



planning/paddock preparation • pre-planting • planting • plant growth and physiology • nutrition and fertiliser • weed control • insect control • nematode control • diseases • crop desiccation and spray out • harvest • storage • environmental issues • marketing • current research

Start here for answers to your immediate canola crop management issues

What variety should I grow?

What's the latest thinking on optimum sowing rate?

How do I approach canola nutrition?

What approach should I take to weed control in my canola crop?

What pre-emergent herbicide control options do I have?

How do I control aphids in canola?

Should I choose windrowing or direct heading?







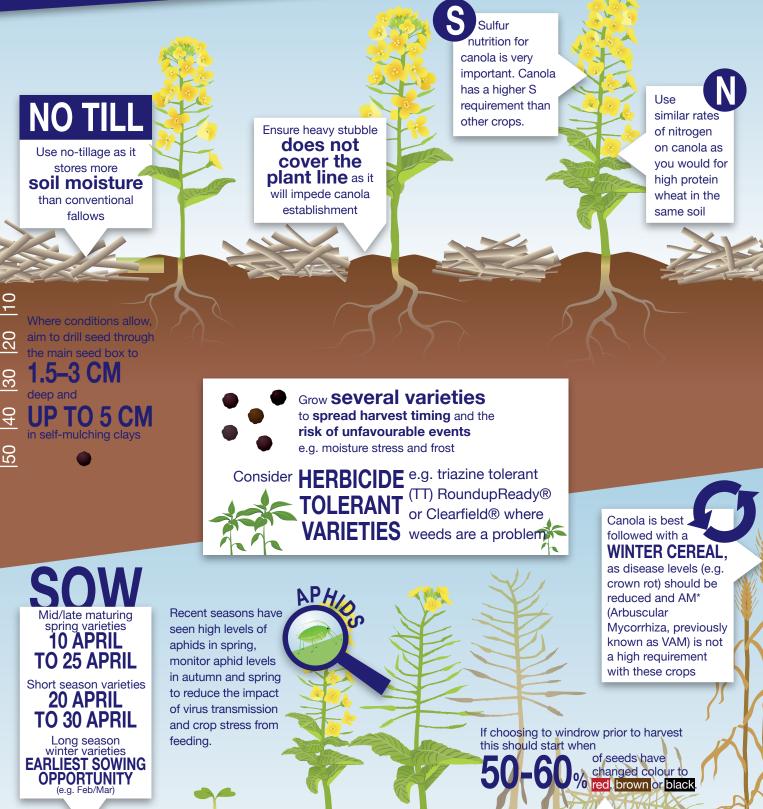




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Key Management Issues for Canola in the Southern Region





ESTABLISHMENT FLOWERING PODDING Monitor crops for insect pests during the critical times. Take account of BENEFICIAL INSECT NUMBERS

when making decisions on control options

WINDROWING

Windrowed crops should be ready to harvest

5-14 DAYS after windrowing depending on the weather. The moisture content of the grain should be

8% or less.

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SECTION A Introduction

A.1 Crop overview

A.1.1 History of canola

Canola refers to the seed and oil that is produced by several cultivars of the rape plant, generally cultivars of either rapeseed (*Brassica napus* L.) or field mustard/turnip rape (*Brassica rapa* subsp. *oleifera*, syn. *B. campestris* L.). ¹

Rapeseed oil was produced in the 19th Century as a source of a lubricant for steam engines; however, it was less useful as food for animals or humans because of high levels of erucic acid and glucosinolates, chemical compounds that significantly lower the nutritional value of rapeseed for animal feed.

Canola was developed in Canada in the early 1970s by traditional plant-breeding techniques to reduce significantly the levels of erucic acid and glucosinolates that were found in the parent rapeseed plant. The name 'canola' is a contraction of 'Can(adian)' O(iI) L(ow) A(cid).²

In the 1970s, intensive breeding programs in several countries including Australia produced high-quality varieties that were significantly lower in the two toxicants. Varieties termed 'canola' must meet specific standards on the levels of erucic acid and glucosinolates. They must yield oil low in erucic acid (<2%) and meal low in glucosinolates (total glucosinolates 30 µmol/g toasted oil-free meal) (<u>CODEX</u> <u>International Food Standards 1999</u>), and are often referred to as 'double low' or 'double zero' varieties. ³

Australian canola typically contains <10 $\mu mol/g$ of glucosinolates, 43–45% oil, and 38–40% protein in oil-free meal. 4

Canola now dominates the consumption markets for oil and meal (Figure 1). Production of high erucic acid rapeseed is confined to production under contract for specific industrial uses, including environmentally friendly lubricants. ⁵

In addition to varieties from the traditional *B. napus* and *B. rapa* species, cross-breeding of multiple lines of *B. juncea* has enabled this mustard variety to be classified as a canola-type variety by lowering both erucic acid and glucosinolates to the market standards. ⁶

- Canolalnfo (2015) Where does canola come from? http://www.canolainfo.org/canola/where.php
- ⁶ Canola. Wikipedia, <u>http://en.wikipedia.org/wiki/Canola</u>



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¹ Canola. Wikipedia, <u>http://en.wikipedia.org/wiki/Canola</u>

² Canolalnfo (2015) Where does canola come from? Canolalnfo, <u>http://www.canolainfo.org/canola/where.php</u>

³ OGTR (2002) The biology and ecology of canola (*Brassica napus*). Office of the Gene Technology Regulator, <u>http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/canola-3/\$FILE/brassica.pdf</u>

⁴ AEGIC. Australian grain note: canola. Australian Export Grains Innovation Centre, <u>http://www.australianoilseeds.com/oilseeds_industry/quality_of_australian_canola</u>



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Figure 1: Canola is now a major oilseed industry, providing national economic benefits in employment, processing, manufacturing and exports.

A.1.2 Canola in Australia

Rapeseed was first trialed in Australia in the early 1960s and grown commercially in 1969, following the introduction of wheat delivery quotas. The first commercial seed, of the variety Target, was imported from Canada in 1967 by Meggitt Ltd.

Early varieties were not well adapted to Australian conditions, being Canadian in origin. Canadian plant breeders had developed varieties much lower in erucic acid than Target and Arlo, but they were also lower in yield, so never became popular in Australia. For the same reason, the first 'double low' varieties were not widely grown in Australia. The varieties available were also quite susceptible to blackