<td>2.6 (166)</td>
</tr>
<tr>
<td>Dunnart</td>
<td>2.7 (32)</td>
<td>3.1 (28)</td>
<td>1.6 (3)</td>
<td>3.8 (4)</td>
<td>2.8 (67)</td>
</tr>
<tr>
<td>Kojonup</td>
<td>2.7 (70)</td>
<td>3.2 (78)</td>
<td>1.6 (3)</td>
<td>3.8 (4)</td>
<td>2.8 (67)</td>
</tr>
<tr>
<td>Mitika</td>
<td>2.7 (66)</td>
<td>3.2 (71)</td>
<td>1.6 (4)</td>
<td>3.9 (13)</td>
<td>2.8 (154)</td>
</tr>
<tr>
<td>Possum</td>
<td>2.7 (29)</td>
<td>3.1 (32)</td>
<td>-</td>
<td>3.7 (3)</td>
<td>3.2 (64)</td>
</tr>
<tr>
<td>Potoroo</td>
<td>2.7 (16)</td>
<td>3.2 (15)</td>
<td>-</td>
<td>-</td>
<td>3.0 (31)</td>
</tr>
<tr>
<td>Wandering</td>
<td>2.9 (71)</td>
<td>3.3 (78)</td>
<td>1.8 (4)</td>
<td>4.0 (14)</td>
<td>3.0 (167)</td>
</tr>
<tr>
<td>Wombat</td>
<td>2.5 (59)</td>
<td>3.1 (63)</td>
<td>1.4 (4)</td>
<td>3.4 (12)</td>
<td>2.6 (138)</td>
</tr>
</tbody>
</table>

2.1.2 Quality

Milling oats are received on the basis of grain physical quality including hectolitre weight, free groats, screenings and moisture. Growers should check prices of particular varieties with potential buyers to determine the most profitable cropping options.

Table 3: Average physical grain quality characters of oat varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Hectolitre Weight (kg/hl)</th>
<th>1000 Grain Weight (g)</th>
<th>Screenings (%2.2mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bannister</td>
<td>49.8</td>
<td>31.2</td>
<td>10.1</td>
</tr>
<tr>
<td>Williams</td>
<td>48.1</td>
<td>30.4</td>
<td>16.1</td>
</tr>
<tr>
<td>Carrolup</td>
<td>51.7</td>
<td>32.3</td>
<td>14.0</td>
</tr>
<tr>
<td>Echidna</td>
<td>48.3</td>
<td>30.2</td>
<td>16.6</td>
</tr>
<tr>
<td>Kojonup</td>
<td>49.2</td>
<td>31.5</td>
<td>11.1</td>
</tr>
<tr>
<td>Mitika</td>
<td>50.4</td>
<td>33.3</td>
<td>9.1</td>
</tr>
<tr>
<td>Possum</td>
<td>49.5</td>
<td>31.1</td>
<td>8.6</td>
</tr>
<tr>
<td>Potoroo</td>
<td>45.7</td>
<td>30.6</td>
<td>19.8</td>
</tr>
<tr>
<td>Wandering</td>
<td>49.5</td>
<td>32.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Wombat</td>
<td>50.2</td>
<td>3.4</td>
<td>13.5</td>
</tr>
<tr>
<td>Yallara</td>
<td>51.4</td>
<td>32.8</td>
<td>8.2</td>
</tr>
<tr>
<td>No. Trials</td>
<td>53</td>
<td>33</td>
<td>53</td>
</tr>
</tbody>
</table>

Many of the physical characteristics of milling and feed oats are similar, however large differences exist in some of the desired chemical characteristics (Table 4). These are important with regard to suitability of varieties for milling or feed, where requirements for each industry may be significantly different. For example - milling requirements call for higher levels of B-glucans and lower oil percent, while oats for animal feed need lower levels of B-glucans and higher oil percent.  

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### Section 2: OATS - Pre-planting

#### Table 4: Average chemical grain quality characters of oat varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>NIR Protein (%)</th>
<th>NIR Oil (%)</th>
<th>NIR Groat (%)</th>
<th>Grain Brightness</th>
<th>Estimated ME (MG/kg dm)</th>
<th>B-Glucan (dry basis)</th>
<th>Hull Lignin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bannister</td>
<td>11.1</td>
<td>7.1</td>
<td>75.1</td>
<td>59.1</td>
<td>12.0</td>
<td>4.3 (3)</td>
<td>High</td>
</tr>
<tr>
<td>Williams</td>
<td>11.1</td>
<td>6.8</td>
<td>7.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carrolup</td>
<td>13.1</td>
<td>5.5</td>
<td>75.6</td>
<td>60.0</td>
<td>11.7</td>
<td>4.7(3)</td>
<td>High</td>
</tr>
<tr>
<td>Echidna</td>
<td>11.2</td>
<td>6.0</td>
<td>74.3</td>
<td>0.7</td>
<td>11.7</td>
<td>5.0 (1)</td>
<td>High</td>
</tr>
<tr>
<td>Kojonup</td>
<td>13.4</td>
<td>5.6</td>
<td>78.4</td>
<td>60.2</td>
<td>12.0</td>
<td>5.4 (2)</td>
<td>High</td>
</tr>
<tr>
<td>Mitika</td>
<td>12.6</td>
<td>6.5</td>
<td>75.6</td>
<td>58.8</td>
<td>12.6</td>
<td>5.5 (3)</td>
<td>Low</td>
</tr>
<tr>
<td>Possum</td>
<td>12.5</td>
<td>5.7</td>
<td>76.3</td>
<td>58.6</td>
<td>11.7</td>
<td>4.9 (3)</td>
<td>High</td>
</tr>
<tr>
<td>Potoroo</td>
<td>11.6</td>
<td>6.6</td>
<td>74.4</td>
<td>61.0</td>
<td>11.8</td>
<td>5.0 (3)</td>
<td>High</td>
</tr>
<tr>
<td>Wandering</td>
<td>12.3</td>
<td>6.2</td>
<td>74.2</td>
<td>61.7</td>
<td>1.6</td>
<td>4.9 (3)</td>
<td>High</td>
</tr>
<tr>
<td>Wombat</td>
<td>12.4</td>
<td>6.1</td>
<td>77.5</td>
<td>59.9</td>
<td>12.0</td>
<td>5.0 (3)</td>
<td>High</td>
</tr>
<tr>
<td>Yallara</td>
<td>11.6</td>
<td>4.6</td>
<td>79.3</td>
<td>61.3</td>
<td>11.7</td>
<td>5.1 (3)</td>
<td>High</td>
</tr>
<tr>
<td>No. Trials</td>
<td>48</td>
<td>42</td>
<td>40</td>
<td>34</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 2.1.3 Disease Resistance

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. BYDV, which occurs most commonly in southern high rainfall areas west of the Albany Highway, can cause significant losses. 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. Although still showing susceptibility to septoria the S and MS ratings these varieties carry should show visible improvements in the field over VS lines (Table 5).

#### Table 5: Disease reactions of oat varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Stem Rust</th>
<th>Leaf Rust</th>
<th>BYDV</th>
<th>Septoria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bannister</td>
<td>R-MR</td>
<td>R</td>
<td>MS</td>
<td>S</td>
</tr>
<tr>
<td>Williams</td>
<td>MR</td>
<td>R</td>
<td>MR-MS</td>
<td>MS</td>
</tr>
<tr>
<td>Carrolup</td>
<td>MS</td>
<td>S</td>
<td>MS</td>
<td>S-VS</td>
</tr>
<tr>
<td>Echidna</td>
<td>S</td>
<td>S</td>
<td>MS</td>
<td>S-VS</td>
</tr>
<tr>
<td>Kojonup</td>
<td>R-MS</td>
<td>S</td>
<td>MS</td>
<td>S-VS</td>
</tr>
<tr>
<td>Mitika</td>
<td>MR-S</td>
<td>R</td>
<td>S</td>
<td>S-VS</td>
</tr>
<tr>
<td>Possum</td>
<td>MR-S</td>
<td>MR</td>
<td>S</td>
<td>S-VS</td>
</tr>
<tr>
<td>Potoroo</td>
<td>MS</td>
<td>S</td>
<td>MS</td>
<td>S</td>
</tr>
<tr>
<td>Wandering</td>
<td>MS</td>
<td>VS</td>
<td>MR-MS</td>
<td>S-VS</td>
</tr>
<tr>
<td>Wombat</td>
<td>MR-S</td>
<td>S</td>
<td>MR</td>
<td>S</td>
</tr>
<tr>
<td>Yallara</td>
<td>MR-MS</td>
<td>R</td>
<td>MS</td>
<td>S</td>
</tr>
</tbody>
</table>

BYDV = Barley Yellow Dwarf Virus. R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible. Rust reactions may vary in different regions depending on the prevailing pathotypes.

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2.2 The National Oat Breeding Program

The National Oat Breeding Program is a partnership between:

Department of Agriculture and Food Western Australia (DAFWA)
South Australian Research and Development Institute (SARDI)
Grains Research and Development Corporation (GRDC)
Rural Industries Research and Development Corporations (RIRDC)

Its mission is to release improved oat varieties for grain or hay production, adapted to Western Australia, South Australia, Victoria and southern New South Wales.

The trial work conducted by GRDC National Variety Trials or NVT are a reflection of the most recent year’s crop yield’s and a long term average for a number of districts. This trial work covers numerous crops including oats.

The NVT program was established in 2005 by the GRDC and is managed by the Australian Crop Accreditation System Limited (ACAS). It is a national program of comparative crop variety testing with standardised trial management, data generation, collection and dissemination. This is managed through an internet accessed database that ensures a common approach and uniformity across the system.6

To go to the website click on the link: http://www.nvtonline.com.au/

2.3 Varieties

Variety selection depends on the crop use, sowing date, likely diseases, and tolerance to acid soil, grain quality and possible market outlet. Most varieties are suitable for grazing.

Growers are warned that there are now no commercial varieties with resistance to all the current field pathotypes of stem rust.

Milling varieties

Milling oats are dehulled, steamed and flaked or milled before processing. The healthy oats are made into oatmeal and breakfast foods, health bars, bakery goods and baby foods. Interest by consumers in oat noodles, oat milk, oat rice and oat health care products is also growing.7

Bannister. A Released in Western Australia in 2012 as a milling oat variety for the western region. It has high grain yield potential and has performed well in trials in WA it is taller than Mitika and heads about 3 to 4 days later than Mitika. It is susceptible to and intolerant to cereal cyst nematodes. Bannister is resistant to leaf rust and moderately resistant to bacterial blight. Bannister has slightly lower hectolitre weight and slightly higher screenings compared to Mitika. In seasons with pre-harvest rainfall growers have experienced some problems with septoria on the seed. Seed can be purchased through Seednet.

Mitika. A 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 resistant to stem rust until 2010 when a new pathotype of stem rust was identified, rendering it susceptible. Moderately susceptible to leaf rust. Mitika has improved resistance to bacterial blight and is superior to Echidna for septoria resistance. Mitika is susceptible to BYDV, septoria and red leather leaf disease. It is very susceptible and intolerant of cereal cyst nematode 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 percent compared to Echidna. Mitika

---


also has improved feed quality with low husk lignin and high grain digestibility. Heritage Seeds.

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 discoulours easily. Low yielding compared to Mitika and Possum. Released by Agriculture Western Australia in 1983.


Williams. A Released in Western Australia in 2013, Williams has a high grain yield potential and has performed well in trials throughout WA. Williams is an early to mid season variety similar to Yallara, but three to seven days later than Mitika. Taller than Mitika by 15 cm, 5 cm taller than Bannister, and 15 cm shorter than Yallara. Williams is resistant to leaf rust and depending on the stem rust pathotype present can range from moderately resistant to susceptible. It is susceptible and intolerant to cereal cyst nematodes. Williams is resistant to bacterial blight and moderately resistant to moderately susceptible to BYDV. Williams has lower hectolitre weight and higher screenings compared to Mitika. Williams is not recommended for low rainfall areas due to higher screenings. Heritage Seeds.

Yallara A A medium–tall, early to midseason variety similar to Euro for flowering and maturity. Yallara was released in 2009. Yallara is a Euro look-alike milling line with slightly better grain quality, but not as susceptible to stem rust. It is resistant but intolerant to cereal cyst nematode. 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 percent. 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. Seednet.

**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.  

Brusher. A A tall, early-mid season hay variety with improved hay digestibility. Resistant and moderately intolerant to cereal cyst nematode. Intolerant of stem nematode. Low husk lignin. Released by SARDI in 2003. AEXCO.

Carrolup A Widely sown variety as a premium milling variety and the most commonly grown export hay variety (a good dual purpose variety). Carrolup is a tall variety with lower yields than new milling varieties Bannister and Williams. Released in 1993 by the Department of Agriculture and Food, Western Australia (DAFWA).

Forester A Very late hay variety adapted to high rainfall and irrigated cropping regions. 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. It is moderately susceptible to cereal cyst nematode. 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. Released by SARDI in 2012. Seed of Forester is available from AGF Seeds, Smeaton, Victoria.


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Graza 80. A erect, quick growing, late maturing grazing variety developed by Agriculture Canada. Susceptible to leaf and stem rust in the northern region. Released by Pioneer Hi-Bred in 2005. Seed available through Elders.

Mammoth. A is a true forage oat, with excellent establishment vigour. It was identified in 2007 from the Heritage Seeds’ program that specifically targets high forage yield and quality for southern Australia. In particular, the program looked at early establishment vigour and winter yield to select Mammoth. Mammoth has shown excellent autumn and winter performance, and good overall yield in multiple locations over a number of years. Heritage Seeds.

Mulgara. A tall mid season hay oat similar in heading time and height to Wintaroo with cereal cyst nematode 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 percent. Mulgara has high husk lignin. Released by SARDI in 2009. AEXCO.


Swan is a tall, medium maturing, older Western Australian hay variety released in 1967 by DAFWA. Swan is not widely accepted by hay exporters as the stem tends to be too thick. It is grown successfully for export, however, in eastern areas. Grain yield is not as high as others although it does have low husk lignin. Seedmark.

Wandering A A dwarf feed variety that has received recognition by the export horse feed industry. A special segregation at selected sites for Wandering has been in place since 2005. Also accepted as an export hay variety. Wandering is suited to mid to late sowings and has good hectolitre weight. Susceptible to leaf and stem rust. Wandering was released in 1999 by DAFWA.

2.4 Other quality traits

2.4.1 Grazing value

Financial returns from grazing oats can be based on:
- Changes in body weight throughout the grazing period. Weight gains of 1.2 kilograms per head per day for steers, and 200 grams per head per day for lambs are common
- Stock value before and after grazing
- Current agistment rates for stock, and
- Hand feeding costs for the same period.

Feed quality tests can accurately measure whole grain digestibility, protein levels and metabolisable energy. For livestock feeding grain protein is an important attribute. Oats can vary widely in protein levels due to varietal factors, paddock variability, fertiliser inputs and yield levels. Oats with low protein levels (<12%) may limit growth rates of young animals.9

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Table 6: Grain quality comparisons

<table>
<thead>
<tr>
<th>Variety</th>
<th>Hectolitre Weight (kg/hl)</th>
<th>Screenings &lt;2mm</th>
<th>1000 Grain weight (g)</th>
<th>Kernel (%)</th>
<th>Probability of reaching milling grade</th>
<th>Protein (%)</th>
<th>Oil (fat) (%)</th>
<th>Hull lignin content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-dwarf husked</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bannister</td>
<td>MH</td>
<td>ML</td>
<td>MH</td>
<td>MH</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Echidna</td>
<td>M</td>
<td>M</td>
<td>ML</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>MH</td>
</tr>
<tr>
<td>Mitika</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>MH</td>
<td>H</td>
<td>MH</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Possum</td>
<td>MH</td>
<td>L</td>
<td>MH</td>
<td>MH</td>
<td>H</td>
<td>MH</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Potoroo</td>
<td>L</td>
<td>MH</td>
<td>M</td>
<td>ML</td>
<td>-</td>
<td>M</td>
<td>MH</td>
<td>H</td>
</tr>
<tr>
<td>Wombat</td>
<td>H</td>
<td>M</td>
<td>MH</td>
<td>H</td>
<td>H</td>
<td>MH</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Semi-dwarf naked</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numbat</td>
<td>VH</td>
<td>H</td>
<td>L</td>
<td>-</td>
<td>-</td>
<td>H</td>
<td>VH</td>
<td>-</td>
</tr>
<tr>
<td>Tall (husked)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brusher</td>
<td>M</td>
<td>M</td>
<td>MH</td>
<td>M</td>
<td>-</td>
<td>MH</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Forester</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>-</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Glider</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>ML</td>
<td>-</td>
<td>MH</td>
<td>ML</td>
<td>L</td>
</tr>
<tr>
<td>Kangaroo</td>
<td>M</td>
<td>ML</td>
<td>MH</td>
<td>ML</td>
<td>-</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Mulgara</td>
<td>M</td>
<td>M</td>
<td>MH</td>
<td>MH</td>
<td>-</td>
<td>MH</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Tammar</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>ML</td>
<td>-</td>
<td>MH</td>
<td>M</td>
<td>SEG</td>
</tr>
<tr>
<td>Tungoo</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>ML</td>
<td>-</td>
<td>MH</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Wallaroo</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>MH</td>
<td>-</td>
<td>M</td>
<td>MH</td>
<td>L</td>
</tr>
<tr>
<td>Williams</td>
<td>MH</td>
<td>M</td>
<td>M</td>
<td>MH</td>
<td>-</td>
<td>M</td>
<td>M</td>
<td>MH</td>
</tr>
<tr>
<td>Wintaroo</td>
<td>M</td>
<td>M</td>
<td>MH</td>
<td>MH</td>
<td>-</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Yallara</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>VH</td>
<td>LH</td>
<td>L</td>
<td>H</td>
</tr>
</tbody>
</table>

Value for trait: L = low, ML = moderately low, M = medium, MH = moderately high, H = high, VH = very high, - not applicable

Research conducted at Wagga Wagga Agricultural Institute in 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 is correlated with lignin (an indigestible carbohydrate) levels in the hulls of the grain — high lignin content results in low digestibility.

Dual-purpose oat varieties like Cooba have high digestibility and varieties grown strictly for milling score poorly.10

The South Australian Research and Development Institute (SARDI) leads the National Oat Breeding program, developing improved milling oats – including improved nutritional value.

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

2.4.2 Maturity

The maturity, or length of time taken for a variety to reach flowering, depends on vernalisation, photoperiod and thermal time requirements. Recommended sowing times

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are arrived at by assessing the maturity of varieties in different environments and with different sowing times.

2.4.3 Grain

While not often used as a grain in feedlot rations, the performance of cattle that are fed oats is equivalent to 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.

The trial showed that when daily feed intake is similar between animals fed either barley or oats, there is a strong similarity between their average daily gains (ADG) and their feed conversion ratios (FCR).

Table 7: Properties of various grains

<table>
<thead>
<tr>
<th>Foodstuff</th>
<th>Dry matter (DM) (%)</th>
<th>Starch (%)</th>
<th>Metabolisable energy (ME) (MJ/kg DM)</th>
<th>Crude protein (CP) (%) DM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Tested range</td>
<td>Average</td>
<td>Tested range</td>
</tr>
<tr>
<td>Oats</td>
<td>90</td>
<td>50</td>
<td>10.5</td>
<td>8.5–12.5</td>
</tr>
<tr>
<td>Barley</td>
<td>90</td>
<td>59–61</td>
<td>13</td>
<td>12.5–13</td>
</tr>
<tr>
<td>Wheat</td>
<td>90</td>
<td>60–76</td>
<td>13</td>
<td>12.5–13.5</td>
</tr>
<tr>
<td>Sorghum</td>
<td>90</td>
<td>75</td>
<td>13</td>
<td>12.5–13</td>
</tr>
<tr>
<td>Maize</td>
<td>90</td>
<td>76</td>
<td>13.5</td>
<td>13–14</td>
</tr>
</tbody>
</table>

Feeding value of oats grain

The GRDC-supported Premium Grains for Livestock Production 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 content is assessed using a simple staining test (phloroglucinol stain test). A list of lignin ratings of a range of oat varieties is presented in the following table. 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.

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

<table>
<thead>
<tr>
<th>Low</th>
<th>Medium</th>
<th>Medium-high</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bass, Bimbi, Brusher, Carbeen, Cooba, Eurabbie, Graza 88, Mannus, Mitika, Mulgara, Nile, Tungoo, Wintaroo, Yarran, Yiddah</td>
<td>Blackbutt (variable), Graza 80, Quoll</td>
<td>Euro, Potoroo, Wandering</td>
<td>Bannister, Carrolup, Coolabah, Dawson, Drover, Dunnart, Echidna, Forester, Genie, Graza 50, Kangaroo, Mortlock, Nugene, Possum, Taipan, Williams, Wombat, Yallara</td>
</tr>
</tbody>
</table>

Table 9: Feedlot performance (117 days)

<table>
<thead>
<tr>
<th></th>
<th>Barley*</th>
<th>Oats*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily feed intake (kg)</td>
<td>13.50</td>
<td>13.42</td>
</tr>
<tr>
<td>Average daily gain (kg/day)</td>
<td>1.39</td>
<td>1.35</td>
</tr>
<tr>
<td>Feed conversion ratio (kg DM / kg LW)</td>
<td>9.72</td>
<td>10.02</td>
</tr>
</tbody>
</table>

Table 10: A guide to the metabolisable energy content of Australian grains based on their crude protein (CP) content (dry matter basis)
Source: Derived from the NSW Agriculture Feed Evaluation Database.\(^\text{13}\)

<table>
<thead>
<tr>
<th>CP (%)</th>
<th>Metabolisable energy (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sorghum</td>
</tr>
<tr>
<td>6</td>
<td>10.2</td>
</tr>
<tr>
<td>7</td>
<td>10.6</td>
</tr>
<tr>
<td>8</td>
<td>10.8</td>
</tr>
<tr>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>11.1</td>
</tr>
<tr>
<td>11</td>
<td>11.4</td>
</tr>
<tr>
<td>12</td>
<td>11.5</td>
</tr>
<tr>
<td>13</td>
<td>11.6</td>
</tr>
<tr>
<td>14</td>
<td>11.7</td>
</tr>
<tr>
<td>15</td>
<td>11.9</td>
</tr>
<tr>
<td>16</td>
<td>12</td>
</tr>
</tbody>
</table>

2.4.4 Hay

Australia exports up to 700,000 tonnes of oaten hay a year.\(^\text{14}\)

Choose a suitable variety for the anticipated market. Increase seed and nitrogen fertiliser rates by at least 20% above those for a grain crop. Pay particular attention to soil test results for potassium if repeated hay crops are taken from the same paddock. There are specific requirements for the export markets that are different to usual on-farm needs. These include earlier cutting times, green hay colour, low moisture content, freedom from weeds, and thin-strawed varieties. At all stages of the hay crop growers should check exporters specific requirements if they are interested in this market.\(^\text{15}\)

Hay quality is essential to meet export hay standards and is greatly influenced by seasonal and nutritional conditions. However, some varieties are more likely to produce hay of higher quality than others.

It is imperative that you check with your hay processor about the quality standards required to make export grade quality hay before you sow a hay crop.\(^\text{16}\)

Before growing oats for export hay, talk to your hay processor. Hay processors have different requirements which will affect how you manage your crop. Your processor can advise you about the production of export hay.

Many export hay companies have preferred varieties they will receive whilst others have no preference. Check with you hay processor prior to planting for their list of preferred varieties. Often they will recommend growing an oat variety suited to your region and ensure the cutting time is correct.

Many common grain varieties (such as Carrolup, Wandering and Winjardi) are grown successfully as export hay. The National Oat Breeding Program has released hay

varieties (Wintaroo and Brusher) with potential for some regions of Western Australia. Older varieties such as Massif, Swan and Vasse are not widely accepted by hay processors as the stems tend to be too thick. The newly released milling oat variety Williams may have a role as a dual purpose variety with some export hay companies.

### 2.4.5 Silage

Table 11: Yield and ME content of triticale, oats and wheat silage cut at the boot, anthesis, milk and soft dough stage at Terang, Victoria.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Stage</th>
<th>Yield (t DM/ha)</th>
<th>ME (MJ ME/kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triticale</td>
<td>Boot</td>
<td>5.1</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>Anthesis</td>
<td>11.9</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>Milk</td>
<td>13.8</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>Soft dough</td>
<td>17.9</td>
<td>8.8</td>
</tr>
<tr>
<td>Oats</td>
<td>Boot</td>
<td>7.5</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>Anthesis</td>
<td>7.7</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>Milk</td>
<td>10.3</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>Soft dough</td>
<td>10.4</td>
<td>8.9</td>
</tr>
<tr>
<td>Wheat</td>
<td>Boot</td>
<td>7.9</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td>Anthesis</td>
<td>8.4</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>Milk</td>
<td>10.1</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Soft dough</td>
<td>10.9</td>
<td>9.3</td>
</tr>
</tbody>
</table>

### 2.5 Planting seed quality

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 (not more than one year old) and free from pests and disease.

Seed should have a high percentage germination, free from weed seeds and inert rubbish.

#### 2.5.1 Seed size

Early seedling growth relies on stored energy reserves in the seed. Good seedling establishment is more likely if seed is undamaged, stored correctly and from a plant that had adequate nutrition. Seed should not be kept from paddocks that were rain-affected at harvest. Seed grading is an effective way to separate good quality seed of uniform size from small or damaged seeds and other impurities, such as weed seeds. Seed size is also important—the larger the seed, the greater the endosperm and starch reserves. 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.

Seed size is usually measured by weighing 1000 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. 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. Coleoptile length is an important characteristic to consider when planting a oat crop, especially in drier seasons when sowing deep to reach soil moisture.

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2.5.2 Seed germination and vigour

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 (not more than one year old) and free from pests and disease.

Seed should have a high percentage germination, free from weed seeds and inert rubbish. 19

Seed germination and vigour greatly influence establishment and yield potential.

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

- water absorption (imbibition)
- activation
- visible germination 20

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. 21

For more information on factors affecting germination, see Section 4: Plant growth 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 (http://aseeds.net.au/seed-testing).

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

2.5.3 Disease

Grain retained for seed from a wet harvest is more likely to be infected with seed-borne 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.  

2.5.4 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.

- Temperature <15°C. High temperatures can quickly reduce seed germination and quality. This is why germination and vigour testing prior to planting is so important in the northern region.
- 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.

2.5.5 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 tine), and soil characteristics such as moisture content and texture.  

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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. See Tables 1 and 2 for more detail.

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

Table 12: Suggested safe rates (kg/ha) of some nitrogen fertilizer products sown with oat seed at planting

<table>
<thead>
<tr>
<th>Row spacing</th>
<th>Maximum nitrogen rate</th>
<th>Urea</th>
<th>DAP</th>
<th>MAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>7</td>
<td>30</td>
<td>65</td>
<td>158</td>
</tr>
<tr>
<td>36</td>
<td>14</td>
<td>15</td>
<td>33</td>
<td>79</td>
</tr>
</tbody>
</table>


SECTION 3
Planting

3.1 Seed treatments

Seed dressing and in-furrow fungicides contain active ingredients for the control or suppression of seed-borne diseases and some fungal root rots in cereal crops. Information on fungicide active ingredients that are registered for wheat, barley, oat and triticale crops in Western Australia is provided along with information on control of specific cereal diseases. For details on application rates and other instructions please refer to product labels.

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. Seed dressing fungicides provide protection from seed-borne diseases, such as smuts and bunts. Some products also suppress or control fungal root rots, such as pythium, rhizoctonia and take-all. Some seed dressing and/or in-furrow products suppress early foliar diseases.

Seed dressing and in-furrow fungicides contain one or more active ingredients and are marketed under many different trade names. When choosing seed dressing or in-furrow fungicides, consider the range of diseases that threaten your crop. Consult product labels for registrations, the Australian regulatory database or InfoPest, or see a list of currently registered active ingredients by crop at http://apvma.gov.au/ Reassess your disease risk before seeding by looking at seasonal forecasts, green bridge updates and crop disease forecasts for your local area, all available through the Department of Agriculture and Food, Western Australia (DAFWA).

3.1.1 Cautions about using fungicide seed dressings

Read and follow directions on fungicide labels carefully.

In some situations, certain fungicide seed dressings may reduce coleoptile length, which could lead to ‘silly seedling syndrome’ (leaves grow under soil surface but don’t emerge), particularly if short coleoptile varieties 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 where it is difficult to obtain good depth control of herbicide incorporation and seed placement, such as in sandy soils.

Pickled seed should not be used as animal feed and should not be delivered to CBH.

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### Table 1: Seed dressing fungicides registered for use on oats in WA – 2016 (Source: DAFWA)*

<table>
<thead>
<tr>
<th>Seed dressing active ingredient (fungicide/insecticide). Rate of product/100 kg/seed</th>
<th>Smut (covered and loose)</th>
<th>Product examples by trade names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboxin + cypermethrina 75/125-250g or mL</td>
<td>Vitaflo®C, Advance®, Vitavax® 750C</td>
<td></td>
</tr>
<tr>
<td>Carboxin + thiram 250-500mL</td>
<td>Vitavax® 200FF</td>
<td></td>
</tr>
<tr>
<td>Difenoconazole + Metalaxyl-M -</td>
<td>Dividend® M (discontinued)</td>
<td></td>
</tr>
<tr>
<td>Difenoconazole + Metalaxyl-M + sedaxane 180mL</td>
<td>Vibrance™ T</td>
<td></td>
</tr>
<tr>
<td>Fluquinconazole -</td>
<td>Jockey® Stayer, Maxiflo®, Quantum®, Quantum® Pro</td>
<td></td>
</tr>
<tr>
<td>Flutriafol + imidacloprid 400mL</td>
<td>Veteran®Plus</td>
<td></td>
</tr>
<tr>
<td>Flutriafol (with zinc) 400mL</td>
<td>Veteran® Zinc</td>
<td></td>
</tr>
<tr>
<td>Ipconazole + cypermethrina 100mL</td>
<td>Rancona® C</td>
<td></td>
</tr>
<tr>
<td>Ipconazole + metalaxyl 80mL</td>
<td>Rancona® Dimension</td>
<td></td>
</tr>
<tr>
<td>Perfluifen -</td>
<td>EverGo® Prime</td>
<td></td>
</tr>
<tr>
<td>Prothioconazole + tebuconazole 15mL</td>
<td>Raxil® Pro</td>
<td></td>
</tr>
<tr>
<td>Tebuconazole + imidacloprid 400mL (200mL)</td>
<td>Hombre® (discontinued), Proguard® Plusb, Hombre® Ultrab</td>
<td></td>
</tr>
<tr>
<td>Tebuconazole+ cypermethrina or triflumuron 100g or mL</td>
<td>Raxil® T, Proguard® T, Tebuconazole 25C or T, Blaster® 25C, Teby-C®, Veto® 25C or T, SeedUp®, Tebu- C® 25</td>
<td></td>
</tr>
<tr>
<td>Triadimenol- imidacloprid 400mL</td>
<td>Proleaf® Plusb, Zoro®t (discontinued), Foliarflo® plusb, Imid-Triadimenol 4Farmers</td>
<td></td>
</tr>
<tr>
<td>Triadimenol + cypermethrina or triflumuron 100-150g or mL</td>
<td>Proleaf® C or T, Foliarflo® C or T, Phoenix® C, Tridin® C, Vanguard® 150C, Seedpik® 150 C, Triadimol 150C (Sygental®) + (4 Farmers), Baytan® T, GoSeed®</td>
<td></td>
</tr>
<tr>
<td>Triticonazole4 + cypermethrina 100mL</td>
<td>Premis® Protect, TitanTM, Premis Pro C®, Triticonazole 200 4Farmers</td>
<td></td>
</tr>
</tbody>
</table>

*Updated 21 January 2016. This information is a guide only. Chemical labels should be read and rates should be checked before using fungicides. Mention of trade names does not imply endorsement of any company’s products. Symbols used refer to footnotes. No in-furrow fungicides are currently registered for use on oats in WA.

Note: 1) Blank indicates that product is not registered for use in the disease specified; 2) ® Registered trademark; 3) Triticonazole® products Real® 200C and Caesar® are not registered for use in oats. 4) Fluquinconazole based products at higher rate suppress take all disease. 5) No in-furrow fungicides are currently registered for oats. 7) No fungicide seed dressings are registered for foliar diseases in oats.

Insecticides:
1) Cypermethrin and triflumuron compounds (insecticides) are effective against insect pests of stored grain. 2) Hombre® Ultra (© 200 mL/100kg seed), Proguard® Plus, Zoro®, Proleaf® Plus and Foliarflo® Plus are also registered for aphid control and the prevention of the spread of “barley yellow dwarf virus” (BYDV) in cereal crops.

For more information please contact Kith Jayasena, Email: kithsiri.jayasena@agric.wa.gov.au, Telephone: (08) 9892 8477.


### 3.2 Time of sowing

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.

In most regions of Western Australia, the ideal time to flower (flowering window) is in September. For areas around and north of the Great Eastern Highway (Beverley, Wongan Hills and Chapman Valley), the flowering window is the whole of September. For the Great Southern (Katanning, Mt Barker and Newdegate), the flowering window ranges from mid September to early October.

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.³

### 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 grain fill will be later in spring when moisture is likely to be limiting and temperatures high
- Foliar diseases, lodging and shedding will be less severe
- Hay quality will be reduced ⁴

With the wide range of oat varieties available, it is possible to choose a variety suitable for sowing in the beginning of autumn. However, not all varieties can be sown this early and are suitable for sowing as late as early winter, although this may vary in southern Australia. Avoid early sowings of leaf rust susceptible varieties and varieties sensitive to very warm soils.⁵

### 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 but also can improve crop competitiveness against herbicide resistant ryegrass.

The recommended plant density is 240 plants per square metre (m²) for both grain and hay oats.⁶

Stem thickness is an important trait for export hay markets and previous DAFWA research has shown that using high seeding rates can reduce stem diameter, with minimal effect on other quality parameters.⁷

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 320 plants/m². Finer stems also dry quicker
- Dwarf varieties - plump-grained varieties can be sown at higher density

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• Seedling emergence and establishment are likely to be reduced
• Plant tillering is expected to be low because of variety or soil fertility effects
• Delays to sowing
• Good rains expected during the season
• Soil fertility and moisture levels are high
• A dry finish is expected
• Likely infestation of insects which may cause seedling mortality
• A high risk of waterlogging (mid-season) - to compensate for a lack of tillering
• Moderate to high grass weed densities are likely - increases 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 stored soil moisture and may deplete most of the moisture before the crop matures

### 3.3.1 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 by suppressing weed growth.

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 give good ground coverage by plants so that the windrow can be held off the ground to improve air circulation and reduce staining.

High seeding rates give rapid growth rates and high forage yields. Use high rates where dense weed populations are expected, when conditions are likely to be wet during winter, in low pH soils, and/or in paddocks with low soil fertility, or if seed quality is substandard.

Seed size varies significantly between oat varieties and season, so it is important to know the 1000 grain weight of the selected variety to calculate the required seeding rate. The seeding rates shown 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.

### 3.4 Calculating seed requirements

Calculate seeding based on seed size, target plant population and calculated germination per cent. Work in terms of plants per square metre rather than kilograms per hectare (kg/ha) because grain size and weight varies between crops, varieties and seasons.

To determine the average grain weight, count and weigh 1000 seeds of the graded sample. The seed rate calculation is:

\[
\text{Seed rate (kg/ha)} = \frac{[\text{Target plant density (plants/m}^2\text{)} \times \text{Average grain weight (mg)]}}{\text{Expected establishment per cent (％)}}
\]

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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 * 40 / 80 = 120 kg/ha

Table 2: Examples of seed rates calculated on the basis of target plant population, seed weight and establishment percentage. 11

<table>
<thead>
<tr>
<th>Average seed weight (mg)</th>
<th>160 plants/m²</th>
<th>240 plants/m²</th>
<th>320 plants/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>66</td>
<td>99</td>
<td>132</td>
</tr>
<tr>
<td>35</td>
<td>70</td>
<td>105</td>
<td>140</td>
</tr>
<tr>
<td>37</td>
<td>74</td>
<td>111</td>
<td>148</td>
</tr>
<tr>
<td>39</td>
<td>78</td>
<td>117</td>
<td>156</td>
</tr>
</tbody>
</table>

3.5 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 and it may fail to emerge
- Cause shallow crown depth that may cause the plants to lodge when soil is very wet and in high winds
- Plants may be more vulnerable to pre-emergent herbicides such as Diuron or metolachlor

Consequences of deep sowing can include:
- Delayed seedling emergence
- Emerging seedlings that 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

Use press-wheels to compress the soil directly above the seed for even distribution during seeding. When using standard tyne 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. The use of press-wheels is also beneficial in creating a furrow to harvest subsequent rainfall into the seed zone.

Coleoptile and mesocotyl length are temperature dependant so early sowing into warmer soils will result in them being longer compared to later sowings in winter. 12

Direct-drilling of early sown varieties is easier in paddocks cropped the previous year. New paddocks can be direct-drilled early with machinery that gives adequate penetration and minimum soil disturbance following chemical fallow.

More information

NSW Department of Primary Industries

 Queensland Department of Agriculture and Fisheries

Pacific Seeds
Oats Agronomy Guide

Department of Agriculture and Food WA

February 2016

A sowing depth of 3-5 cm is ideal, but oats can be sown as deep as 7 cm if moisture seeking.  

Oat seed is best sown at 30-75 mm depth in 18-25 cm row spacing into moist soil in a well prepared seedbed.  

Seed should be placed deep enough to give it adequate moisture, but in general should be shallower than 7.5 cm (3 inches) particularly with small seeded varieties. If planting seed at the deeper end of the range (75 mm) you need to consider the risk that furrow fill may result in a deeper than ideal planting depth.


SECTION 4

Plant growth and physiology

4.1 Dormancy affecting germination and emergence

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

4.2 Plant growth stages

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

4.2.1 Zadoks Cereal Growth Stage Key

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 3) used in relation to disease control and N management are those from the start of stem elongation through to early flowering: GS30–GS61.
Zadoks Growth Stage
Development phase

GS 00-09 GS10-19 GS20-29 GS30-39 GS40-49
Germination Seedling growth Tillering Stem elongation Booting

GS 50-59 GS60-69 GS70-79 GS80-89 GS90-99
Ear emergence Flowering Milk development (grain fill period) Dough development (grain fill period) Ripening

Figure 1: Zadoks growth stages

Early stem elongation GS30–GS33 (pseudostem erect–third node on the main stem)

This period is important for both timing of N application and protection of key leaves. In order to ensure the correct identification of these growth stages, plant stems are cut longitudinally, so that internal movement of the nodes (joints in the stem) and lengths of internodes (hollow cavities in the stem) can be measured.

Leaf dissection at GS32 and GS33

This is a method for determining which leaves are emerging from the main stem prior to the emergence of the flag leaf. Knowing which leaves are present is critical if fungicide use is to be optimised to protect leaves.

The Zadoks Cereal 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 four, five and six 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 determined by main stem and number of tillers per plant; for example, GS22 is main stem plus two tillers and GS29 is main stem plus nine or more tillers.

In Australian cereal crops, plants rarely reach GS29 before the main stem starts to stem elongate (GS30). Because 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, 23, 17, 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 timing fungicide; for example, GS39 is full flag leaf on the main stem, meaning that not all flag leaves in the crop will be fully emerged. ¹

SECTION 5

Nutrition and fertiliser

Oats have traditionally been considered a low input crop and have 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 has to be more carefully considered when growing oats.

Most oat varieties grown on poor soil (e.g. low in nitrogen) could develop red-tipping on the leaves and this may result in below-optimum yields.

Nutrition requirements for nitrogen (N), phosphorus (P) and potassium (K) in oat grain crops are similar to those recommended for wheat or barley.

It is important for growers to use both soil testing and tissue testing to ensure the crop nutrient status is adequate for plant growth. As per other cereals, nutritional inputs should be based on soil test data and yield potential of the crop.¹

Apply fertiliser at above the normally recommended rates to crops used for grazing and grain, as they have a longer productive period than grain-only crops.

5.1 Crop removal rates

Table 1: Nutrients removed (kg) per tonne of grain production ²

<table>
<thead>
<tr>
<th>Crop type</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Potassium</th>
<th>Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>21</td>
<td>3.0</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>Triticale</td>
<td>21</td>
<td>3.0</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>Barley</td>
<td>20</td>
<td>2.7</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>Oats</td>
<td>17</td>
<td>2.5</td>
<td>4</td>
<td>1.5</td>
</tr>
</tbody>
</table>

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 before sowing so that results and recommendations are available in time to order the right fertiliser product(s). Crop nutrition can be monitored by tissue testing to check the availability of soil and applied nutrients.

Choose a laboratory that has the Australasian Soil and Plant Analysis Council certification for the tests they offer. National Association of Testing Authorities accreditation is also desirable.

Regular soil testing using the same GPS locations in paddocks (e.g. every three years) allows monitoring of fertility trends over time.  

The most common soil sampling depth for nutrient analysis is 0 to 10 cm for broadacre crops. This layer was chosen because nutrients, especially P and plant roots are concentrated within this layer. To obtain more comprehensive soil data, including nutrient data, sampling below 10 cm should be considered for some nutrients.  

5.3 Plants and/or tissue testing for nutrition levels

Figure 1: Oats crops remove significant quantities of all major nutrients. (Photo: DAFWA)

The agricultural areas of Western Australia are dominated by sandy soils. They contain low amounts of organic matter and are poor at retaining water and nutrients. As with wheat and barley crops, oat crops grow poorly if nutrients aren’t added. The major nutrients required for healthy growth are N, P, K and S; and the micronutrients Cu, Mn, Mo and Zn.

Oat crops, particularly eaten hay, remove significant quantities 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. 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.

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

While oats have a higher tolerance to acidic soil and high aluminum levels than barley and wheat, economic responses to liming are still achieved. Therefore it is important to monitor top- and sub-soil pH levels to determine if liming is required.

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5.4 Nitrogen

5.4.1 The importance of N management

Nitrogen 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 plant's 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. 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.

The amount of N fertiliser required to grow a grain or oat hay can be estimated from your fertiliser decision support programs. As a rule of thumb, N fertiliser at 40 to 80 kg per hectare (N/ha) has been found ideal for most growing conditions in Western Australia. The amount of N required will be modified by seasonal conditions and the oat variety. 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 response to applied N depends on the soil moisture available during the season. In a dry season there is usually a poor crop response to applied N due to water being more limiting to yield than N supply. Poor finishes to the season also reduce crop yield and grain quality irrespective of how much N is applied.

Nitrogen can leach in wet seasons, 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. In waterlogged soils, applying UAN can achieve better responses than urea. 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.

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

The method of N application needs to be considered. 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 the amount and method of applied N.

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Interaction with seeding rates

- Increasing the seeding rate will increase oat grain and hay yields irrespective of N fertiliser levels. Higher seeding rates can 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 which improves hay quality.

Interaction with potassium

- Maintaining adequate amounts of N and K nutrition are necessary for optimum grain and hay yields. Supplying adequate 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.

Whilst 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 NDF and crude protein and increases WSC of the hay.

Grain yield increases as combined N and K fertiliser rates increase. 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, K provides little benefit, but if N supply is high, a lack of K can affect quality.

**N-deficiency symptoms**

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 multicoloured 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 onto the soil. Grain yield is reduced primarily due to there being fewer kernels per head and lower head density.

5.5 **Phosphorus**

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

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Phosphorus is a major nutrient for improving oat 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 from 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.

It is suggested that P can be applied at crop establishment as an adequate supply is critical for rapid development. Phosphorus is needed during early growth for plant root development and elongation, so P fertilisers are drilled with the seed during sowing. 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 and Phosphorous Buffering Index < 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 mL/g and >15 mL/g, reactive Fe 280–1000 mg/kg and > 1000 mg/kg, respectively), P is held more tightly with less 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. 9

**P-deficiency symptoms**

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. 10

### 5.6 Potassium

Potassium 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. A deficiency of K results in poor root growth, restricted leaf development, few grains per head and smaller grain size which affects yield and quality.

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, which are peaty and occur on the south coast, are the most prevalent K-deficient soils of the high rainfall zone of Western Australia. Potassium deficiency is likely to occur if the soil has less than 60 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 Western Australia 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.

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Symptoms of K deficiency 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 top dressing either before seeding or up to 5 weeks after seeding. If K deficiency is diagnosed in the soil by Colwell-extractable soil tests, applying 20–40 kg K/ha as muriate of potash (40–80 kg/ha) may give an economic yield increase. Potassium at low rates can be banded below or with the seed at sowing, with sulfate of potash safer than muriate of potash. Higher amounts of K drilled with seed can decrease seedling germination, mainly due to salt effect. Western Australian research has shown that banded K is twice as efficient as top-dressed K. In other words, applying 10 kg of K in the furrow achieves an equivalent plant response of top-dressing 20 kg/ha of K.

Hay crops remove greater amounts of K (about 10 kg K/t) 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 five recommended K application rates.  

**K-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.

**5.7 Sulfur**

Sulfur has an important role in forming proteins and is essential for producing chlorophyll. Crops that have a high N requirement must have adequate S to optimise N utilisation and protein synthesis.

Sulfur deficiency in oat crops is rare in Western Australia, mainly because of the widespread use of superphosphate (11% S). 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 sulfate before being taken up by roots. Sulfate 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) indicates likely S deficiency. However, S in the soil frequently decreases 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

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**Notes:**


compound fertilisers that apply S at 5 to 10 kg/ha can avoid S deficiency. Similarly sulfate of ammonia can be a cost-effective source of N and S.

S-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.\textsuperscript{13}

5.8 Zinc
Zinc 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. Tissue testing is the only effective way to determine if there is adequate plant-available Zn in the soil.

Although plant symptoms may be sufficient to diagnose Zn deficiency, a tissue test may also 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 to 2 kg/ha zinc oxide (75% Zn) will correct a deficiency for many years. A foliar spray of 1 kg/ha zinc sulfate (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.

Zn-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.

With severe deficiency the stem remains very short and youngest leaves have difficulty emerging fully. The symptoms can be mistaken with that of Barley yellow dwarf virus and severe P deficiency.\textsuperscript{14}

5.9 Manganese
Oats can be found to be highly susceptible to Mn deficiency which can cause significant yield losses. In severe cases, the crop may die.

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 across oat varieties.

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

Applying ammonium sulfate 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.

One of the side effects of correcting an acidic soil with lime is that higher soil pH levels reduce the availability of manganese. This is most common on gravelly soils.


Mn-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. 15

5.10 Copper

Oats are less susceptible to copper deficiency when compared to wheat and barley; however, 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 affects 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 < 1.3 mg/kg indicate the plant is severely Cu deficient. Applying 3 to 9 kg/ha of copper sulfate (25% Cu) with fertiliser at seeding in areas suspected to be deficient in Cu correct 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 the youngest leaves can help monitor the plant-available Cu in the soil.

If a deficiency is detected in a tissue test, it can be corrected with a foliar application of Cu sprayed on the crop up to booting stage. This is relatively inexpensive and very effective at correcting a deficiency and optimising yield.

Cu-deficiency symptoms

Copper-deficient crops have a patchy appearance. Plants in poor areas are stunted, pale green and look limp and wilted even with ample soil water. Late tillers may develop at nodes or joints above ground. Young leaves turn pale green whereas 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 seedset from sterile pollen which results in ‘white heads’, similar to the ear heads affected by drought, heat stress and frost. 16

Cereal grain yield can often be severely limited by Cu deficiency without showing any previous visual symptoms until there is a failure to form grain. That is why tissue testing earlier in the season is so valuable in areas where Cu deficiency may occur.

SECTION 6

Weed control

6.1 Cost of weeds to Australian agriculture

Weeds cost Australian agriculture an estimated $2.5–$4.5 billion per annum. For winter cropping systems alone, the cost is $1.3 billion, equivalent to ~20% of the gross value of the Australian wheat crop. Consequently, any practice that can reduce the weed burden is likely to generate substantial economic benefits to growers and the grains industry. ¹

Weed control is essential if crops are to make full use of summer rainfall, and in order to prevent weed seeds from contaminating the grain sample at harvest. Weed management should be planned well before planting and options considered such as chemical and non-chemical control. ²

Weed control is important, because weeds:
- rob the soil of valuable stored moisture
- rob the soil of nutrients
- cause issues at sowing time, restricting access for planting rigs (especially vine-type 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
- carry disease including leaf diseases such as rust and septoria leaf blotch and root diseases including nemotades and take all
- host insects

6.2 Weed management in oats

Oats compete better than barley, wheat, canola and pulses when sown at recommended seeding rates because of their greater tillering ability. 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.

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.

Cutting hay is a common method used for reducing the weed seedbank—it is important to actually cut hay as per the rotation, as harvesting grain instead can result in huge weed increases the following season. But effective weed management for hay crops is also essential, as weed contamination is directly related to quality. Weeds can cause

downgrading or rejection of export hay as there is a weed contamination limit of 5%. There is also a nil tolerance to annual ryegrass toxicity (ARGT) and prickly weeds such as doublegee. 3

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.

### 6.3 Integrated weed management

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 integrated weed management (IWM) are to:

- use weed-free seed
- clean machinery when moving between paddocks and other areas on farms
- tarp loads when moving grain
- control weeds along roadsides at the edge of paddocks
- eradicate small patches of new invading weeds
- consider weeds when importing hay
- don’t import grain or products that may contain certain herbicide-resistant weed seeds
- for crop and pasture rotations use species with different competitive abilities, sowing dates and harvesting techniques such as swathing
- increase seeding rates to maximise crop–weed competition and yield without reducing grain size
- sow cereals in an east–west direction
- implement tickle cultivation to stimulate germination of ryegrass and other weeds prior to seeding
- graze sheep or cattle 5
- introduce harvest weeds seed management strategies (e.g. chaff carts, windrow burning)

#### 6.3.1 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 + diquat, providing better ryegrass, capeweed and radish control than the reverse
- spraying the first herbicide at the 2–6 leaf stage of ryegrass, resulting in the best control

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ensuring the interval between knockdowns is at least 1 day when using the glyphosate followed by paraquat + diquat but a 2–10 day interval, which is more effective, if seasonal conditions permit

allowing a longer interval before the second spray to ensure plants emerging after the first knockdown are killed

An interval of 7-10 days is better and use full herbicide label rates with both applications.

Agronomist’s view

6.3.2 Protecting herbicides

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 MOA.

Effective herbicides are key components of profitable cropping systems. Protecting their efficacy directly contributes to the future sustainability and profitability of cropping systems.

The last significant new herbicide MOA released in Australia was Group H chemistry, first launched in Australia in 2001. Prior to that, the most recent new MOA was Group B chemistry, when chlorsulfuron was commercialised in Australia in 1982.

Successful weed management requires a paddock-by-paddock approach. Weeds present and weed-bank status, soil types in relation to herbicide used, and cropping and pasture plans are critical parts of the picture. Knowledge of paddock history and of how much the summer and winter weeds have been subjected to selection for resistance (and to which herbicide MOAs) can also assist.

When resistance has been identified, knowledge of which herbicides still work becomes critical.

The following five-point 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.

6.3.3 Broad-leaved weeds

The range of broad-leaved weeds found in crops is generally larger than in grasses; however, a few, such as capeweed, doublegee and wild radish, are widespread. Others, such as soursob, sorrel, dock, fumitory, self-sown legumes and wire weed are of significant local importance.

Capeweed (along with wild radish) is the most common broad-leaved weed given its widespread occurrence in pastures. It is cost-effectively controlled by a wide range of products.

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Doublegee infestation is generally on a lesser scale but dormancy and staggered germination pose problems with regard to optimum timing of herbicides. Seed production can begin at relatively early growth stages (four leaves), especially on stressed or later emerging plants. If the aim of control is to reduce seed production, delays in application to ensure adequate emergence may be counterproductive.

Wild radish is among the most widespread weeds of cereal crops. Staggered germination and dormancy make their control difficult.

### 6.3.4 Grass weeds

Annual ryegrass and wild oats are two of the most competitive weeds of cereal crops. The conditions of cereal cropping favour their germination and vigorous growth, which, when combined with their high seed populations from preceding crops or pasture, can often lead to very large reductions in potential yield. Both species exhibit staggered germination, which often leads to poor control.

Where these weeds emerge after seeding and before crop emergence, a knockdown treatment can be used to burn off the small grass seedlings, but it is important to ensure that no crop emergence has occurred. Do not use glyphosate-based knockdowns in this way. These grasses are often a problem in emerging crops after early seeding.

Control options include:
- delayed seeding
- shallow cultivation-tickle

### 6.3.5 Annual ryegrass toxicity

Annual ryegrass toxicity (ARGT) is a disease of grazing livestock that results from the ingestion of annual ryegrass seed heads that have been infected by the toxin-forming bacteria *Rathayibacter toxicus*. The bacteria adhere to seed-gall nematodes (*Anguina funesta*) in the soil and enter the plants, with the nematodes, as they attempt to complete their life cycle. Bacteria colonise the galls, displacing the nematodes, and toxicity develops as the plants hay off.

There is a zero tolerance to ARGT in export hay. In Western Australia the considered safe level of ARGT in feed is 200–300 galls/kg of grain and hay. The requirement for export hay is less than 1 gall/kg.

Conditions that favour the development of ARGT are:
- paddocks with moderate to high frequency of cropping
- high density of ryegrass
- short growing seasons
- spread of contaminated materials from ARGT areas
- late hay cutting

Export hay is often grown to aid in ryegrass control, but all export hay is tested for ARGT prior to processing. To ensure the continued acceptance of WA hay into export markets it is critical that supplies remain ARGT-free. Deformed heads, bacterial galls and sometimes slime can be detected in the field but lab tests are recommended to determine the levels present.

### 6.3.6 Harvest weed-seed control

Controlling weed seeds at harvest is emerging as the key to managing the increasing levels of herbicide resistance, which is putting Australia’s no-till farming system at risk.

For information on harvest weed-seed control and its application for the western grains region, see [GrowNotes Oats West Section 12, Harvest](#).
SECTION 7

Insect control

Damage from field insects is not generally a major factor for oat crops. Mites can be a threat when oats are at the seedling stage, and aphids are able to transmit viruses. Damage from other pests can occur if populations build up. Grain insects are not permitted in export grain or grain for sale, and there is a zero tolerance for insects in export hay. Protecting against field and stored grain pests is therefore critical. ¹

7.1 Field pests

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. Control redlegged earth mite and lucerne flea during the seedling stage if necessary. Check for and control aphids from the flag-leaf stage, and later in crops considered high yielding. Aphids can transmit Barley yellow dwarf virus (BYDV). If growing susceptible varieties in areas with moderate to high risk of BYDV, then spraying the crop with a synthetic pyrethroid at ~30 days after sowing is advisable.

Correct identification of the insect is critical for successful management.²

7.1.1 Cockchafer

Crop stage

Look for cockchafers before seeding.

Description

There are several important pest species, and adults range in size from 5 to 20 mm. Adults are usually brown or blackish beetles. The beetles fly readily and are attracted to lights. Cockchafer larvae are characteristically C-shaped, creamy white grubs 2–25 mm long (Figure 1).

Life cycle

Some species have a long larval stage that extends over 12–18 months. In most species, larvae are 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.

Damage

Cockchafer larvae feed underground and some species are serious pests that 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 because they feed on tree foliage.

Control

Control of cockchafer larvae is rarely warranted. The pest species in Western Australia cannot be controlled with chemicals after planting because the larvae remain underground. Cultivation, shallow planting and a high seeding rate may help to overcome the problem, which is most serious when early growth is slow. Large populations may be present under young crops and in pasture without causing significant damage.³

![Cockchafer larvae and adults](https://www.agric.wa.gov.au/oats/oats-insect-pests)

Figure 1: Cockchafer larvae (left panel) and adults (right panels). (Photos: DAFWA)

7.1.2 Desiantha weevil

Crop stage
Look for Desiantha weevil larvae before seeding and at seedling stage.

Description
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 (Figure 2).

Life cycle
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. Adults are common in spring and summer, hiding under wood or stones; they can be found on cereal heads, where they can be harvested with the grain.

Damage
Desiantha weevil is a sporadic pest of cereal seedlings in southern coastal areas. The larval stage can 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.

Control
Control with chemicals is not possible after planting. The problem is most likely where shallow sand occurs over gravel or clay. Larvae will be larger following summer rain, so crops should be planted early and shallow to minimise attack. Where the pest is confirmed, planting with treated seed at 90 kg/ha is recommended. 4

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### 7.1.3 Cutworm

#### Crop stage

Look for cutworms before seeding and at seedling stage.

#### Description

Several species (*Agrotis infusa, A. munda*, various other species) occur in Western Australia, and they vary in appearance, but the larvae are all smooth and plump (Figure 3). Larvae of the most common species, the pink cutworm, are grey-green with a pink tinge and are usually found in sandy soils. Larvae of another common species, the Bogong moth, are dark grey. Larvae usually hide by day but they may be found under the surface and often close to a damaged plant. They curl up when disturbed. At times, brown cutworms with a herringbone pattern along the back damage crops. In southern coastal areas, they are more likely than pink or black cutworms to be found on the soil surface by day. The adults of these herringbone cutworms are of various species, and can range from black, through grey to brown. Occasionally, autumn attack by armyworm in cereals resembles cutworm damage. This is significant, because armyworms are harder to kill with insecticides than are cutworm.

#### Life cycle

Eggs are laid on the soil or on plant material close to the ground. The larvae may grow 50 mm long before pupating and then finally becoming adult moths. Adults are stout-bodied, with a wingspan of up to 40 mm. The forewings are patterned brown or dark grey. Several generations are possible in one season.

#### Damage

As the name implies, the cutworm chews through plant parts, often felling the plant at ground level. 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.

#### Control

Weather and food supply are the most important factors determining abundance. Biological control, such as by fungal diseases, may be very successful. Wasp and fly parasites are also very active in preventing more frequent and serious outbreaks.  

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**Figure 3:** Cutworm larvae (left panel) and moths (right panel). (Photo: DAFWA)
7.1.4 Webworm

Crop stage

Webworms are present before seeding and at the seedling stage.

Description

Webworm caterpillars are seldom seen, being above ground level only when conditions are cool and damp usually at night. They may be 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 (Figure 4). Fully grown caterpillars are ~15 mm long.

Life cycle

Caterpillars hatch from eggs laid amongst grass in autumn and they feed throughout 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. By day, they hide in camouflage in dry grass.

Damage

The continual chewing damage of a heavy webworm infestation may destroy large areas of emerging wheat or barley crops. 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.

Control

The paddock condition in autumn and the weather are important in determining webworm numbers. In a bare paddock or in stubble, eggs will not be laid in great numbers and they will not survive well. Grassy situations favour survival. Cultivations leading to a weed-free paddock over ~21 days 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 ~25% of the plants are being seriously damaged at or just after emergence, spraying should not be delayed; the continued feeding will kill many plants and result in bare ground or thin areas. 6

Figure 4: Webworm larvae (left) and moth (right). (Photos: DAFWA)
7.1.5 Redlegged earth mite

Crop stage

Look for mites before seeding and at seedling stage.

Description

Adult mites are about the size of a pinhead (up to 1 mm). They have velvety black bodies and eight bright orange-red legs. The mites are often gregarious and are found clumped together in large numbers (Figure 5). They disperse quickly when disturbed.

Life cycle

Mites hatch from over-summering eggs during autumn when adequate moisture and sufficiently low temperatures occur. Eggs produced through the growing season are thin-walled and hatch immediately, and several generations may develop over winter and spring. As pastures begin to senesce, the mites produce thick-walled eggs, which resist drying over summer and carry the mite through to the next season.

Damage

Large numbers of redlegged earth mites are commonly found in annual pastures at the break of the season, and they may cause heavy loss of subterranean clover and annual medic seedlings. These species are susceptible throughout the growing season. Normally, mites do not affect grasses or cereals severely. Mites rupture cells on the surface of leaves and feed on exuding sap; affected leaves look silvered, but do not have holes as with lucerne flea attack. Mite damage to seedlings is more severe if plant growth is slowed. This could be caused by cold and/or waterlogging, low seedling density after a false break, low seedbanks after a crop, or if pastures or stubble are being reseeded. Cape weed increases their reproductive potential.

Control

Seed treatment with a systemic insecticide before sowing of pastures or crops protects seedlings from attack. Post-emergent sprays are also effective. Use systemic chemicals if >60% of plants have emerged. If few plants have come up and cotyledons are damaged as they emerge, it is more effective to use a contact insecticide. Hard spring grazing reduces damage. Biological control is being promoted through collection of a predatory mite, the Anystis mite, from original CSIRO establishment sites, and spreading them throughout the agricultural region. Establishment of this predator depends on careful handling during collection and transport, and on ensuring areas of adequate dry plant cover in paddocks for shelter over summer. 7

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Figure 5: Redlegged earth mites (Halotydeus destructor). (Photos: left, DAFWA; right, cesar)

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7.1.6 Balaustium mite

Crop stage

*Balaustium* mites can be found at the seedling stage.

Description

The *Balaustium* mite has a greyish to red body and red legs and is similar in appearance to the redlegged earth mite. If viewed under a magnifying glass or microscope, short stout hairs can be seen covering the body (Figure 6). The adult grows to almost twice the size of redlegged earth mites.

Life cycle

*Balaustium* mites require rainfall before over-summering eggs can hatch. Newly hatched nymphs have six legs and are orange. Development from egg to adult takes about 5–6 weeks. Several generations can occur each year.

Damage

Although *Balaustium* mites are seen in pastures and occasionally in crops, it was not until 1997 that reports were received of them being an economic pest. Some properties west of Ravensthorpe and some in the Esperance area have had cereal, lupin and canola crops severely bleached and wilted to the point of death from this pest. Mites feed on the leaves of plants by probing into the surface cells with their mouthparts and sucking out sap. Reports indicate that crops sown into paddocks that were in pasture the previous year, with high levels of broadleaf weeds (especially cape weed), will be most at risk from mite damage.

Control

In most situations, crops will not require spraying and the mites will cause little or no damage. Early control of summer weeds in paddocks that are to be cropped will prevent buildup of mite populations. Weeds present in paddocks prior to cropping should be checked to determine the numbers of *Balaustium* mites present. If there are very large numbers, incorporation of insecticide with herbicide immediately prior to sowing is a more effective strategy than spraying when the crop is emerging and has very little cover of green material. No chemicals are currently registered for control of *Balaustium* mite. Farmer trials have shown high rates of synthetic pyrethroids can be effective; however, the mites can be difficult to kill. High rates of dimethoate, omethoate, chlorpyrifos and phosmet have been found ineffective in controlling these mites. 8

Figure 6: *Balaustium* mite (*Balaustium medicagoense*). (Photo: cesar)

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7.1.7 Bryobia mite

Crop stage

*Bryobia* mites are present at seedling stage.

Description

The adult mites are slightly smaller than a pinhead with a dark grey body and pale red–orange legs. They can be confused with redlegged earth mite and are difficult to separate without the use of a hand lens. However, redlegged earth mites are not usually present until later in autumn because they have a cold temperature requirement before hatching. The front legs on *Bryobia* mites are very long and held in front of the body like a pair of feelers (Figure 7). The body is rounded and plump, but if the mite is starved, its body shape changes to flat on the top and rounded underneath with a flange around the sides.

Life cycle

Adult *Bryobia* mites are active in late spring, summer and autumn. Eggs are present over winter, and they hatch as conditions dry and warm up in spring and early summer. Winter eggs are usually laid in batches, whereas eggs over the dry period are laid singly on backs of leaves of host plants. Nymphs newly hatched have six legs and are bright red, but turn dark-grey in a few days. They moult to a nymph with eight legs, then again to become a third-stage nymph, before finally molting to the adult stage. One month from egg hatching to young adult is usual. There are several generations per year.

Damage

When in high numbers, *Bryobia* mites have caused severe damage to emerging canola and lupin crops in autumn. Mites feed on the tops of leaves by stabbing into the surface cells with their sharp mouthparts, and sucking out sap. Whitish grey spots result, giving leaves a stippled wilted look. Summer rains followed by warm mild autumns give *Bryobia* mites the best conditions for survival and increase. They do not tolerate cold wet weather but can persist into June following warm autumn conditions. Crops planted into paddocks with a history of summer–early autumn weeds, and experiencing warm dry conditions after crop emergence, are most at risk. Reports of damage have increased since 1995, before which *Bryobia* mites were considered a minor and sporadic pest in some southern districts of Western Australia. They were reported as being a serious pest in central and some northern cropping zones during autumn 1998 and 1999. Minimum tillage, earlier sowing times and tolerance to some insecticides have led to the increased importance of this pest.

Control

Early control of summer weeds in paddocks that are to be cropped will prevent the buildup of mite populations. Weeds present in paddocks prior to cropping should be checked to determine the numbers of mites present. If they are found in large numbers, then incorporation of insecticide with herbicide immediately prior to sowing is more effective than spraying when the crop is emerging and has very little cover of green material. Omethoate is registered for control of *Bryobia* mite in pastures and some crops. Rates of insecticides commonly used to control redlegged earth mite and lucerne flea are not effective against *Bryobia* mites. ⁹

Figure 7: *Bryobia* mite. (Photo: DAFWA)

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### 7.1.8 Blue oat mite

Blue oat mites are often confused with RLEM. There are four recognised species of blue oat mite in Australia: *Penthaeleus major*, *P. falcatus*, *P. minor* and *P. tectus*. Accurate identification of the species requires examination by an entomologist. The four species vary in their geographical distribution in Australia.

Damage to crops and pastures is incurred in the establishment phase. Host-plant preferences vary with the species, as do their life cycles and tolerances to various pesticides. Host plants include black thistle, chickweed, curled dock, dandelion, deadnettle, prickly lettuce, shepherds purse, variegated thistle and wild oat. Cultivated field-crop hosts include wheat, barley, oats, rye, canola, field peas, lupins and linseed.

**Description**

Adult mites have eight legs and are ~1 mm long with oval, rounded, dark brown to black bodies, bright red or pinkish red legs and mouthparts, and a red spot or streak towards the hind end of the back.

**Seasonal development**

Overlapping generations of the blue oat mite usually occur between mid-autumn and late spring. Blue oat mites oversummer as aestivating eggs laid in mid–late spring by the second-generation adults. These aestivating eggs are highly resistant to desiccation. They do not begin to develop until late summer–early autumn and they do not hatch until favourable conditions of temperature and moisture occur in the following mid-autumn to early winter.  

### 7.1.9 Lucerne flea

**Crop stage**

Look for lucerne fleas at seedling stage.

**Description**

Lucerne fleas usually spring from the plants when approached, using a specialised organ underneath the body. The lucerne flea is a dumpy looking and wingless creature of varied colour, but the larger specimens of 2–4 mm are predominantly green or yellow (Figure 8).

**Life cycle**

The first soaking autumn rains cause the over-summering egg batches to hatch. Several generations may then develop over the growing period depending on the weather. Eggs are laid in the soil and they usually hatch in a few days. With the onset of warm and dry conditions in spring, the resting-stage eggs, which are able to withstand summer conditions, are laid.

**Damage**

Pastures, legume crops and cereals may be seriously retarded by the lucerne flea, and seedling death may occur during heavy infestations. Frequently, the green leaf tissues are eaten, leaving a surface of the leaf as a whitish film. From a distance, severely affected areas appear bleached.

**Control**

The lucerne flea is favoured by heavy soils and cannot live in very sandy situations. It is also dependent on plentiful moisture. Control in crops and pastures may be obtained with systemic or contact insecticides, as for redlegged earth mites. A predatory mite, the *Bdellodes* mite, is present over most of the area occupied by lucerne flea and exerts

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**References**

a useful level of control. Another predatory mite, the Neomolgus mite, was introduced by the CSIRO and it has been released throughout the agricultural area. It will extend the range and level of biological control.\footnote{DAFWA (2015) Oats: insect pests. Department of Agriculture and Food Western Australia, \url{https://www.agric.wa.gov.au/oats/oats-insect-pests?path=0%2FC4}}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{lucerne_flea.jpg}
\caption{Lucerne flea (Sminthurus viridis). (Photo: DAFWA)}
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### 7.1.10 Cereal aphids

**Crop stage**

Aphids are damaging at tillering and from flowering to maturity, and they transmit BYDV.

**Description**

The corn aphid (*Rhopalosiphum maidis*) and wheat or oat aphid (*R. padi*) cause the greatest yield loss (Figure 9). Wingless females are about 0.2–2.5 mm long. Rice-root aphid (*R. rufulabdominalis*) and grain aphid (*Sitobion miscanthi*) are also found in cereals and may be important as virus vectors.

Corn aphids are dark blue-green to grey-green, often with a fine white powdery dust over the body. Colonies develop within the furled tip of tillers, starting any time from seedling stage to head emergence. Few farmers see them because they are hidden in the furled leaves. Corn aphid probably kills tillers, resulting in fewer heads.

Wheat or oat aphids vary from mottled yellow-green through olive green and dusky brown, to a blackish green. Colonies develop on the outside of tillers from the base upwards, on stems, nodes and backs of mature leaves, starting any time between late tillering and grain filling. Heavy infestations can blacken heads and flag leaves, and these are the aphids most commonly reported by farmers. Wheat or oat aphids are more mobile than corn aphids, and can drop to the soil and crawl to other plants. They cause yield losses probably by reducing grain weight and grains per head. They may also be important in spreading BYDV.

Rice root aphids are similar to wheat or oat aphids, but they can also infest plant roots. They have a reddish patch in the middle of the back, and are most likely to be found in drier agricultural areas. Grain aphids are dusky green with yellow-green tinges, usually found in spring, without developing large colonies. Rose-grain aphids are potentially serious pests, but have not yet reached Western Australia.

\begin{figure}[h]
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\includegraphics[width=0.5\textwidth]{oat_wheat_aphid.jpg}
\caption{Oat or wheat aphid (*Rhopalosiphum padi*) and corn aphid (*R. maidis*). (Photos: DAF Qld)}
\end{figure}
Australia from the eastern states where they are widespread. They are green spindle-shaped aphids attacking wheat and barley during grain filling.

**Life cycle**

Winged aphids fly into crops from pasture grasses or other crops and start colonies of wingless aphids. Reproduction is rapid when weather conditions are favourable, leading to population outbreaks. Plants can become sticky with honeydew excreted by the aphids. When plants become unsuitable or overcrowding occurs, winged aphids redevelop and migrate to other plants or crops. They can carry viruses in saliva or on their feeding tubes. BYDV damage is most serious after plant infection early in the season.

**Damage**

Cereal aphid damage in oats, barley and wheat has no obvious signs or symptoms. Research in medium- and high-rainfall zones has shown that aphids can cause losses up to 30% where crop yield potential is ≥3 t/ha. Damaging populations may develop in 60% of years. Aphids affect cereals by direct feeding on plants, and/or by transmitting BYDV, which affects wheat, oats and barley. 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, number of aphids per tiller, and the duration of the infestation.

**Control**

In southern areas, crops should be checked from late tillering onwards for corn aphids in the furled growing tips, and for wheat or oat aphids on stems, backs of leaves and in the crown. High yielding crops are most at risk. Spraying is worthwhile if 50% of tillers have >10 aphids. Mixed infestations of both aphid species may cause more damage than either species on their own. Crops sprayed before Zadoks growth stage (GS) 30 may need respraying at GS50 or later if aphid numbers build up again. Parasitic wasps, ladybeetles, lacewings and hoverflies can provide useful biological control, mainly by preventing secondary outbreaks. Use of ‘soft’ insecticides that kill only aphids is advocated. 12

**Thresholds for control**

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

The decision to control aphids on winter cereals depends on the size of the aphid population and the duration and timing of the infestation. Controlling aphids during early crop development generally results in a recovery of the rate of root and shoot development, but there can be a delay. Aphids are more readily controlled in seedling and pre-tillering crops, which are less bulky than post-tillering crops. Corn aphids in the terminal leaf tend to disappear as crops come into head, and other species usually decline in abundance about this time as natural enemy populations build up. Note that because the rice root aphid feeds belowground, it cannot be controlled effectively by non-systemic foliar treatments. 13

No firm economic thresholds exist (taking into account current costs of control and crop value), but there are thresholds suggested from research in Western Australia and by the Northern Grower Alliance. The Western Australian threshold, based on checking crops regularly from late tillering, is to consider control if the aphid population exceeds 15 aphids/tiller on 50% of tillers.

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7.1.11 Armyworm

Crop stage
Armyworms are most damaging from flowering to maturity.

Description
Four species of armyworm occur in Western Australia: the common armyworm, the southern armyworm, the inland armyworm and the sugarcane armyworm. Of these, the common armyworm (Leucania convecta) is the most damaging. Moths are stout-bodied, grey–cream, with a wingspan of ~40 mm. The moths fly at night and they are strongly attracted to lights.

Armyworm caterpillars vary in colour depending on their numbers in a crop. At high numbers, they become dark, whereas if the population is smaller, the caterpillars are much paler. Armyworms are about 40 mm long when fully grown and can be distinguished from cutworms and budworms by their large heads and by three prominent white stripes on the ‘collar’ behind the head (Figure 10). Often they will not be seen because they feed mainly at night; however, their droppings, which look like small green ‘square’ hay bales, will be obvious on the ground below the crop canopy. Another indicator that armyworms are present is damage to ryegrass seed heads.

Life cycle
Armyworms have three or four generations each year, and on the south coast they survive over summer on self-sown cereals and grasses that germinate with summer rains. In spring, it is about 21 days from when eggs are laid to when the caterpillars reach head-lopping size. Once damage begins, many heads can be lopped in a short time.

Damage
Armyworms are regular pests of coarse grain crops on the south coast of Western Australia and occasional pests in inland areas. Towards the end of spring, when crops are approaching maturity, large caterpillars chew through the stem just below the head, causing the head to fall to the ground. If in large numbers earlier in the season, they may eat leaves and they may be confused with cutworm.

Control
Heatwaves may kill most of the caterpillars. Native parasites can exercise good control, and spraying is not usually required every year. Several wasp parasites including Apanteles ruficrus have been released to increase biological control. 14

Figure 10: Armyworm caterpillar. (Photo: DAF Qld)

7.1.12 Australian plague locust

Crop stage
Plague locusts affect crops from flowering to maturity.

Description
Newly emerged nymphs are about the size of houseflies and hop actively. Adults have a characteristic black tip to the hind wing. Swarming locusts are light brown, but solitary individuals may be green or yellow (Figure 11).

Life cycle
Two generations occur annually. Nymphs of the first generation appear when soil temperatures begin to rise in spring. Attainment of adulthood may take 30–55 days depending on climatic conditions. Eggs laid by the first generation require at least 21 days to hatch and will hatch only if sufficient soil moisture is present. Eggs laid by the second generation enter a resting phase, enabling them to overwinter.

Damage
Adult locusts will eat almost any green plant material, but crops most at risk are ripening cereals in early summer, summer pastures and green pasture growth following summer rain. Locust plagues in Western Australia are rarely as severe as the eastern states.

Control
Egg parasites are common but rarely cause significant losses. Several fly parasites are common and the second locust generation is often heavily parasitised. The species is declared under the Agriculture and Related Resources Protection Act and control is obligatory.  

Figure 11: Australian plague locust (Chortoicetes terminifera). (Photo: DAFWA)

7.2 Stored grain pests

Grain insects are not permitted in export grain or grain for sale. Protecting your grain intended for use on-farm from insect attack saves money.

- Even light infestations of weevils can reduce germination of the grain.
- Weevils eat or contaminate food intended for livestock.
- Weevils overwintering in stored grain can re-infest machinery.

Grain stored on-farm will eventually become infested with grain beetles or moths unless specific control methods are undertaken. Good hygiene is critical. Other options include:

- cooling grain with aeration
- fumigating a sealed silo with phosphine-generating tablets
- applying a malathion insecticide
- treating grain by mixing with amorphous silica (e.g. Dryacide®)

Aeration will suppress insect populations but not eliminate them. If delivering grain to a nil-tolerance market, farmers will eventually need to fumigate. ¹⁶ See GrowNotes Oats Western, Section 13, Storage.

SECTION 8

Nematode management

Root-lesion nematodes (RLN; Pratylenchus spp.) are microscopic, worm-like animals that extract nutrients from plants, causing yield loss.¹

Root-lesion nematodes are found over 5.74 million ha (or ~65%) of the cropping area of Western Australia (WA). Populations potentially limit yield in at least 40% of these infested paddocks.

The main species found in broadacre cropping in WA are Pratylenchus neglectus, P. quasitereoides (formerly known as P. teres), P. thornei and P. penetrans.

The host range of RLN is broad and includes cereals, oilseeds, grain legumes and pastures, as well as many broadleaf and grass weeds.

Which nematode species are present will affect the suitability of the rotational options.

Oats in the western region are considered moderately susceptible to P. neglectus, and susceptible to P. quasitereoides and P. penetrans.

Management of RLN in winter crops includes:

- Observation and monitoring of above- and below-ground symptoms of plant disease followed by diagnosis of the cause(s) of any root disease are the first steps in implementing effective management. Although little can be done during the current cropping season to ameliorate nematode symptoms, the information will be crucial in planning effective rotations of crop species and varieties in following seasons.

- Well-managed rotations with resistant or non-host break-crops are vital. To limit RLN populations, avoid consecutive host crops (Table 1).

- Use a state department of agriculture Crop Variety Guide to choose varieties with high resistance ratings. These will result in fewer nematodes remaining in the soil to infect subsequent crops.

- Reducing RLN can lead to higher yields in following cereal crops.

- Healthy soils and good nutrition can partly alleviate RLN damage through good crop establishment, and healthier plants may recover more readily from infestation under more suitable growing conditions.

- Observe crop roots to monitor development of symptoms.

- Weeds can host parasitic nematodes within and between cropping sequences, so choice of pasture species and control of host weed species and crop volunteers is important (Table 2).²

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¹ KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet
Table 1: Resistance of major crop broadacre species to Pratylenchus neglectus, P. quasitoeides and P. penetrans

<table>
<thead>
<tr>
<th>Susceptible</th>
<th>Moderately susceptible</th>
<th>Resistant</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. neglectus</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>Canola</td>
<td>Field peas</td>
</tr>
<tr>
<td>Barley</td>
<td>Oats</td>
<td>Lupins</td>
</tr>
<tr>
<td>Chickpeas</td>
<td>Durum wheat</td>
<td>Faba beans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lentils</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Triticale</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rye</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safflower</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Narbon beans</td>
</tr>
<tr>
<td><em>P. quasitoeides (formerly P. teres)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>Canola</td>
<td>Field peas</td>
</tr>
<tr>
<td>Barley</td>
<td></td>
<td>Lupins</td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>P. penetrans</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field peas</td>
<td>Barley</td>
<td></td>
</tr>
<tr>
<td>Lupins</td>
<td>Canola</td>
<td></td>
</tr>
<tr>
<td>Chickpeas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durum wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faba beans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild oats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild radish</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Information for *P. quasitoeides* and *P. penetrans* is based on samples received by Agwest Plant Laboratories for diagnosis, combined with data from preliminary field and glasshouse trials.

Table 2: Resistance of pasture species to Pratylenchus neglectus

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Species</th>
<th>Resistance rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanjil lupin</td>
<td><em>Lupinus angustifolius</em></td>
<td>R</td>
</tr>
<tr>
<td>Charano yellow serradella</td>
<td><em>Ornithopus compressus</em></td>
<td>R</td>
</tr>
<tr>
<td>Flamenco sulla</td>
<td><em>Hedysarum coronarium</em></td>
<td>R</td>
</tr>
<tr>
<td>Yelbini yellow serradella</td>
<td><em>Ornithopus compressus</em></td>
<td>R</td>
</tr>
<tr>
<td>Margurita French serradella</td>
<td><em>Ornithopus sativus</em></td>
<td>R</td>
</tr>
<tr>
<td>Cadiz French serradella</td>
<td><em>Ornithopus sativus</em></td>
<td>MR</td>
</tr>
<tr>
<td>Santorini yellow serradella</td>
<td><em>Ornithopus compressus</em></td>
<td>MR</td>
</tr>
<tr>
<td>Erica French serradella</td>
<td><em>Ornithopus sativus</em></td>
<td>MR</td>
</tr>
<tr>
<td>Hykon rose clover</td>
<td><em>Trifolium hirtum</em></td>
<td>MS</td>
</tr>
<tr>
<td>Electra purple clover</td>
<td><em>Trifolium purpureum</em></td>
<td>MS</td>
</tr>
<tr>
<td>Sceptre lucerne</td>
<td><em>Medicago sativa</em></td>
<td>MS</td>
</tr>
<tr>
<td>Mauro biserrula</td>
<td><em>Biserrula pelecinus</em></td>
<td>S</td>
</tr>
<tr>
<td>Casbah biserrula</td>
<td><em>Biserrula pelecinus</em></td>
<td>S</td>
</tr>
<tr>
<td>Caprera crimson clover</td>
<td><em>Trifolium incarnatum</em></td>
<td>S</td>
</tr>
<tr>
<td>Cefalu arrowleaf clover</td>
<td><em>Trifolium vesiculosis</em></td>
<td>S</td>
</tr>
<tr>
<td>Sothis eastern star clover</td>
<td><em>Trifolium dasyrurum</em></td>
<td>S</td>
</tr>
<tr>
<td>CFD27 bladder clover</td>
<td><em>Trifolium spumosum</em></td>
<td>S</td>
</tr>
<tr>
<td>2002ESP4 biserrula</td>
<td><em>Biserrula pelecinus</em></td>
<td>S</td>
</tr>
</tbody>
</table>
**Background**

Root-lesion nematodes use a syringe-like ‘stylet’ to extract nutrients from the roots of plants (Figure 1). Plant roots are damaged as RLN feed and reproduce inside the plant roots. *Pratylenchus thornei* and *P. neglectus* are the most common RLN species in Australia. These nematodes can be found deep in the soil profile (to 90 cm depth) and in a broad range of soil types, from heavy clays to sandy soils. *Oats* are considered resistant to *P. thornei* and have intermediate susceptibility to *P. neglectus*.

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

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Species</th>
<th>Resistance rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coolamon subterranean clover</td>
<td><em>Trifolium subterraneum</em></td>
<td>S</td>
</tr>
<tr>
<td>Machete wheat</td>
<td><em>Triticum aestivum</em></td>
<td>S</td>
</tr>
<tr>
<td>Nitro Plus Persian clover</td>
<td><em>Trifolium resupinatum</em></td>
<td>S</td>
</tr>
<tr>
<td>Frontier balansa clover</td>
<td><em>Trifolium michelianum</em></td>
<td>S</td>
</tr>
<tr>
<td>Dalkeith subterranean clover</td>
<td><em>Trifolium subterraneum</em></td>
<td>S</td>
</tr>
<tr>
<td>Caliph barrel medic</td>
<td><em>Medicago truncatula</em></td>
<td>S</td>
</tr>
<tr>
<td>Urana subterranean clover</td>
<td><em>Trifolium subterraneum</em></td>
<td>S</td>
</tr>
<tr>
<td>Santiago burr medic</td>
<td><em>Medicago polymorpha</em></td>
<td>VS</td>
</tr>
<tr>
<td>Prima gland clover</td>
<td><em>Trifolium glanduliferum</em></td>
<td>VS</td>
</tr>
</tbody>
</table>

R - Resistant, MR - moderately resistant, MS - moderately susceptible, S - susceptible, VS - very susceptible

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*Figure 1: Microscope image of a root-lesion nematode. Notice the syringe-like ‘stylet’ at the head end, which is used for extracting nutrients from the plant root. This nematode is less than 1 mm long. (Photo: Sean Kelly, DAFWA)*

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8.2 Symptoms and detection

Root-lesion nematodes are microscopic organisms that occur in soil and plants. The most reliable way to confirm the presence of RLN is to have soil tested in a laboratory. Fee-for-service testing of soil offered by the PreDicta B root disease testing service of the South Australian Research and Development Institute (SARDI) can determine levels of *P. thornei*, *P. neglectus*, CCN and stem nematodes present.  

Similar results can be obtained by soil testing either by manual counting (under microscopes) or by DNA analysis (PreDicta B), with commercial sampling generally at depths of 0–10 cm.  

Signs of nematode infection in roots include dark lesions or poor root structure (Figure 2). The damaged roots are inefficient at taking up water and nutrients—particularly nitrogen (N), phosphorus (P) and zinc (Zn)—causing symptoms of nutrient deficiency and wilting in the plant shoots. Intolerant wheat varieties may appear stunted, with yellowing of lower leaves and poor tillering. These symptoms may not be present in other susceptible crops such as barley and chickpea. 

![Figure 2: 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)](image-url)

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8.2.1 What is seen in the paddock?

Above-ground symptoms are often indistinct and difficult to identify. The first signs are poor establishment, stunting, poor tillering of cereals, and plants possibly wilting despite moist soil. Nematodes are usually distributed unevenly across a paddock, resulting in irregular crop growth (Figure 3). Sometimes symptoms are confused with nutrient deficiency and they can be exacerbated by a lack of nutrients.

![Image of paddock with symptoms](image_url)

Figure 3: Above-ground symptoms of RLN, primarily in the form of moisture stress and nutrient deficiency. (Photo: Doug Sawkins)

When roots are damaged by RLN, the plants become less efficient at taking up water and nutrients, and less able to tolerate stresses such as drought or nutrient deficiencies. Depending on the extent of damage and the growing conditions, affected plants may partly recover if the rate of new root growth exceeds the rate at which nematodes damage the roots.

To gain the full picture requires examining what is going on under the ground. Primary and secondary roots of cereals will show a general browning and discoloration and there will be fewer, shorter laterals branching from the main roots.

The root cortex (or outer root layer) is damaged and it may disintegrate.

Diagnosis is difficult and can be confirmed only with laboratory testing. This is essential if identification is sought to species level as all RLN species cause identical symptoms. The PreDicta BTM soil test (SARDI Diagnostic Services) is a useful tool for several nematode species and is available through accredited agronomists. In-crop testing can also be a useful tool by sending whole plants with roots and soil to the [Agwest Labs](http://www.agwest.com.au).

Contact information:
Agwest Plant Laboratories
+61 (0)8 9368 3721
Email [Agwest Plant Laboratories](mailto:info@agwest.com.au)

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8.3 Management

The most important management tool is using rotations that effectively reduce RLN populations. In heavily infested paddocks, resistant break-crops should be grown for 1 or 2 years to decrease the population. Resistant varieties should be selected for the following years using a current Crop Variety Guide (Figure 4).

Adequate nutrition (especially N, P and Zn) help crops to compensate for the loss of root function caused by RLN, although this does not necessarily lead to lower nematode reproduction. In field trials in areas infested with *P. neglectus*, yield losses for intolerant wheat ranged from 12% to 33% when minimal levels of P were applied, but losses were reduced to only 5% with a high rate of P (50 kg/ha).

Weeds can play an important role in the increase or persistence of nematodes in cropping soils. Thus, poor control of susceptible weeds compromises the use of crop rotations for RLN management.

Wild oats, barley grass, brome grass and wild radish are susceptible to *P. neglectus*.

Several pasture species and varieties are suitable in rotations to reduce RLN when targeted to the species in your paddock (Table 1), but weeds must be managed because they can strongly influence nematode populations at the end of the pasture phase.

Manage volunteer susceptible crop plants, because they can harbour nematodes.

Nematodes cannot move great distances unaided. However, they can be spread through surface water, and in soil adhering to vehicles and farm machinery. In uninfested areas, good hygiene should be practised. They can also be spread in dust when they are dehydrated over summer.8

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SECTION 9

Diseases

Diseases can severely affect yield and quality in oats. In some cases, diseases are controlled through simple cultural practices and good farm hygiene. One of the major practices used in the control of diseases is crop rotation.

To minimise the effect of diseases:

- 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., yellow leaf spot and 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.
- Control summer weeds and volunteer plants that may act as a green bridge.
- Rotate crops.

Oats can be infected by diseases, including barley yellow dwarf virus (BYDV), that are transmitted by aphids. Early-sown crops are more at risk. Sow tolerant varieties or be prepared to control aphids to prevent disease transmission.

Seed dressings will offer some anti-feeding protection for your oat crop against aphids. Imidacloprid is registered for use on cereal crops as a seed dressing for the management of aphids and BYDV spread in cereal crops. For more information, go to the Australian Pesticides and Veterinary Medicines Authority website at www.apvma.gov.au.

FAQ

The major diseases of oats are the rust suite. Significant production losses can result from either stem rust or leaf rust. With the development of new pathotypes in some regions for stem rust, there are no remaining genetic resistances available in commercially grown varieties to fully protect crops from stem rust.

Leaf rust resistance levels in some varieties provide useful field tolerance to the disease. Monitor crops in season for the presence of these rusts. Rusts can be managed by selecting appropriate varieties for sowing and avoiding sowing later maturing varieties, or can be controlled by the use of foliar fungicides in-crop.  

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**Table 1:** Cereal insecticide seed dressings for aphid and barley yellow dwarf virus (BYDV) control 2015

<table>
<thead>
<tr>
<th>Active ingredient of insecticide and fungicide</th>
<th>Examples of seed treatment trade name and manufacturer</th>
<th>Rate to apply to each 100 kg</th>
<th>Approx. cost to treat 100 kg of seed ($)</th>
<th>Aphid feeding damage suppression (wheat aphid and corn aphid)</th>
<th>Reduces spread of BYDV</th>
<th>Grazing withholding period (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imidacloprid 180 g/L + tebuconazole 6.25 g/L</td>
<td>Hombre® – Bayer CropScience</td>
<td>400 mL</td>
<td>8.36</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
</tr>
<tr>
<td>Imidacloprid 360 g/L + tebuconazole 12.5 g/L</td>
<td>Hombre® Ultra– Bayer CropScience</td>
<td>200 mL</td>
<td>8.03</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
</tr>
<tr>
<td>Imidacloprid 180 g/L + triadimenol 56 g/L</td>
<td>Zorro® – Bayer CropScience</td>
<td>400 mL</td>
<td>8.62</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
</tr>
<tr>
<td>Imidacloprid 180 g/L + flutriafol 6.25 g/L</td>
<td>Veteran® Plus – Crop Care</td>
<td>400 mL</td>
<td>8.42</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
</tr>
<tr>
<td>Imidacloprid 180 g/L + flutriafol 25 g/L</td>
<td>Arrow® Plus – Crop Care (registered for barley only)</td>
<td>400 mL</td>
<td>8.69</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
</tr>
<tr>
<td>Imidacloprid – 350 g/L</td>
<td>Gaucho® 350 – Bayer CropScience</td>
<td>200 mL – 400 mL</td>
<td>8.11–16.22</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
</tr>
<tr>
<td>Imidacloprid – 600 g/L</td>
<td>Gaucho® 600 – Bayer CropScience Senator® 600 Red – Crop Care</td>
<td>120 mL – 240 mL</td>
<td>6.11–12.21</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
</tr>
</tbody>
</table>

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### Table 2: Guide to oat diseases

<table>
<thead>
<tr>
<th>Disease/Cause</th>
<th>Symptoms</th>
<th>Occurrence</th>
<th>Spread</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foliar Diseases</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacterial stripe blight Pseudomonas striafaciens pv. striafaciens</td>
<td>Water soaked stripes on leaves, drying to tan/red stripes, leaf death.</td>
<td>More severe in early maturing crops in wetter seasons.</td>
<td>Rain splash, insects, seed-borne.</td>
<td>Nil</td>
</tr>
<tr>
<td>Barley yellow dwarf Barley yellow dwarf virus (BYDV)</td>
<td>Yellowing, dwarfing of infected plants, floret blasting, leaf reddening in some varieties.</td>
<td>Most common near perennial grass pastures and in early sown crops.</td>
<td>Transmitted by aphids from infected grasses and cereals.</td>
<td>Resistant and tolerant varieties; controlling aphids, insecticidal seed treatments.</td>
</tr>
<tr>
<td>Leaf (Crown) rust Puccinia coronata f.sp. avenae</td>
<td>Orange powdery pustules on upper leaf surface.</td>
<td>In wet seasons; more important on the coast.</td>
<td>Air-borne spores from living plants.</td>
<td>Graze infected crops in autumn. Varieties with the best possible field resistance. Foliar fungicides.</td>
</tr>
<tr>
<td>Foliar Diseases</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf spots Several fungi</td>
<td>Leaf spots, leaf death.</td>
<td>Usually minor.</td>
<td>Depends on disease.</td>
<td>None</td>
</tr>
<tr>
<td>Stem rust Puccinia graminis f.sp. avenae</td>
<td>Reddish-brown, powdery, oblong pustules with tattered edges on leaf and stem; progressive death of plant.</td>
<td>More important inland, from spring to summer in warm, wet weather.</td>
<td>Air-borne spores from living plants.</td>
<td>Early maturing varieties to avoid rust. Foliar fungicides.</td>
</tr>
<tr>
<td>Smuts Ustilago avenae, U. segetum var. hordei</td>
<td>Replacement of florets by black sooty mass.</td>
<td>Statewide.</td>
<td>Spores on or in the seed infect the seedling after sowing.</td>
<td>Thorough treatment of seed with appropriate fungicide.</td>
</tr>
</tbody>
</table>

If hay production is the end use for your crop, care must be taken to ensure a quality product is produced, in particular if the hay is headed to the lucrative export market. The table below explores which diseases are of the greatest threat to hay quality.

### Table 3: Priority of disease constraints to oaten hay production in Australia (RIRDC)

<table>
<thead>
<tr>
<th>Highest priority</th>
<th>High priority</th>
<th>Medium priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septoria blotch</td>
<td>Barley yellow dwarf (BYDV)</td>
<td>Root lesion nematodes</td>
</tr>
<tr>
<td>Leaf rust</td>
<td>Windburn</td>
<td>Aphids</td>
</tr>
<tr>
<td>Stem rust</td>
<td>Bacterial blight diseases</td>
<td>Red leather leaf</td>
</tr>
<tr>
<td>Cereal cyst nematode (CCN)</td>
<td>Stem nematode</td>
<td></td>
</tr>
<tr>
<td>Annual ryegrass toxicity (ARGT)</td>
<td>Crown rot</td>
<td>Oat attacking strain of take-all</td>
</tr>
</tbody>
</table>

---


9.1 Causes of cereal diseases

Cereal diseases are caused by fungi, viruses, bacteria and nematodes.

9.1.1 Fungi
Fungi and other pathogens (disease-causing organisms) often reduce grain yields by damaging green leaves, preventing them from producing the sugars and proteins needed for growth. In other cases, they block or damage the plant's internal transport mechanisms, reducing the movement of water and sugars through the plant. Yields are also reduced when the pathogen diverts the plant's energy to reproducing more of the pathogen at the expense of plant growth or grain formation.

Fungi come in a diverse variety of forms. They spread by producing one or more types of spores, which may be carried by wind, through raindrop splashes or, in the case of smuts, by mechanical movement and mixing during harvest. Some fungi survive as spores in the soil, on seed or on plant debris, such as septoria. Others survive as fine threads of growth inside plant debris or seed, and produce fresh spores in the following season. Spores are sometimes produced inside small fruiting bodies on infected plant tissue or stubble. Some diseases such as rust require continuous green host plants to survive from one season to the next.

9.1.2 Viruses
Viruses are invisible to the eye and even through a conventional microscope. Unlike other pathogens, viruses are totally dependent on the host for growth and multiplication. They cannot survive outside the plant, except in an insect or other animal that transmits the disease. They often damage plants by blocking their transport mechanisms. Barley yellow dwarf virus (BYDV) affects all of the cereals, with aphids as the vector for transmission of this disease.

9.1.3 Bacteria
Bacteria differ from fungi in that they do not form fine threads of growth, but instead multiply rapidly by continually dividing. They grow best under damp conditions and do not survive as well as fungi under dry conditions.

9.1.4 Nematodes
Nematodes are worm-like animals that cause various diseases in cereals. Most nematodes attack the plant roots or lower stems. Nematodes feeding on plants cause direct damage by reducing root area, damaging the transport mechanism, or, in the case of the seed gall nematode, by replacing the grain with galls full of nematodes. Cereal cyst nematode (CCN) is one such nematode that attacks wheat. For more information see Section 8, Nematodes.

9.2 The disease triangle
Plant pathologists talk about the occurrence of disease in terms of the ‘disease triangle’ (Figure 1)—an interaction of host, pathogen and environment. Alteration to any of these components of the disease triangle will influence the level of disease.

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6 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
The disease triangle.

For disease to occur, there must be a susceptible host and a virulent pathogen, and the environment must be favourable. Following are some important examples of interactions of environmental conditions with diseases of grain crops.

- Low temperatures reduce plant vigour. Seedlings become more susceptible to *Pythium*, *Rhizoctonia* and other root and damping-off pathogens if they are emerging in soils below their optimum temperature.

- Pathogens have different optimum temperature ranges. For example, hatching in nematodes tends to occur over narrow soil temperature ranges, within a 10–25°C range and optimal at 20°C, whereas the take-all fungus *Gaeumannomyces graminis var. tritici* is more competitive with the soil microflora in cooler soils. This can lead to diseases being more prevalent in certain seasons or in different areas, such as wheat stem rust in warmer areas and stripe rust in cooler areas.

- Fungi such as *Pythium* and *Phytophthora*, which have swimming spores, require high levels of soil moisture in order to infect plants; hence, they are most severe in wet soils.

- Foliar fungal pathogens such as rusts require free water on leaves for infection (see Section 9.3). The rate at which most leaf diseases progress in the crop depends on the frequency and duration of rain or dew periods.

- Diseases that attack the roots or stem bases, such as crown rot, reduce the ability of plants to move water and nutrients into the developing grain. These diseases generally have more severe symptoms and larger effects on yield if plants are subject to water stress.

9.3 Rusts

Rusts grow and reproduce only on living plants and must continually infect new hosts. They survive over summer by infecting wild oats and volunteer 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 (‘green bridge’)
- spring conditions are suitably wet

Each factor depends on locality, so it is possible to assess rust risk in your locality.

Oat rusts have been very effective in breaking down resistance in commercially grown varieties of oats. As the pathotype of these diseases is constantly evolving, it is important that both growers and advisers are vigilant in the paddock, noting any cases of disease. Monitoring rust variability and forwarding samples to DAFWA is a crucial part of using genetic resistance to combat these diseases.

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UNE Agronomy of Grains Production course notes.

PBI Cobbity is home to the Australian Cereal Rust Control Program (ACRCP), established in 1973, which is funded largely by the grains industry, through the GRDC. Pathogenicity surveys are conducted on an annual basis to monitor pathogenic change in the cereal rust pathogen populations. 

Growers and agronomists are encouraged to submit samples for confirmation of rust identity and subsequent pathotype and virulence analyses. Samples should be sent in paper bags, not plastic to:

University of Sydney
Australian Rust Survey
Reply Paid 88076
Narellan NSW 2567

9.3.1 Stem rust (*Puccinia graminis f. sp. tritici*)

Figure 2: Stem rust in oats. (Photo: Robert Park)

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Stem rust is caused by the fungus *Puccinia graminis* f. sp. *tritici*. It can attack wheat, barley, rye and triticale. Oat stem rust will not attack wheat and wheat stem rust does not attack oats.\(^\text{10}\)

Stem rust is similar in appearance to leaf rust and they can often be confused.

Stem rust can cause major yield loss in forage oat crops grown for seed or hay production. Stem rust has had the ability to cause significant economic damage (50–100% of yield).\(^\text{11}\)

Stem rust produces reddish-brown spore masses in oval, elongated or spindle-shaped pustules on the stems and leaves, which appear about 7–10 days after infection. Unlike leaf rust, pustules erupt through both sides of the leaves. Ruptured pustules release spores.

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\(^\text{10}\) H Wallwork (2000) Cereal leaf and stem diseases. GRDC.

\(^\text{11}\) H Wallwork (2000) Cereal leaf and stem diseases. GRDC.


masses of stem rust spores, which are disseminated by wind and other carriers. It is darker in colour and has tended to be more of a problem in milling oats.

Stem rust develops at higher temperatures than the other oat ruts, within a range of 18–30°C. Spores require free moisture (dew, rain or irrigation) and take up to six hours to infect the plant, and pustules can be seen after 10–20 days of infection.

Inoculum must be present for the disease to develop. Practising crop hygiene by removing volunteer wheat, which forms a green bridge for the fungus through the summer, can eliminate or delay the onset of stem rust.

The disease is most common in high-rainfall areas in large bulky crops.

### 9.3.2 Leaf or crown rust (Puccinia coronata var. avenae)

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. It is closely related to leaf rust of wheat and barley, and has similar characteristics; however, oat, wheat and barley leaf rusts are specific strains that do not cross-infect the other cereals.

The characteristic symptom is the development of round to oblong, orange to yellow pustules, primarily on leaves but also on stems and heads, appearing about 7–10 days after infection. The powdery spore masses in the pustules are readily dislodged. The pustule areas turn black with age. 14

This disease is most severe under mild temperatures and moist conditions (e.g. in early autumn and early spring after wet, overcast conditions). This disease will build up very quickly on susceptible varieties. It will complete its life cycle and re-infect new leaves every 2–3 weeks. 15

Oat leaf rust is potentially a very damaging disease, reducing both grain and forage yields and forage quality and palatability. The fungus is carried over on volunteer oats and wild oats from season to season.

Control is similar to control for stem rust. Foliar fungicide registrations exist for control of this disease. 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. 16

Growers need to be aware that there are pathotypes of oat leaf rust present in Australia that can overcome resistance in all cultivars (not all in WA).

In early 2013, the appearance of a new pathotype (strain) of crown rust on oats from north-eastern Australia was reported that could attack the previously resistant cultivar, Drover. This left Aladdin as the only oat cultivar with resistance to this disease. Unfortunately, in late 2014, yet another pathotype of crown rust was found that can infect Aladdin, meaning that there are now no grazing oat cultivars with good levels of resistance to crown rust. Options for controlling this disease in grazing oats in north-eastern Australia are now very limited.17 Currently these strains do not occur in Western Australia (WA), but its existence elsewhere highlights why growers need to be vigilant with biosecurity, crop monitoring and submitting suspected rust samples to DAFWA.

New research being funded by the GRDC is fast-tracking the identification and incorporation of minor gene or adult plant resistance to crown rust in Australian oat germplasm. Intensive efforts are also under way to find new sources of resistance to stem rust that can be used in the development of new cultivars.

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Australian oat breeders are not alone in dealing with the challenges of rust. An oat rust forum was held at the University of Minnesota in the United States in February 2015 and brought together oat breeders, rust pathologists and industry stakeholders from North America and Australia. The meeting sought to develop a strategy for a community-wide approach to manage oat rust resistance and to set clear direction for funding agencies on how this effort should be supported. 18

Figure 5: Leaf rust (Puccinia coronata var. avenae) may first appear in crops as ‘hotspots’ from an initial infection. Hotspots in early spring allow leaf rusts to build up to very severe levels by the end of the season. (Photo: DAFWA)

Table 4: Tracking the breakdown of crown rust resistance in oats

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Year of release</th>
<th>Virulence first detected</th>
<th>Seedling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culgoa II</td>
<td>1991</td>
<td>1996</td>
<td>PcMortlock, PcCulgoa</td>
</tr>
<tr>
<td>Bettong</td>
<td>1992</td>
<td>2001</td>
<td>PCBett</td>
</tr>
<tr>
<td>Cleanleaf</td>
<td>1992</td>
<td>1995</td>
<td>Pc38, Pc39, Pc52</td>
</tr>
<tr>
<td>Barcoo</td>
<td>1996</td>
<td>2001</td>
<td>Pc39, Pc61, PcBett</td>
</tr>
<tr>
<td>Graza 68</td>
<td>1997</td>
<td>1999</td>
<td>Pc68</td>
</tr>
<tr>
<td>Moola</td>
<td>1998</td>
<td>1999</td>
<td>Pc68</td>
</tr>
<tr>
<td>Gwydin</td>
<td>1999</td>
<td>2001</td>
<td>Pc56</td>
</tr>
<tr>
<td>Warrego</td>
<td>1999</td>
<td>1998</td>
<td>Pc61+</td>
</tr>
<tr>
<td>Nugene</td>
<td>2000</td>
<td>2005</td>
<td>Pc48+</td>
</tr>
<tr>
<td>Taipan</td>
<td>2001</td>
<td>2005</td>
<td>Pc48+</td>
</tr>
<tr>
<td>Volta</td>
<td>2003</td>
<td>2008</td>
<td>Pc50, Pc68</td>
</tr>
<tr>
<td>Genie</td>
<td>2008</td>
<td>2010</td>
<td>Pc48, Pc56</td>
</tr>
<tr>
<td>Drover</td>
<td>2006</td>
<td>2012</td>
<td>Pc91</td>
</tr>
<tr>
<td>Galileo</td>
<td>2006</td>
<td>?</td>
<td>Not tested</td>
</tr>
<tr>
<td>Qantom</td>
<td>2006</td>
<td>2008</td>
<td>Pc50</td>
</tr>
<tr>
<td>Dawson</td>
<td>2009</td>
<td>?</td>
<td>Not tested</td>
</tr>
<tr>
<td>Aladdin</td>
<td>2001</td>
<td>Not yet detected</td>
<td>Pc50, Pc91</td>
</tr>
</tbody>
</table>

Management of leaf rust

The frequency and severity of losses from leaf rust infection can be reduced by a range of management strategies.

1. Grazing management. Losses from leaf rust can be reduced by grazing or cutting rusted crops as early as possible once leaf rust is conspicuous below the top two leaves on each tiller and before the disease becomes severe. Given suitable conditions, it takes 7–14 days for a rust spore to infect and produce more spores. During this period, oat plants will normally produce several new leaves on each tiller. During active growth of the crop, the upper canopy may remain free of rust symptoms. Therefore, it is necessary to regularly inspect the crop to monitor rust occurrence. If leaf rust is obvious below the top two leaves on each stem, the crop should be grazed or cut regardless of growth stage.

2. Cultivar selection. Select cultivars with good resistance to leaf rust. Although new varieties can become susceptible to rust after commercial release.

3. Planting time. Early sown oats have a higher risk of developing rust and other leaf diseases. However delaying sowing can come at a significant trade off in yield. Growers need to weigh up the risk of leaf disease against potential yield penalty for later sowing.

4. Crop hygiene. Control volunteer oat plants and wild oats. Both leaf and stem rust survive over summer between cropping seasons on volunteer oat plants, providing a continual supply of spores for fresh rust outbreaks each year.

5. Nutrition. Maintaining good soil nutrition and ensure that the crop is supplied with adequate potassium. Cereal crops deficient in potassium can be more vulnerable to leaf disease.

6. Fungicide. A number of fungicides are registered for control of leaf rust on oats (Table 5). In recent years the cost of older fungicides has dropped significantly (e.g. $3–$6/ha). This now makes fungicides a more economic way to manage leaf diseases. Crops should be monitored from the first node onwards for leaf disease levels. When managing rust it is important to apply fungicides early, before severe crop infection occurs. Fungicide sprays should aim to protect the top three leaves (Flag, Flag-1 and Flag-2) for as long as possible. If in doubt, seek advice from your consultant or agronomist. All registered fungicides have withholding periods for grazing, hay cutting and harvest. It is critical that these withholding periods are followed.

Table 5: Commercially available foliar fungicides for control of rust disease in cereals in Australia 2015

<table>
<thead>
<tr>
<th>Product name</th>
<th>Active ingredient</th>
<th>Company</th>
<th>Indicative cost</th>
<th>App rate (per ha)</th>
<th>App cost</th>
<th>Withholding period (grazing)</th>
<th>Registered for oats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilt 250SC</td>
<td>Propiconazole</td>
<td>Syngenta + Generic</td>
<td>$14/L</td>
<td>500 mL</td>
<td>$7/ha</td>
<td>7 days</td>
<td>Yes</td>
</tr>
<tr>
<td>Follicur 430SC</td>
<td>Tebuconazole</td>
<td>Bayer + Generic</td>
<td>$13/L</td>
<td>290 mL</td>
<td>$4/ha</td>
<td>14 days</td>
<td>Yes</td>
</tr>
<tr>
<td>Prosaro 420SC</td>
<td>Prothioconazole + Tebuconazole</td>
<td>Bayer</td>
<td>–</td>
<td>300 mL</td>
<td>–</td>
<td>14 days</td>
<td>Yes</td>
</tr>
<tr>
<td>Tilt Xtra</td>
<td>Propiconazole + Cyproconazole</td>
<td>Syngenta</td>
<td>$46/L</td>
<td>500 mL</td>
<td>$23/ha</td>
<td>21 days</td>
<td>No</td>
</tr>
<tr>
<td>Amistar Xtra</td>
<td>Azoxyostrobin + Cyproconazole</td>
<td>Syngenta</td>
<td>$54/L</td>
<td>800 mL</td>
<td>$43/ha</td>
<td>21 days</td>
<td>No</td>
</tr>
</tbody>
</table>

Figure 6: Close-up of leaf rust on leaves. (Photo: DAFWA)

Figure 7: Leaf rust in oats. (Photo: Bob Rees)

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Figure 8: Leaf rust in oats. (Photo: Hugh Wallwork)\textsuperscript{21}

Figure 9: Leaf rust in oats. (Photo: Hugh Wallwork)\textsuperscript{22}

\textsuperscript{21} H Wallwork (2000) Cereal leaf and stem diseases. GRDC.

\textsuperscript{22} H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
9.4 Barley yellow dwarf virus

Symptoms of barley yellow dwarf virus (BYDV) can be confused with those caused by nutrient deficiencies, waterlogging or other plant stresses that cause yellowing, reddening and striping of leaves. Leaf symptoms differ between wheat, oats and barley. The severity depends on the age of the plant at infection, environmental conditions, the virus present and the cereal variety involved.  

In oats, the symptoms of BYDV infection are very striking. Most varieties develop reddening (crimson-pink) of the leaves from the tips down, which sometimes begins as blotching especially on older leaves. Young leaves often have yellow stripes. However, some varieties only develop a yellow or orange coloration. Stunting, an increase in sterile tillers or abortion of florets result in low grain yields and shrivelled grain. As for wheat and barley the effect of this virus is greatest in early-infected plants.

In 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 tip-reddening and death of older leaves.

Distribution of infection within the paddock is as for all viruses, that being patchy, but in some cases the whole crop may show symptoms.

Aphids are the vector or vehicle of transmission of the disease (see Section 7. Insects).

Use the following control methods, among others, to lessen the severity of the disease:

- Sow resistant varieties.
- Use an appropriate seed dressing that has an effect on aphids.
- Use an insecticide in-crop to prevent build-up of aphid numbers if aphid risk is high.

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Figure 11: Barley yellow dwarf virus in oats. (Photo: Hugh Wallwork)  

Figure 12: Barley yellow dwarf virus in oats, showing sterility (blasting) at stem base. (Photo: Terry Hahn)  

Figure 13: Stunting occurs when seedlings are infected. (Photo: Andrew Barr)  

29 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
9.5 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. Yield losses in crops affected by bare patches can be over 50% and crops with uneven growth may lose up to 20%.

In cereals, oats are most tolerant, followed by triticale, wheat and then barley, which is the most intolerant.

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.

Figure 15: Above-ground symptoms of crop unevenness (left) are seen when Rhizoctonia damages crown roots, even when seminal roots (right) escape the infection.
Management of rhizoctonia requires an integrated approach to reduce inoculum and control infection and impact on yield.

Rhizoctonia inoculum levels will be greatest following cereals, 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.

Rhizoctonia disease is often a problem in low-fertility, sandy or calcareous soils of southern and western Australia.  

Table 6: Management of rhizoctonia disease in cereal crops

<table>
<thead>
<tr>
<th>Year 1 crop (Sept-Nov)</th>
<th>Summer (Dec-April)</th>
<th>Season break (April-May)</th>
<th>Year 2 crop (May-August)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check for inoculum build-up</td>
<td>Facilitate inoculum decline</td>
<td>Select appropriate crop</td>
<td>Manage infection and disease impact through management practices</td>
</tr>
</tbody>
</table>

- 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, inoculum levels do not change
- Adopt practices that prolong soil moisture in the upper layers (e.g. stubble retention and no cultivation), which helps maintain higher microbial activity
- Consider soil testing for pathogen inoculum level (PreDicta B™ test in Feb-March), to identify high disease risk paddocks and if disease is not confirmed in the previous cereal crop, especially if planning to sow cereals back on cereals
- 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
- Use soil openers that disturb soil below the seed to facilitate root growth – knife points reduce disease risk compared to discs
- Avoid pre-sowing SU herbicides,
- Supply adequate nutrition (N, P and trace elements) to encourage healthy seedling growth
- Avoid stubble incorporation at sowing to minimize N deficiency in seedlings
- Consider seed dressings and banding fungicides to reduce yield loss
- Remove grassy weeds early
- Apply nutrient/trace elements, foliar in crop, if required

9.6 Crown rot (Fusarium graminearum)

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. Cereal-on-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 grain filling. Yield loss can be up to 90% in durum and 50% in bread wheat or barley with increased screening.

Oat crops are considered ‘symptomless hosts’ of crown rot that may contribute to the maintenance of inoculum.

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

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GRDC (2016) Rhizoctonia Tips and Tactics–Western Region.
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 1989 was greatest after two prior wheat crops and lowest after one or two years of mown oats.

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.  31


9.7 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.  32

These diseases can reduce the appearance of hay and hence downgrade its value.

Using these control measures can help avoid blights:

- Avoid susceptible varieties, referring to your local state variety sowing guide for resistance ratings.
- Use seed from uninfected crops.
- Destroy infected oat stubbles.

9.7.1 Stripe blight (Pseudomonas syringae pv. striafaciens):

Bacterial stripe blight is the main blight disease in oats. 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. 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.  33

The bacteria multiply in huge numbers in the stripes and bacterial slime can sometimes occur on the lesions. When a lesion is cut transversely and the leaf put on a microscope slide, a faint white slime can sometimes be seen coming from the leaf veins. Bacterial ooze from veins is easily observed under a microscope.  34

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32 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.

33 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.

9.7.2 Halo blight: \textit{(Pseudomonas syringae pv. coronafaciens)}

Halo blight causes light green or buff-coloured, oval-shaped spots surrounded by a pale halo with a water-soaked appearance up to 10 mm in diameter. The centre of the spots changes to a straw or brown colour, and a yellow-green halo develops in the surrounding leaf. Later the patches turn brown, join together and form irregular blotches. 37

\footnotesize

36 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
37 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
Figure 18: Halo blight (bacterial blight) in oats. (Photo: Bob Rees)  

Figure 19: Halo blight (bacterial blight) in oats, showing water-soaked halo. (Photo: Hugh Wallwork)  

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29 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
9.8 Other diseases

9.8.1 Red leather leaf (Spermospora avenae)

The first recorded incidence of this disease was in Victoria in 1978. The disease is characterised by small lesions with light centres that are surrounded by a bright-red or red-brown colour that may extend along a large area of the leaf. The central green area later becomes necrotic and frequently disintegrates to leave a ragged hole surrounded by a reddish-brown border. Leaf margins and tips can die prematurely. Infected leaves can become stiff, may be slightly rolled and will assume a leathery appearance. Plants may be slightly stunted.

In severe cases, whole fields can take on a brilliant red colour in winter, as reported in the Pacific north-west of the United States.

Survival of the fungus is in plant debris. The disease occurs in high-rainfall areas with high humidity.

The severity of the disease is not known, although large yield losses are likely where the foliage is severely damaged.

Control measures:

- Avoid susceptible varieties in high-risk areas.
- Use fungicides that have proven to suppress the spread of this disease.

Figure 20: Red leather leaf in oats. (Photo: Andrew Barr)

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40 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
42 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
43 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
SECTION 9

OATS - Diseases

Figure 21: Red leather leaf in oats. (Photo: Hugh Wallwork) "" 

9.8.2 Septoria blotch (Phaeosphaeria avenaria)

Septoria blotch is the most common oat disease in Western Australia; it is less common in New South Wales and Queensland. It is most severe in early-sown crops in high-rainfall areas. Septoria blotch survives between growing seasons on oat stubble.

This disease 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. 45

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. 46

The disease is also known as speckled blotch and septoria black stem. It can occur on any aboveground part of the oat plant.

It reduces yield, quality and appearance of hay. Septoria is more likely to be a problem in early-sown susceptible crops that are exposed to frequent rainfall, which disperses rain-splashed spores. 47

Septoria blotch affects leaves, inflorescence and seed. Leaf lesions are small, dark brown to purple, and oval to elongated. They are restricted and distinct at first but may enlarge to cover most of the leaf. They enlarge to light-brown or dark-brown blotches up to 2 cm, with surrounding yellow areas. They can coalesce and kill the entire leaf.

Infections on the leaf sheath can grow onto the stem to produce greyish-brown or shiny black lesions. Severely affected tillers can lodge.

References:

44 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
Dark-brown blotches can develop on the florets and seed. Small brown to black fruiting bodies (pycnidia) develop in lesions. Sometimes these are prominent but often are difficult to see, even with a magnifying lens. 48

The fungus produces its sexual stage in fruiting bodies, called perithecia, on oat stubble in autumn and releases wind-borne ascospores when wetted by rain or heavy dew in autumn and winter. The ascospores can travel long distances by wind to infect young oat plants. Ascospores are probably the chief source of primary inoculum, although the epidemiology has not been studied under Australian conditions.

Infections in the crop produce a second type of fruiting body, the pycnidia, in the leaf lesions. Asexual spores called pycnidiospores ooze from pycnidia in wet weather and are spread short distances (< 1 m) by rain splash. Pycnidiospores are the secondary inoculum; their number and the number of generations of the asexual stage in the crop determine the severity of the epidemic. Frequent rain favours cycles of infection by pycnidiospores.

These are the current recommendations for control of septoria blotch:

- Sow partially resistant varieties.
- Avoid sowing early in high-rainfall areas.
- Burn or bury infested oat straw when oat crops are to be sown nearby.
- Do not sow susceptible oats continuously in the same or neighbouring paddocks.

Foliar fungicide registrations exist for control of this disease. 49

Figure 22: Septoria blotch in oats, showing the brown blotches surrounded by a yellow area. (Photo: Bob Rees) 50


50 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
9.8.3 Loose smut (*Ustilago avenae*) and covered smut (*Ustilago hordei*)

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.

Affected plants may be slightly taller and heads emerge earlier than the main part of the crop. Each spikelet, including the chaff, is replaced with a spore mass that is at first covered with a fine white or grey membrane. This membrane soon bursts, releasing the spores to contaminate healthy heads and leaving a bare stalk or rachis on the infected plant.  

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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. 54

Smuts have exceeded 50% incidence in susceptible varieties when no control is applied. 55

Control measures:
- Low cost by seed treatments.
- Do not sow seed harvested from crops with obvious smut.
- Avoid growing susceptible varieties.

![Figure 25: Damaged oat floret from smut infestation. (Photo: Hugh Wallwork)](image)

54 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
56 H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
9.8.4 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 kernels are similar in size to seed, they will contaminate grain harvested from crops.

H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
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. Ergot kernels 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.

The causal fungus survives in and on soil for several years. These kernels 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.  

Figure 28: Ergot in oats. (Photo: Ken Holden)

More Information on oat diseases, especially in hay production, can be found in:


H Wallwork (2000) Cereal leaf and stem diseases. GRDC.
SECTION 10

Canopy management

10.1 Canopy management

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

Adopting canopy-management principles and avoiding excessively vegetative crops may enable growers to achieve a better match of canopy size with yield potential, as defined by the available water. Other than sowing date, plant population is a starting point for the grower to influence the size and duration of the crop canopy.

The concept of canopy management has been primarily developed in Europe and New Zealand—both different production environments from those typically found in most grain-producing regions of Australia.

Canopy management includes a range of crop-management tools for crop growth and development, to maintain canopy size and duration, thereby optimising photosynthetic capacity and grain production. One of the main tools available to growers to manage the crop canopy is the rate and timing of applied fertiliser nitrogen (N).

10.1.1 Importance of canopy management

If the canopy becomes too big, it competes with the growing heads for resources, especially during the critical 30-day period before flowering. This is when the main yield component (grain number per unit area) is set. Increased competition from the canopy with the head may reduce yield by reducing the number of grains that survive for grainfill.

After flowering, temperature and evaporative demand increase rapidly. If there is not enough soil moisture, the canopy dies faster than the grain develops and results in small grain.

Excessive N application and high seeding rates are the main causes of excessive vegetative production. Unfortunately, optimum N and seeding rates are season-dependent. Under drought conditions, N application and seeding rates that would be regarded as inadequate under normal conditions may maximise yield, whereas higher input rates may result in progressively lower yields. Alternatively, in years of above-average rainfall, yield may be compromised with normal input rates.

The extreme of this scenario of excessive early growth is haying-off, where a large amount of biomass is produced, using a lot of water and resources. Then, later in the season, there is insufficient moisture to keep the canopy photosynthesising and not enough stored water-soluble carbohydrates to fill the grain. Therefore, grain size and yield decrease.


To attain maximum yield, it is important to achieve a balance between biomass and resources. The main factors that can be managed are:

- plant population
- row spacing
- inputs of N
- sowing date
- weed, pest and disease control
- plant growth regulation with grazing or specific plant growth regulator products

Of these, the most important to canopy management are N, row spacing and plant population.

### 10.1.2 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. The challenge for growers is to find the balance of optimising DM removal without compromising grain production.

### 10.1.3 Key stages for disease control and canopy management

The optimum timing for foliar-applied fungicides in cereals is from the start of stem elongation to ear emergence (GS30–59).

The optimum time for spraying a fungicide to protect a leaf is at full emergence. Leaves not emerged at the time of application will not be properly protected. Leaves will usually be free from foliar disease on emergence. The time between when the disease spores land on the leaf and when an infection point is visible is called the latent period or latent phase. This period is temperature driven and differs between diseases. It can be as short as seven days for diseases such as powdery mildew.

It was common 5–10 years ago to make decisions on fungicide applications for foliar disease based on thresholds of infection. These thresholds varied from 1% to 5% of plants infected. However, growers and advisers found that in the paddock it was difficult to calculate when this disease threshold had been reached, not least because of the sporadic nature of the initial foci of the disease. In addition, by the time growers realised that the threshold had been reached and carried out the spray operation, the crops were badly infected. When crops that are badly infected with stripe rust are treated with fungicides, the control is poor because fungicides work better as protectants than as curatives.
SECTION 11

Crop desiccation/spray out

Not applicable for this crop.
SECTION 12

Harvest

Australian oats are harvested during October to December by direct heading as soon as the crop is ripe (Figure 1). 1

While the direct heading of grain is the cheapest method of harvesting, the danger is that 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.

In environments that regularly receive pre-harvest rainfall, oats should be harvested at a moisture content above 12% and below 18% and then placed under aeration to maintain quality or passed through a grain dryer to reduce the moisture content to a level that can be safely stored.

Prioritise the varieties that are likely to shed or lodge. Delays can lead to significant lodging and shedding due to crop movement in the wind.

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 pick-up. Fitting crop lifters to the harvester front can make a larger difference to harvest yield and efficiency.

Consider management of stubble for the following crop (straw length and spreading) and collection of weed seeds for herbicide resistance management in an effort to reduce the weed burden for the following crop.

Care must be taken in harvesting milling varieties to minimise the amount of dehulled grain. Harvester settings can be adjusted to manage the amount of dehulled grains.

Swathing involves cutting the crop and placing it in rows held together by interlaced straws, supported above the ground by the remaining stubble. It can be considered as an option where:

- the crop is uneven in maturity, or the climate does not allow for rapid drying of the grain naturally
- there is a risk of crop losses from shedding and lodging

High-yielding crops may gain more from swathing than low-yielding crops. Generally, crops expected to yield less than 2 t/ha should not be swathed. Picking up swathed 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 swathed. Heads on the ground may sprout and attempts to pick up heads that are lying close to the soil surface will pick up soil. 2

12.1 Wet harvest issues and management

Ideally, harvest begins as soon as the crop is mature or ripe. A cereal crop can be harvested any time after it reaches physiological maturity and dries down from about 20% moisture content (MC). In most situations, however, harvest does not begin as soon as the crop is ready. The actual start of harvest is usually dictated by the options each grain grower has available to deal with high-moisture grain. CBH receival standards in Western Australia (WA) indicate moisture of oats must be <13%.

Oats can often be the first crop harvested after a rainfall event during harvest because the architecture of the head (grain hanging down) minimises the amount of moisture taken up by the groat.

12.1.1 Delaying harvest

Every day a crop stands in the paddock it is exposed to ongoing yield loss and quality degradation (Figure 1). 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). Research on this topic in the 1980s at Esperance, by M Bolland and J Richardson (WA Department of Agriculture), revealed daily DM losses for wheat of 0.18%–0.53% DM and for barley of 0.25%–0.75% DM (depending on the season and distance from the ocean).

Most growers have also experienced some form of grain-quality loss due to delayed harvest. Barley becomes darker in colour, reducing its acceptance for malting grade; wheat sprouts, reducing its flour-quality characteristics; 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.

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12.2 Fire prevention

With research showing an average of 12 harvesters are burned to the ground every year in Australia, agricultural engineers encourage care in keeping headers clean to reduce the potential for crop and machinery losses (Figure 3).

Figure 3: Keeping headers clean can reduce the risk of fire. (Photo: Rebecca Thyer)

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.
- Regular removal of flammable material from the engine bay is urged.  

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12.3 Receival standards

For up-to-date information on oats trading standards from Grain Trade Australia, visit


12.4 Harvest weed seed management (HWSM)

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.

12.4.1 Intercepting annual weed seed

WA has been leading the way in the fight against resistant weeds, where high frequencies of herbicide-resistant weed populations have been driving farming practices for the last decade. Techniques have been developed to target 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 1). Additionally, for some of these species, such as wild radish, high levels of seed retention are maintained over much of the harvest period (Figure 4). Therefore, the collection and management of the weed-seed-bearing chaff fraction can result in significant reductions in population densities of annual weeds.

Table 1: Proportion of total seed production retained above a low harvest cutting height (15 cm)

<table>
<thead>
<tr>
<th>Species</th>
<th>Seed retention above 15 cm (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual ryegrass</td>
<td>88</td>
</tr>
<tr>
<td>Wild radish</td>
<td>99</td>
</tr>
<tr>
<td>Brome grass</td>
<td>73</td>
</tr>
<tr>
<td>Wild oats</td>
<td>85</td>
</tr>
</tbody>
</table>

Figure 4: Seed retention above a harvest height of 15 cm over the first four weeks of harvest for the major weeds of WA wheat crops.

WA farmers have driven the development of several systems such as windrow burning, and chaff carts that reduce inputs of annual ryegrass, wild radish, wild oats and brome grass into the seedbank. The adoption of these systems has been critical for the continuation of intensive cropping systems across Australia. 6

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 (e.g. ‘beer can’ height).

12.4.2 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. 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 (Figures 5 and 6). 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. 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. 7

When burning oat windrows it is common for the whole paddock to burn due to the heavier stubble load. This must be taken into account when considering windrow burning.

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Figure 5: Harvest in action—producing narrow chaff rows for burning in the following autumn. (Photo: A. Storrie)

Figure 6: Windrow burning. (Photo: Penny Heuston)
12.4.3 Chaff carts

Chaff carts are towed behind headers during harvest to collect the chaff fraction as it exits the harvester (Figure 7). Collected piles of chaff are then burnt the following autumn or used as a source of stock feed.

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 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 burned in the following autumn. In some instances, though, chaff is removed from the paddock and used as a source of feed for livestock.

12.4.4 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.

The bale-direct system was developed by the Shields family in Wongan Hills as a means of improving straw hay production. 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.

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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 and access to market.  


**12.4.5 Chaff grinding—the Harrington Seed Destructor**

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, WA, 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.  

Evaluation under commercial harvest conditions by AHRI has determined that the HSD will destroy ≥95% of annual weed seed during harvest. With the efficacy of the HSD system well established, its development has progressed to commercial production.  

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A new chaff grinder that is integrated into the back of the header is nearing commercial production stage. It has similar principles to the HSD and it was developed at the University of South Australia.

### 12.4.6 Cutting oaten hay to reduce weed seeds

If you have a weedy oat crop, cutting this for hay can be a viable option to clean up the paddock and prevent a weed blow-out.

Usually oat crops planted for grain have a thicker stem diameter than that planted for hay and can struggle to make premium export hay due to the lower seeding rate. However, export and domestic hay can tolerate a relatively high level of ryegrass without compromising hay quality.

While export hay regularly has high returns, it can be a time-consuming and expensive exercise if you don’t have your own equipment, so it is important to make sure contractors are available and to undertake your own market research.¹⁶

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
- Preserve soil moisture
- Maintain or improve 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.

¹⁶ Personal comms G. Knell 2016
An on-farm storage system designed for good hygiene that includes aeration and sealable silos for fumigation is essential for growers who wish to maximise their returns from cereal grains. Without sealable silos, growers could be contributing to Australia’s problem of insect resistance to phosphine, the most common fumigant used in the Australian grain industry. Without aeration cooling, growers see warmer grain temperatures in storage, favouring rapid breeding of insect pests and negative impacts to grain quality.

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

**Figure 1:** Storage aeration is important for maintaining grain quality and protecting Australia’s markets. (Photo: QDAFF)

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

Growers should aim for stored oats grain temperatures of 20 to 23°C during summer and less than 15°C in winter. On-farm storage trials in New South Wales and southern Queensland demonstrated how properly managed, aerated silos, will achieve average summer time grain storage temperature of 20°C. This reduces pest and grain quality problems.

13.1 How to store oats on-farm

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

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

Table 1: Advantages and disadvantages of grain storage options

<table>
<thead>
<tr>
<th>Storage type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Gas-tight sealable silo | • Gas-tight sealable status allows phosphine and controlled atmosphere options to control insects  
  • Easily aerated with fans  
  • Fabricated on-site or off-site and transported  
  • Capacity from 15 t up to 3000 t  
  • Up to 25 years plus service life  
  • Simple in-loading and out-loading  
  • Easily administered hygiene (cone base particularly)  
  • Can be used multiple times in-season | • Higher initial investment required  
  • Seals must be maintained  
  • Requires an annual test to check gas-tight sealing |
| Non-sealable silo     | • Easily aerated with fans  
  • 7–10% cheaper than sealed silos  
  • Capacity from 15 tonnes up to 3,000 tonnes  
  • Up to 25–35 years of service life  
  • Can be used multiple times in-season | Grain in non-sealable silo cannot be fumigated for pest control — see phosphine label  
Insect control options are limited, that is, protectants in eastern states and Dryacide in Western Australia. |
| Grain storage bags    | • Low initial cost  
  • Can be laid on a prepared pad in the paddock  
  • Provide harvest logistics support  
  • Can provide segregation options  
  • Are all ground operated  
  • Can accommodate high-yielding seasons | Requires purchase or lease of loader and unloader  
Increased risk of grain damage beyond short-term storage (typically three months)  
Limited insect control options, fumigation only possible under specific protocols  
Requires regular inspection and maintenance which needs to be budgeted for  
Aeration of grain in bags is not practical in most circumstances  
Should be fenced off from domestic and native animals  
Bags and grain 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 of bag |

<table>
<thead>
<tr>
<th>Storage type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain storage</td>
<td>• Can be used for dual purposes</td>
<td>• Aeration systems require specific design</td>
</tr>
<tr>
<td>sheds</td>
<td>• 30 year plus service life</td>
<td>• Risk of contamination from dual-purpose use</td>
</tr>
<tr>
<td></td>
<td>• Low cost per stored tonne</td>
<td>• Difficult to seal for fumigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Vermin control may be difficult</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited insect control options without sealing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Difficult to unload</td>
</tr>
</tbody>
</table>

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

When growers use aerated, sealable silos, they should be pressure-tested once a year to check for damaged seals on openings or other fittings. Storages must be able to be sealed properly for the short period (e.g. 7, 10 or 20 days – see label) while fumigation is in progress. This ensures high phosphine gas concentrations are held long enough to give an effective kill of all insect pests.

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 phosphate. This resistance has come about because of the prevalence of storages that are poorly sealed or unsealed during fumigation. 3

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

Research shows that fumigating in a storage that is not gas-tight does not achieve a sufficient concentration of fumigant for long enough to kill pests at all life-cycle stages. For effective phosphine fumigation (Figure 2), a minimum gas concentration of 300 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 (Figure 3). The rest of the silo also suffers from reduced gas levels. 4

![Figure 2: Good gas concentration maintained over time in gas-tight sealable silo. (Source: QDAFF)](image-url)

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 in storage.

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

It is important to be aware of the differences between aeration systems used for ‘aeration cooling’ and aeration systems designed specifically to achieve reliable ‘aeration drying’. Aeration drying systems require much higher airflow rates. Serious grain damage has occurred when fan performance has not met the required airflow rates as measured in litres per second per tonne (L/s.t).

If aeration drying of grain is attempted with elevated moisture levels using an inadequate airflow rate and/or a poor system design, sections of the storage can develop very high moisture and grain temperatures. With low airflow rates, moisture drying fronts move too slowly to prevent grain spoilage. Grain-quality losses from moulds and heat occur rapidly. This type of damage often makes the grain difficult to sell and may cause physical damage to the silo itself.

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

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

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Figure 3: Gas concentration is poor over the 10 days in a non-gas-tight silo. (Source: QDAFF)

To find out more about how to pressure-test silos, visit ‘Fumigating with phosphine, other fumigants and controlled atmospheres’ at DAFWA (2015) Oats: harvesting, swathing and grain storage.

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13.2 Hygiene

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

In one year, a bag of infested grain can produce more than one million insects, which can walk and fly to other grain storages where they will start new infestations (Figure 4). 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 storages 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 insect predators.

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

A trial in Queensland revealed more than 1000 lesser grain borers (*Rhyzopertha dominica*) (Figure 5) in the first 40 L of grain through a harvester at the start of harvest; this harvester was considered reasonably clean at the end of the previous sorghum harvest. Further studies in Queensland revealed that insects are least mobile during the colder winter months. Clean in and around silos, equipment and sheds on farm in

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the winter months before early spring. This will reduce insect pest numbers during the warmer months around harvest time.

Figure 5: Lesser grain borer - Ryzopertha dominica. (Photo: QDAFF)

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

After grain storages and handling equipment are cleaned, they can 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 of 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. DE is generally acceptable as a structural treatment for all storages used for cereals, pulses, oilseeds and organic grains. However, before using any treatment, including DE, always check with grain buyers first and use it according to the label.

Although shown on the DE label, the treatment of grain with DE dust (rate 1 kg/t) is generally not accepted by grain handlers or buyers.

Cereal grains buyers may accept other approved chemical insecticide structural treatments to storages, but growers should avoid using them, or wash the storage out, before storing oilseeds and pulses.

There are a number of export and domestic grain markets that require ‘pesticide residue free’ grain (PRF), so growers are advised to check with potential grain buyers before using grain protectants or structural treatments.

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

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

Markets that require PRF grain do not rule out the use of some fumigants, including phosphine (Figure 6). However, PRF grain should not have any chemical residues from treatments that are applied directly to the grain as grain protectants. Before using a grain protectant or fumigant, growers need to check with prospective buyers, as the use of some chemical may exclude grain from certain markets.

Although phosphine has some pest resistance issues, it is widely accepted as having no chemical residue issues. The grain industry has adopted a voluntary strategy to manage the build-up of phosphine resistance in pests. Its core recommendations are to limit the number of conventional phosphine fumigations on undisturbed grain to three per year, and to employ a break strategy. The break is provided by moving the grain to eliminate pockets where the fumigant may fail to penetrate, and by retreating it with an alternative fumigant or protectant.

![Figure 6: Phosphine is widely accepted as having no residue issues. (Photo: QDAFF)](image)

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

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

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

Effective phosphine fumigation can be achieved by placing the chemical at the rate directed on the label onto a tray and hanging it in the top of a pressure-tested, sealable silo. A ground-level application system is also an efficient method and these can be combined with a silo recirculation system on larger silos to improve the speed of gas distribution. After fumigation, grain should be ventilated for a minimum of 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 stockfeed. The total time required for fumigating ranges from 7 to 20 days depending on grain temperature and the storage structure.


Two new grain protectants have recently become available. These include:

- **Conserve On-Farm**: Has three active ingredients (chlorpyrifos-methyl 550 g/L, S-methoprene 30 g/L, spinosad 120 g/L) to control most major insect pests of stored grain, including the resistant lesser grain borer. The maximum residue limits have been established with key trading partners and there are no issues with meat residue bioaccumulation. A ‘product stewardship’ program from Dow AgroScience is in place to ensure correct use of the product.

- **K-Obiol** (active ingredients deltamethrin 50 g/L, piperonyl butoxide 400 g/L): Features acceptable efficacy against the common storage pest lesser grain borer, which has developed widespread resistance to current insecticides. Insect resistance surveys in the past consistently detected low levels of deltamethrin-resistant insect strains in the industry. This is a warning that resistant populations could increase quickly with widespread excessive use of one product. A ‘product stewardship’ program has been developed to ensure correct use of the product.

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

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

Controlled atmosphere/non-chemical treatment options include:

- **Carbon dioxide (CO2)**: Involves displacing the oxygen inside a gas-tight silo with a high concentration of CO2 combined with a low oxygen atmosphere lethal to grain pests. To achieve a complete kill of all grain pests at all life stages, CO2 must be maintained at a minimum concentration of 35% for 15 days.

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• Nitrogen (N$_2$): This also displaces the oxygen inside a gas-tight silo with a high concentration of N$_2$ to create a low oxygen atmosphere lethal to grain pests. It provides insect control and quality preservation without chemicals. It is safe to use and environmentally acceptable. The main operating cost is electricity used by the equipment to produce N gas. This process of flushing out oxygen from a silo can take many hours. There is also a high capital cost of purchasing this equipment. The process uses pressure swing adsorption or membrane technology to produce N$_2$. There are no residues, so grains can be traded at any time.

Silo bags as well as silos can be fumigated (Figure 7). Research conducted by Andrew Ridley and Philip Burrill from DAFF Queensland and Queensland farmer Chris Cook found that sufficient concentrations of phosphine can be maintained for the required time to successfully fumigate grain in a silo bag. Trials on a typical, 75-m-long bag containing approximately 230 t of grain successfully controlled all life stages of the lesser grain borer.

![Figure 7: Silo bags can also be fumigated. (Photo: QDAFF)](image)

When using phosphine in silos or silo bags it is illegal to mix phosphine tablets directly with grain due to tablet residue issues. As trays in silo bags are not practical, tablets are placed in perforated conduit to contain tablets and spent dust. The 1 m tubes are speared horizontally into the silo bag and removed at the end of the fumigation. Trial results suggest that the spears should be no more than 7 m apart and fumigation should occur over 12–14 days (Figure 8). In previous trials when spears were spaced 12 m apart, the phosphine gas took too long to diffuse throughout the whole bag. 11

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

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 (Figure 9). Wheat at typical harvest temperatures of 28–35°C and moisture content greater than 13–14% provides ideal conditions for mould and insect growth (Table 2).  

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

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

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Table 2: The effect of grain temperature on insects and mould. (Source: Kondinin Group)

<table>
<thead>
<tr>
<th>Grain temperature (°C)</th>
<th>Insect and mould development</th>
<th>Grain moisture content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40–55</td>
<td>Seed damage occurs, reducing viability</td>
<td></td>
</tr>
<tr>
<td>30–40</td>
<td>Mould and insects are prolific</td>
<td>&gt;18</td>
</tr>
<tr>
<td>25–30</td>
<td>Mould and insects active</td>
<td>13–18</td>
</tr>
<tr>
<td>20–25</td>
<td>Mould development is limited</td>
<td>10–13</td>
</tr>
<tr>
<td>18–20</td>
<td>Young insects stop developing</td>
<td>9</td>
</tr>
<tr>
<td>&lt;15</td>
<td>Most insects stop reproducing, mould stops developing</td>
<td>&lt;8</td>
</tr>
</tbody>
</table>

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

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

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

Research by the NSW Department of Primary Industries has shown that if grain temperatures are kept below 15°C it can protect seed quality and stop all major insect infestations. Aeration slows the rate of deterioration of grain even if the moisture content is in the 12.5–14% range for a short period.

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

![Figure 10: Effects of temperature and moisture on stored grain.](http://www.grdc.com.au/~media/36D51B725EF44EC892BCD3C0A9F4602C.pdf)


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

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

Aeration drying when correctly set up forces large volumes of air through the grain in storage and slowly removes moisture. Aeration can be done in a purpose-built drying silo or a partly filled silo with high-capacity aeration fans.

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

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

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

13.5 Monitoring oats

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

Oats for domestic or export use must not contain live storage pests, and feed grades can lose nutritional value and palatability through infestations. Keeping storage pests out of planting seed grain is also important because they can reduce the germination and vigour quality of seed with serious consequences for the next oats crop.
When monitoring stored grain by sieving, trapping and quality inspections, growers should keep monthly records. If possible, grain temperature should also be checked regularly. Any grain treatments, such as fumigations, should also be recorded.  

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

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


Here are some basic points to follow when monitoring for insect pests in your grain:

- Sample and sieve grain from the top and bottom of grain storages every month (four weeks) for early pest detection. Pitfall or probe traps installed in the top of the grain store will also help early detection of storage pests.

- Holding the insect sieve in the sunlight, this will encourage insect movement, making pests easier to see. Sieve samples on to a white tray, again to make small insects easier to see. Sieves for pest detection should have 2 mm mesh and need to hold at least 1 L of grain.

- To help identify live grain pests, place them into a clean glass container. Warm the jar in the sun for two minutes to encourage insect activity. Weevils and saw-toothed grain beetles can walk up the walls of the glass easily, but flour beetles and lesser grain borer cannot. Look closely at the insects walking up the glass—weevils have a curved snout at the front and saw-toothed grain beetles do not.


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

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

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14.1 Frost issues for oats

Frost occurs on clear nights in early spring when the air temperature drops to 2°C or lower. 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. ¹

14.1.1 Industry costs

The real cost of frost is a combination of the actual cost, due to both reduced yield and quality, and the hidden cost of management tactics used to try to minimise frost risk. The hidden costs associated with conservative management to minimise frost risk include:

- delayed sowing and its associated yield reduction
- sowing less profitable crops such as barley and oats
- avoiding cropping on the valley floors, which also contain some of the most productive parts of the landscape.

The historical incidence of frost varies strongly across the agricultural regions of Western Australia (WA), with greatest occurrence in the central, eastern and southern regions. Northern and coastal regions in general have a lower risk. ²

14.1.2 Impacts

Frost does not have any direct off-site impact on resource, biosecurity, economy or industry.

Frosts can have quite a large social impact as it happens so suddenly, unlike drought, which growers can adapt to mentally and financially by reducing further inputs as it unfolds. ³

14.1.3 Frost tolerance of crops

Growers can lower frost risk in paddocks that frequently experience frost by growing either frost-tolerant crops or growing more pastures. If a grower wishes to sow a crop in a high-risk paddock, either for rotational or price reasons, they can choose a more frost-tolerant crop, as this will help reduce losses from frost damage. ⁴

Frost-tolerant crops

Oats is regarded as the cereal crop least susceptible to frost damage, followed by cereal rye, barley, wheat and triticale. Oats is thought to be about 4°C more tolerant than wheat, while barley is thought to be about 2°C more tolerant.  

<table>
<thead>
<tr>
<th>Crop in order of tolerance</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oats</td>
<td>About 4°C more tolerant than wheat</td>
</tr>
<tr>
<td>Cereal rye</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>About 2°C more tolerant than wheat</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
</tr>
<tr>
<td>Triticale</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Order of frost tolerance of cereal crops

Canola is quite susceptible to frost and least tolerant to frost damage from flowering to the clear watery stage (about 60% moisture). Field peas are the most frost-susceptible pulse crop, followed by faba beans and lupins.

14.1.4 Growing oaten hay on 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. 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.  

![Growing hay on frost-prone paddocks](https://www.agric.wa.gov.au/frost/frost-and-cropping)

Figure 1: Growing hay on frost-prone paddocks can benefit farming systems and whole farm profitability. (Photos. DAFWA)

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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.  

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.  

Management options
By sowing oats in frost-prone paddocks, the expectation is that frost damage will occur if a severe frost event is experienced after ear emergence.

Sustainability and off-site impacts
Hay crops remove greater amounts of potassium (about 10 kg/t) than other cereals harvested for grain. If potassium deficiency is diagnosed in a crop, applying 40 to 80 kg/ha as muriate of potash near seeding may give an economic yield increase if applied early enough.

References

14.2 Waterlogging and salinity

14.2.1 Diagnosing waterlogging and salinity in oats
Waterlogging and salinity often occur together. Oats are very tolerant of waterlogging but are more susceptible to salinity damage than wheat and barley.

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Figure 2: Nitrogen deficiency symptoms. (Photo: DAFWA)

Figure 3: Old leaf discolouration and brown seminal root. (Photo: DAFWA)

Figure 4: Old leaf browning, necrosis from waterlogging and mild salinity. (Photo: DAFWA)
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.

Plant: waterlogging symptoms
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. 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.

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.

Premature death.

What else could it be?

<table>
<thead>
<tr>
<th>Condition</th>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosing nitrogen deficiency in oats</td>
<td>Similar foliar symptoms</td>
<td>No root browning and less old leaf necrosis and symptoms are not confined to wet or saline areas.</td>
</tr>
</tbody>
</table>

Where does it 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.

A number of situations increase the damage caused by waterlogging damage.
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, high-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.

Management strategies
Avoid sowing on saline areas.
Sow as early as possible with a higher seeding rate if there is a waterlogging risk.
On waterlogged sites treating crops with liquid UAN is a quicker and more efficient way to help the plants recover than using urea. This is due to a small amount of leaf uptake of nitrogen and that 50% of the nitrogen is in the nitrate form ready for root uptake.
Drainage may be appropriate on sandy duplex soils on sloping sites.

How can it be monitored?
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.  

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## Marketing

The final step in generating farm income is converting the tonnes produced into dollars at the farm gate. This section provides best in class marketing guidelines for managing price variability to protect income and cash-flow.

### Figure 1: Grain selling flow chart.

Figure 1 shows a grain selling flow chart that summarises:

- The decisions to be made
- The drivers behind the decisions
- The guiding principles for each decision point

<table>
<thead>
<tr>
<th>Decisions</th>
<th>Decision drivers</th>
<th>Guiding principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. WHEN to sell?</td>
<td>Production risk - estimate tonnage</td>
<td>A: Don’t sell what you don’t have</td>
</tr>
<tr>
<td></td>
<td>Target price - cost of production</td>
<td>B: Don’t lock in a loss</td>
</tr>
<tr>
<td></td>
<td>Cash flow requirements</td>
<td>C: Don’t be a forced seller</td>
</tr>
<tr>
<td>2. HOW to sell?</td>
<td>Fixed price - maximum certainty (cash/futures)</td>
<td>D: If increasing production risk, take price risk off the table</td>
</tr>
<tr>
<td></td>
<td>Floor price - protects downside (options)</td>
<td>E: Separates the pricing decision from the delivery decision</td>
</tr>
<tr>
<td></td>
<td>Floating price - minimal certainty (pools, managed products)</td>
<td></td>
</tr>
<tr>
<td>3. WHICH markets to access?</td>
<td>Storage and logistics (on-farm, private, BHC)</td>
<td>F: Harvest is the first priority</td>
</tr>
<tr>
<td></td>
<td>Costs of storage / carry costs</td>
<td>G: Storage is all about market access</td>
</tr>
<tr>
<td>4. EXECUTING the sales?</td>
<td>“Tool box” - Info / professional advice / trading facilities</td>
<td>H: Carrying grain is NOT free</td>
</tr>
<tr>
<td></td>
<td>Contract negotiations &amp; terms</td>
<td>I: Seller beware</td>
</tr>
<tr>
<td></td>
<td>Counterparty risk</td>
<td>J: Sell valued commodities. Not undervalued commodities</td>
</tr>
<tr>
<td></td>
<td>Relative commodity values</td>
<td>K: Sell when there is buyer appetite</td>
</tr>
<tr>
<td></td>
<td>Contract (load) allocations</td>
<td>L: Don’t leave money on the table</td>
</tr>
<tr>
<td></td>
<td>Read market signals (liquidity)</td>
<td></td>
</tr>
</tbody>
</table>

### Figure 2: Selling principles

![Graph showing Kwinana APW2 wheat prices](image)

**Source:** Profarmer Australia

**Note to figure:** Kwinana APW2 wheat prices have varied A$60-$160/t over the past 6 years (25-60% variability). For a property producing 2,000 tonne of wheat this means $120,000-$320,000 difference in income depending on price management skill.
15.1 Selling Principles

The aim of a selling program is to achieve a profitable average price (the target price) across the entire business. This requires managing several unknowns to establish the target price and then working towards achieving that target price.

Unknowns include the amount of grain available to sell (production variability), the final cost of that production, and the future prices that may result. Australian farm gate prices are subject to volatility caused by a range of global factors that are beyond our control and difficult to predict.

The skills growers have developed to manage production unknowns can be used to manage pricing unknowns. This guide will help growers manage and overcome price uncertainty.

15.1.1 Be prepared

Being prepared and having a selling plan is essential for managing uncertainty. The steps involved are forming a selling strategy and a plan for effective execution of sales.

A selling strategy consists of when and how to sell.

When to sell

This requires an understanding of the farm’s internal business factors including:

- production risk
- a target price based on cost of production and a desired profit margin
- business cash flow requirements

How to sell?

This is more dependent on external market factors including:

- time of year determines the pricing method
- market access determines where to sell
- relative value determines what to sell

The following diagram (Figure 3) lists key selling principles when considering sales during the growing season.

![Selling Principles Diagram](image)

Figure 3: Grower commodity selling principles timeline.
### 15.1.2 Establish the business risk profile (when to sell?)

Establishing your business risk profile allows the development of target price ranges for each commodity and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify those risks during the production cycle are described below.

#### Figure 4: Typical farm business circumstances and risk.

**Production risk profile of the farm**

Production risk is the level of certainty around producing a crop and is influenced by location (climate and soil type), crop type, crop management, and time of the year.

**Principle:** “You can’t sell what you don’t have” – Don’t increase business risk by over committing production.

Establish a production risk profile by:

1. Collating historical average yields for each crop type and a below average and above average range.
2. Assess the likelihood of achieving average based on recent seasonal conditions and seasonal outlook.
3. Revising production outlooks as the season progresses.

#### Figure 5: Typical risk profile of farm operation.

**Farm costs in their entirety, variable and fixed costs (establishing a target price).**

A profitable commodity target price is the cost of production per tonne plus a desired profit margin. It is essential to know the cost of production per tonne for the farm business.
Principle: “Don’t lock in a loss” – If committing production ahead of harvest, ensure the price is profitable.

Steps to calculate an estimated profitable price based on total cost of production and a range of yield scenarios is provided below.

### Estimating cost of production - Wheat

<table>
<thead>
<tr>
<th>Fixed costs</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insurance and General Expenses</td>
<td>$100,000</td>
</tr>
<tr>
<td>Finance</td>
<td>$80,000</td>
</tr>
<tr>
<td>Depreciation/Capital Replacement</td>
<td>$70,000</td>
</tr>
<tr>
<td>Drawings</td>
<td>$60,000</td>
</tr>
<tr>
<td>Other</td>
<td>$30,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable costs</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed and sowing</td>
<td>$48,000</td>
</tr>
<tr>
<td>Fertiliser and application</td>
<td>$156,000</td>
</tr>
<tr>
<td>Herbicide and application</td>
<td>$78,000</td>
</tr>
<tr>
<td>Insect/fungicide and application</td>
<td>$36,000</td>
</tr>
<tr>
<td>Harvest costs</td>
<td>$48,000</td>
</tr>
<tr>
<td>Crop insurance</td>
<td>$18,000</td>
</tr>
</tbody>
</table>

| Total fixed and variable costs | $742,000             |
| Per Tonne Equivalent (Total costs + Estimated production) | $212 /t |

<table>
<thead>
<tr>
<th>Per tonne costs</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levies</td>
<td>$3 /t</td>
</tr>
<tr>
<td>Cartage</td>
<td>$12 /t</td>
</tr>
<tr>
<td>Freight to Port</td>
<td>$11 /t</td>
</tr>
<tr>
<td>Total per tonne costs</td>
<td>$22 /t</td>
</tr>
<tr>
<td>Cost of production Port track equivalent</td>
<td>$259.20</td>
</tr>
<tr>
<td>Target profit (ie 20%)</td>
<td>$52.00</td>
</tr>
<tr>
<td>Target price (port equiv)</td>
<td>$311.20</td>
</tr>
</tbody>
</table>

Step 1: Estimate your production potential. The more uncertain your production is, the more conservative the yield estimate should be. As yield falls, your cost of production per tonne will rise.

Step 2: Attribute your fixed farm business costs. In this instance if 1,200 ha reflects 1/3 of the farm enterprise, we have attributed 1/3 fixed costs. There are a number of methods for doing this (see M Klause “Farming your Business”) but the most important thing is that in the end all costs are accounted for.

Step 3: Calculate all the variable costs attributed to producing that crop. This can also be expressed as $ per ha x planted area.

Step 4: Add together fixed and variable costs and divide by estimated production

Step 5: Add on the "per tonne" costs like levies and freight.

Step 6: Add the “per tonne” costs to the fixed and variable per tonne costs calculated at step 4.

Step 7: Add a desired profit margin to arrive at the port equivalent target profitable price.

Figure 6: GRDC’s “Farming the Business Manual” also provides a cost of production template and tips on grain selling vs grain marketing. [http://www.grdc.com.au/FarmingTheBusiness](http://www.grdc.com.au/FarmingTheBusiness)

### Income requirements

Understanding farm business cash-flow requirements and peak cash debt enables grain sales to be timed so that cash is available when required. This prevents having to sell grain below the target price to satisfy a need for cash.

Principle: “Don’t be a forced seller” – Be ahead of cash requirements to avoid selling in unfavourable markets.

A typical cash-flow to grow a crop is illustrated below (Figures 7 and 8). Costs are incurred upfront and during the growing season with peak working capital debt incurred at or before harvest. This will vary depending on circumstance and enterprise mix. The second figure demonstrates how managing sales can change the farm’s cash balance.
When to sell revised

The “when to sell” steps above result in an estimated production tonnage and the risk associated with that tonnage, a target price range for each commodity, and the time of year when cash is most needed.

15.1.3 Managing your price (how to sell?)

The first part of the selling strategy answers the question “when to sell” and establishes comfort around selling a portion of the harvest.

The second part of the strategy addresses “how to sell”.

Methods of price management

Pricing products provide varying levels of price risk coverage:

<table>
<thead>
<tr>
<th>Description</th>
<th>Wheat</th>
<th>Barley</th>
<th>Canola</th>
<th>Oats</th>
<th>Lupins</th>
<th>Field peas</th>
<th>Chick peas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed price products</td>
<td>Cash, futures, bank swaps</td>
<td>Cash, futures, bank swaps</td>
<td>Cash, futures, bank swaps</td>
<td>Cash</td>
<td>Cash</td>
<td>Cash</td>
<td>Cash</td>
</tr>
<tr>
<td>Floor price products</td>
<td>Options on futures, floor price pools</td>
<td>Options on futures</td>
<td>Options on futures</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Floating price products</td>
<td>Pools</td>
<td>Pools</td>
<td>Pools</td>
<td>Pools</td>
<td>Pools</td>
<td>Pools</td>
<td>Pools</td>
</tr>
</tbody>
</table>
Figure 9: Summary of where different methods of price management are suited for the majority of farm businesses.

**Principle:** “If increasing production risk, take price risk off the table” – When committing unknown production, price certainty should be achieved to avoid increasing overall business risk.

**Principle:** “Separate the pricing decision from the delivery decision” – Most commodities can be sold at any time with delivery timeframes negotiable, hence price management is not determined by delivery.

**Fixed price**
A fixed price is achieved via cash sales and/or selling a futures position (swaps).

It provides some certainty around expected revenue from a sale as the price is largely a known except when there is a floating component in the price. For example, a multi-grade cash contract with floating spreads or a floating basis component on futures positions.

Note to figure: Fixed price product locks in price and provides certainty over what revenue will be generated regardless of future price movement.

**Floor price**
Floor price strategies can be achieved by utilising “options” on a relevant futures exchange (if one exists), or via a managed sales program product by a third party (i.e. a pool with a defined floor price strategy). This pricing method protects against potential future downside whilst capturing any upside. The disadvantage is that the price ‘insurance’ has a cost which adds to the farm businesses’ cost of production.
Flooding price

Many of the pools or managed sales programs are a floating price where the net price received will move both up and down with the future movement in price. Floating price products provide the least price certainty and are best suited for use at or after harvest rather than pre harvest.

Floating price strategy.

Figure 12: Floating price strategy.

How to sell revised

Fixed price strategies include physical cash sales or futures products and provide the most price certainty, but production risk must be considered.

Floor price strategies include options or floor price pools. They provide a minimum price with upside potential and rely less on production certainty but cost more.

Floating price strategies provide minimal price certainty and are best used after harvest.

15.1.4 Ensuring access to markets

Once the selling strategy of when and how to sell is sorted, planning moves to storage and delivery of commodities to ensure timely access to markets and execution of sales. At some point growers need to deliver the commodity to market. Hence planning on where to store the commodity is important in ensuring access to the market that is likely to yield the highest return.

Figure 13: Effective storage decisions.
Storage and logistics

Return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access to maximise returns as well as harvest logistics.

Storage alternatives include variations around the bulk handling system, private off-farm storage, and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity.

**Principle**: “Harvest is the first priority” – Getting the crop in the bin is most critical to business success during harvest, hence selling should be planned to allow focus on harvest.

Bulk export commodities requiring significant quality management are best suited to the bulk handling system. Commodities destined for the domestic end user market (e.g. feed lot, processor, or container packer), may be more suited to on-farm or private storage to increase delivery flexibility.

Storing commodities on-farm requires prudent quality management to ensure delivery at agreed specifications and can expose the business to high risk if this aspect is not well planned. Penalties for out-of-specification grain on arrival at a buyer’s weighbridge can be expensive. The buyer has no obligation to accept delivery of an out-of-specification load. This means the grower may have to incur the cost of taking the load elsewhere whilst also potentially finding a new buyer. Hence there is potential for a distressed sale which can be costly.

On-farm storage also requires prudent delivery management to ensure commodities are received by the buyer on time with appropriate weighbridge and sampling tickets.

**Principle**: “Storage is all about market access” – Storage decisions depend on quality management and expected markets.

For more information on on-farm storage alternatives and economics refer to GRDC Western Region - Wheat - GrowNote, Chapter 14 Grain Storage.
**Figure 14: Grain storage decision making.**

**Cost of carrying grain**

Storing grain to access sales opportunities post-harvest invokes a cost to “carry” grain. Price targets for carried grain need to account for the cost of carry.

Carry costs are typically $3-4/t per month consisting of:

- monthly storage fee charged by a commercial provider (typically ~$1.50-2.00/t per month)
- the interest associated with having wealth tied up in grain rather than cash or against debt (~$1.50-$2.00/t per month depending on the price of the commodity and interest rates).

The price of carried grain therefore needs to be $3-4/t per month higher than what was offered at harvest.

The cost of carry applies to storing grain on farm as there is a cost of capital invested in the farm storage plus the interest component. $3-4/t per month is a reasonable assumption for on farm storage.

**Principle:** “Carrying grain is not free” – The cost of carrying grain needs to be accounted for if holding grain and selling it after harvest is part of the selling strategy.
15.1.5 Ensuring market access revised

Optimising farm gate returns involves planning the appropriate storage strategy for each commodity to improve market access and cover carry costs in pricing decisions.

15.1.6 Executing tonnes into cash

This section provides guidelines for converting the selling and storage strategy into cash by effective execution of sales.

Set-up the tool box

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox includes:

1. Timely information

   This is critical for awareness of selling opportunities and includes:
   - market information provided by independent parties
   - effective price discovery including indicative bids, firm bids, and trade prices
   - other market information pertinent to the particular commodity

2. Professional services

   Grain selling professional service offerings and cost structures vary considerably. An effective grain selling professional will put their clients' best interest first by not having conflicts of interest and investing time in the relationship. Return on investment for the farm business through improved farm gate prices is obtained by accessing timely information, greater market knowledge and greater market access from the professional service.

3. Futures account and bank swap facility

   These accounts provide access to global futures markets. Hedging futures markets is not for everyone however strategies which utilise exchanges such as CBOT can add significant value.

References:

The link below provides current financial members of Grain Trade Australia including buyers, independent information providers, brokers, agents, and banks providing over-the-counter grain derivative products (swaps).

http://www.graintrade.org.au/membership

The link below provides a list of commodity futures brokers.

How to sell for cash

Like any market transaction, a cash grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components with each component requiring a level of risk management:

- **Price** - Future price is largely unpredictable hence devising a selling plan to put current prices into the context of the farm business is critical to manage price risk.
- **Quantity and quality** - When entering a cash contract you are committing to delivery of the nominated amount of grain at the quality specified. Hence production and quality risk must be managed.
- **Delivery terms** - Timing of title transfer from the grower to the buyer is agreed at time of contracting. If this requires delivery direct to end users it relies on prudent execution management to ensure delivery within the contracted period.
- **Payment terms** - In Australia the traditional method of contracting requires title of grain to be transferred ahead of payment; hence counterparty risk must be managed.

**Figure 16: Typical cash contracting.**

Grain Trade Australia is the industry body ensuring the efficient facilitation of commercial activities across the grain supply chain. This includes contract trade and dispute resolution rules. All wheat contracts in Australia should refer to GTA trade and dispute resolution rules.
The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. The below image depicts the terminology used to describe pricing points along the grain supply chain and the associated costs to come out of each price before growers receive their net farm gate return.

Note to figure:
The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. The below image depicts the terminology used to describe pricing points along the supply chain and the associated costs to come out of each price before the growers receive their net farm gate return.

Figure 17: Cost and pricing points throughout the supply chains.
Cash sales generally occur through three methods:

- Negotiation via personal contact - Traditionally prices are posted as a “public indicative bid”. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and available for all commodities.

- Accepting a “public firm bid” - Cash prices in the form of public firm bids are posted during harvest and for warehoused grain by merchants on a site basis. Growers can sell their parcel of grain immediately by accepting the price on offer via an online facility and then transfer the grain online to the buyer. The availability of this depends on location and commodity.

- Placing an “anonymous firm offer” - Growers can place a firm offer price on a parcel of grain anonymously and expose it to the entire market of buyers who then bid on it anonymously using the Clear Grain Exchange, which is an independent online exchange. If the firm offer and firm bid match, the parcel transacts via a secure settlement facility where title of grain does not transfer from the grower until funds are received from the buyer. The availability of this depends on location and commodity. Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

Counterparty risk

Most sales involve transferring title of grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

Principle: “Seller beware” – There is not much point selling for an extra $5/t if you don’t get paid.

Counterparty risk management includes:

- Dealing only with known and trusted counterparties.
- Conduct a credit check (banks will do this) before dealing with a buyer they are unsure of.
- Only sell a small amount of grain to unknown counterparties.
- Consider credit insurance or letter of credit from the buyer.
- Never deliver a second load of grain if payment has not been received for the first.
- Do not part with title of grain before payment or request a cash deposit of part of the value ahead of delivery. Payment terms are negotiable at time of contracting, alternatively the Clear Grain Exchange provides secure settlement where-by the grower maintains title of grain until payment is received by the buyer, and then title and payment are settled simultaneously.

Above all, act commercially to ensure the time invested in a selling strategy is not wasted by poor counterparty risk management. Achieving $5/t more and not getting paid is a disastrous outcome.

Relative values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well and hold commodities that are not well priced at any given time. That is, give preference to the commodities of the highest relative value. This achieves price protection for the overall farm business revenue and enables more flexibility to a grower’s selling program whilst achieving the business goals of reducing overall risk.

Principle: “Sell valued commodities; not undervalued commodities” – If one commodity is priced strongly relative to another, focus sales there. Don’t sell the cheaper commodity for a discount.

An example based on wheat and barley production system is provided below (Figure 18).
Figure 18: Kwinana ASW wheat vs feed barley.

If the decision has been made to sell wheat, CBOT wheat may be the better alternative if the futures market is showing better value than the cash market.

Note to figure:
Price relativities between commodities is one method of assessing which grain types 'hold the greatest value' in the current market.

Example:
Feed barley prices were performing strongly relative to ASW wheat values (normally ~15% discount) hence selling feed barley was more favourable than ASW Kwinana ASW wheat vs feed barley.

Figure 19: Kwinana APW2 vs CBOT wheat A$/t.

Contract allocation

Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (price, premiums-discounts, oil bonuses, etc.), and optimising your allocation reflects immediately on your bottom line.

Principle: “Don’t leave money on the table” - Contract allocation decisions don’t take long, and can be worth thousands of dollars to your bottom line.

To achieve the best average wheat price growers should:

• Allocate your lower grades of wheat to contracts with the lowest discounts.
• Allocate higher grades of wheat to contracts with the highest premiums.
Read market signals

The appetite of buyers to buy a particular commodity will differ over time depending on market circumstances. Ideally growers should aim to sell their commodity when buyer appetite is strong and stand aside from the market when buyers are not that interested in buying the commodity.

Principle: “Sell when there is buyer appetite” – When buyers are chasing grain, growers have more market power to demand a price when selling.

Buyer appetite can be monitored by:

- The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate buyer appetite is strong. However if there is one buyer $5/t above the next best bid, it may mean cash prices are susceptible to falling $5/t if that buyer satisfies their buying appetite.
- Monitoring actual trades against public indicative bids. When trades are occurring above indicative public bids it may indicate strong appetite from merchants and the ability for growers to offer their grain at price premiums to public bids.

15.1.7 Sales execution revised

The selling strategy is converted to maximum business revenue by:

- ensuring timely access to information, advice and trading facilities
- using different cash market mechanisms when appropriate
- minimising counterparty risk by effective due diligence
- understanding relative value and selling commodities when they are priced well
- thoughtful contract allocation
- reading market signals to extract value from the market or prevent selling at a discount

15.2 Western oats – market dynamics and execution

15.2.1 Price determinants for WA oats

The global oat crop is estimated at 20-23Mt each year and Australia is an important player; typically producing 1-1.5Mt annually. Australia exports about 20% of its production each season while the bulk of the crop is consumed domestically. The large majority of exported oats is used for human consumption.

WA is Australia’s largest oat production state accounting for about 1/3 of the crop each season.

Given this dynamic WA farm gate prices are heavily influenced by both local and global factors. Importantly they are also influenced heavily by the supply and demand of other local feed grains such as wheat and barley. While the commodities are not necessarily
substitutable the price relativity is important in order to ensure consumer supply requirements are met each season.

![Graph showing price relativity over time](image)

**Figure 21: Kwinana MOAT vs OAT2.**

**15.2.2 Ensuring market access for WA oats**

Domestic consumers in WA demand a majority proportion of the oat crop. Growers who are well positioned to service these markets will likely return premiums to the bulk export market. Private commercial or on-farm storage can be a more effective method of accessing the domestic consumer market.

This is particularly prudent for off-spec oats that don’t meet the milling requirements. Downgraded oats will typically be consumed by the domestic feed market, hence private commercial or on-farm storage may make it easier to access.

The bulk handling system does, however, offer a reasonable alternative for accessing the export market, which is predominately for human consumption milling quality oats. The bulk of this is exported in containers and the bulk handling system can provide efficiencies to access this market.
Figure 23: Australian supply chain flow.

15.2.3 Executing tonnes into cash for WA oats

Knowing where the Western Australian oat crop is likely to end-up will help refine a grower’s selling and logistics decisions. Understanding whether your grain will be used for milling or feed purposes will help determine the best path to market.

For milling quality oats it is of the upmost importance to maintain grain quality given the discounts in place if the grain fails to meet milling grade standards. Milling oats are often contracted prior to production with consumers looking to lock in supply, or alternatively sold into the cash market post-harvest. Given consumers have rigid supply requirements each season, forward selling a portion of your crop may offer a premium. It is always important, however, to manage prospective sales prior to harvesting the crop against your production risk.

Comparatively, feed oats are more heavily influenced by domestic factors including the relative price of other feed grains and local feed grain supply and demand fundamentals.

Given the lack of active participants in the oat market in Western Australia, monitoring liquidity using the Grow Note to Bank Note principles minimises the risk of being exposed to sudden price drops.

15.2.4 Risk management tools available for WA oats

An Australian cash price is made up of three components - futures, foreign exchange, and basis. Each component impacts on price – a higher futures and basis and a lower exchange rate will create a higher Australian grain price.
**Figure 24: Pricing components.**

- **Basis** (Estimated 15%)
- **Currency** A$/US$ (Estimated 15%)
- **CBOT futures** (Estimated 70%)

**Note to figure:**

**Basis** - The divergence in the local cash price from the futures price is known as basis. Australian cash prices will trade at a premium or discount to futures depending on local grain supply, demand and quality.

**Foreign Exchange** - The exchange rate impacts cash prices given most Australian canola is sold off-shore. A lower Australian dollar supports Australian prices.

**CBOT futures** - The futures market is the major determinant of Australian cash prices. Futures provide the opportunity for buyers and sellers to agree on a price for the sale of a commodity at an agreed time in the future. Price is influenced by anticipated supply and demand.
Table 2: Products available to manage WA oats prices; the major difference in products is the ability to manage the individual components of price.

<table>
<thead>
<tr>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot cash contracts</td>
<td>Futures, foreign exchange, basis all locked at time of contracting</td>
<td>Simple to use.</td>
</tr>
<tr>
<td></td>
<td>Locks in all components of price.</td>
<td>Immediate grain delivery required.</td>
</tr>
<tr>
<td></td>
<td>Cash is received almost immediately (within payment terms).</td>
<td>Sales after harvest require storage which incur costs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Locks away three pricing components at the same time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risk of counterparty default between transfer and payment.</td>
</tr>
<tr>
<td>Forward cash contracts</td>
<td>Futures, foreign exchange, basis all locked at time of contracting</td>
<td>Simple to use.</td>
</tr>
<tr>
<td></td>
<td>Locks in all components of price (no uncovered price risk).</td>
<td>Often inflexible and difficult to exit.</td>
</tr>
<tr>
<td></td>
<td>No storage costs.</td>
<td>Locks away the three pricing components at the same time.</td>
</tr>
<tr>
<td></td>
<td>Cash income is a known ahead of harvest.</td>
<td>Future delivery is required resulting in production risk.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Counterparty default risk must be managed.</td>
</tr>
<tr>
<td>Futures contracts</td>
<td>Futures, foreign exchange, basis are able to be managed individually</td>
<td>Liquid markets enable easy entry and exit from the marketplace.</td>
</tr>
<tr>
<td></td>
<td>Locks in only some components of price, hence more flexible than cash contracts.</td>
<td>Requires constant management and monitoring.</td>
</tr>
<tr>
<td></td>
<td>Price determined by the market, and is completely transparent.</td>
<td>Margin calls occur with market movements creating cash-flow implications.</td>
</tr>
<tr>
<td></td>
<td>No counterparty risk due to daily clearing of the contracts.</td>
<td>Grain is required to offset the futures position, hence production risk exists.</td>
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<td>Cash prices may not move inline with futures, hence some price risk.</td>
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<td>You still have to sell the underlying physical grain.</td>
</tr>
<tr>
<td>Over-the-counter bank swaps on futures contracts</td>
<td>Futures, foreign exchange, basis are able to be managed individually</td>
<td>Based off an underlying futures market so reasonable price transparency.</td>
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<td></td>
<td>Liquid markets enable easy entry and exit from the marketplace.</td>
<td>Requires constant management and monitoring.</td>
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<td></td>
<td>Locks in only some components of price, hence more flexible than cash contracts.</td>
<td>Margin calls occur with market movements creating cash-flow implications.</td>
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<td>Counter party risk is with the bank, hence it is low.</td>
<td>Grain is required to offset the futures position, hence production risk exists.</td>
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<td></td>
<td>The bank will manage some of the complexity on behalf of the grower, including day to day margin calls.</td>
<td>Cash prices may not move inline with futures, hence some price risk.</td>
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<td>You still have to sell the underlying physical grain.</td>
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<td>Options on futures contracts</td>
<td>Futures, foreign exchange, basis are able to be managed individually</td>
<td>No counterparty risk due to daily clearing of the contracts.</td>
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<td>No margin calls.</td>
<td>Options can be costly and require payment upfront.</td>
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<td>Protects against negative price moves but can provide some exposure to positive moves if they eventuate.</td>
<td>The value of options erode overtime as expiry approaches - depreciating asset.</td>
</tr>
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<td></td>
<td>Liquid markets enable easy entry and exit from the marketplace.</td>
<td>Perceived to be complicated by growers.</td>
</tr>
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<td>Price risk can be reduced without increasing production risk.</td>
<td>Move in option value may not completely offset move in cash markets.</td>
</tr>
<tr>
<td></td>
<td>Price determined by the market, and is completely transparent.</td>
<td>You still have to sell the underlying physical grain.</td>
</tr>
</tbody>
</table>

SECTION 16

Current research

Project Summaries of GRDC-supported projects in 2013-14

Each year the GRDC supports several hundred research and development, and capacity building projects.

In the interests of improving awareness of these investments among growers, advisers and other stakeholders, the GRDC has assembled summaries of projects active in 2013-14.

These summaries are written by our research partners as part of the Project Specification for each project, and are intended to communicate a useful summary of the research activities for each project investment.

The review expands our existing communication products where we summarise the R&D portfolio in publications such as the Five-year Strategic Research and Development Plan, the Annual Operating Plan, the Annual Report and the Growers Report.

GRDC’s project portfolio is dynamic with projects concluding and new projects commencing on a regular basis. Project Summaries are proposed to become a regular publication, available to everyone from the GRDC website.

Projects are assembled by GRDC R&D investment Theme area, as shown in the PDF documents available. For each Theme a Table of Contents of what is contained in the full PDF is also provided, so users can see a list of project titles that are covered. The GRDC investment Theme areas are:

- Meeting market requirements;
- Improving crop yield;
- Protecting your crop;
- Advancing profitable farming systems;
- Maintaining the resource base; and
- Building skills and capacity.

The GRDC values the input and feedback it receives from its stakeholders and so would welcome your feedback on any aspect of this first review. This way we can continue to improve and extend this summary.

To send us your feedback please email us at feedback@grdc.com.au
Key contacts

Peter Roberts (Chair)

Peter Roberts, who farms at Dunn Rock, in the Esperance port zone, was appointed western panel chairman in 2011.

Peter places a strong emphasis on ensuring that all GRDC-funded investments are squarely targeted at addressing the most important issues facing growers. Another key focus is for the panel to have a strong level of engagement with the WA grains industry.

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Dr Mike Ewing (Deputy Chair)

Mike Ewing brings a background in farming systems science to his role on the western panel.

In a career spanning more than 40 years - working with or leading key research organisations - he concentrated on identifying break crop technologies that improve the profitability and sustainability of crop sequences and rotations. He has tackled constraints associated with a variable climate and hostile soils.

M 0409 116 750
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Gemma Walker

In addition to her hands-on farming experience, Gemma worked for many years managing farming systems groups to deliver development and extension activities.

These included Mallee Sustainable Farming and the South East Premium Wheat Growers Association. Gemma has a Bachelor of Agribusiness (Hons) from Curtin University.

M 0428 751 095
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Dr Greg Rebetzke

Greg Rebetzke is a wheat geneticist with CSIRO, and is committed to delivering traits and germplasm for improving crop variety water productivity.

He works closely with commercial breeders to understand the relative benefits of one trait over another, and how to integrate new genetics more efficiently in the development of higher-yielding, more robust cereals.

M 0429 994 226
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Jules Alvaro

Jules Alvaro is involved in all aspects of the 5400-hectare cropping business she operates with her husband at Merredin in WA's central grainbelt.

She is the WA sub-coordinator for Partners in Grain and a founding member of Agricultural Women Wheatbelt East. Jules is a firm believer in farm businesses keeping up with technology while keeping an eye on the bottom line.
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Chris Wilkins

Chris Wilkins, based in Badgingarra, is an agronomic and agribusiness adviser.

He has 24 years’ experience in WA agriculture, including offering farm business, agronomy, farming systems and crop protection advice through his Vision Agribusiness Services company for the past 17 years.

Chris is also a director of agricultural consultancy business Synergy Consulting WA, chairs the Council of Grain Grower Organisations Ltd and is a member of WA Agriculture Minister Ken Baston’s Ministerial Agricultural Advisory Council.
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Dr Bill Ryan

Bill Ryan has had a long career in agriculture’s research and corporate sectors. He spent 21 years with the WA Department of Agriculture and then seven years with the Heytesbury Group.

He was CEO of the Kondinin Group from 2003 to 2008. He chairs the Agricultural Produce Commission and is on the Rural Industries Research and Development Corporation board as well as providing independent consulting services.
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Darrin Lee

Darrin Lee worked for the National Australia Bank before taking up farming in 1998 north-east of Mingenew, WA.

His background in the finance has equipped him well for farm business analysis and agribusiness. A special area of interest includes precision agriculture.

Another area of interest is value-adding, which he has achieved with his albus lupin production through a ‘paddock to plate’ joint venture initiative. Darrin is also a member of CBH Group’s Grower Advisory Council.
M 0427 281 021
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Paul Kelly

Paul Kelly and his wife, Sue, farm 3100 hectares in the mid-west of WA. He is an active member of the Mingenew Irwin Group and has a strong interest in both farm safety and encouraging young men and women to embrace agriculture.

Paul has completed two terms with the Western Panel and is keen to promote innovation that will drive profitability, productivity and sustainability for all grain growers.

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Andy Duncan

Andy Duncan is managing partner in a mixed broadacre family farming business in the West River area on the south coast of WA, producing wheat, malt and feed barley, canola, lupins and field peas.

He has been involved with several organisations including the Grains Industry Association of WA (GIWA) Barley Council, the South East Premium Wheat Growers Association, the GRDC Esperance Regional Cropping Solutions Network and the Ravensthorpe Agricultural Initiative Network.

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Stuart Kearns (GRDC Executive Manager Regional Grower Services)

Stuart Kearns joined the GRDC in 1998 as the northern panel officer and has worked in several roles since then. He is the executive manager grower services.

The aim of the Grower Services Business Group is to listen to growers and package and deliver new and improved locally relevant products and services that meet the needs of growers and their advisers.

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Roger States

( GRDC Manager Grower Services – West)

As one of the three regionally based managers, Roger helps identify regional research, development and extension (RD&E) needs, manage the regional delivery of information, oversee regionally specific research and promote the GRDC’s products and services.

Roger works closely with growers and industry representatives to ensure that RD&E investments create the best quality information for growers and their advisors.

Before his appointment to the GRDC, Roger worked for a number of years in the fields of crop protection and agronomy, based in WA. Most recently, he was responsible for product development and technical support with crop protection company Sipcam Pacific Australia.

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SECTION 18

References

Section A Introduction


Section 1 Planning and preparation
Australian CliMate. Climate tools for decision makers. Commonwealth of Australia, www.australianclimate.net.au


Crown Analytical Services, https://sites.google.com/site/crownanalyticalservices/


Section 2 Pre-planting


Section 3 Planting


Section 4 Plant growth and physiology


Section 5 Nutrition and fertiliser


Section 6 Weed control


Section 7 Insect control


Section 8 Nematode control


Section 9 Diseases


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Section 10 Canopy management


Section 12 Harvest


de Bruin Engineering. Harrington Seed Destructor. Projects. De Bruin Engineering


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Section 13 Storage


Section 14 Environmental issues


Section 15 Marketing
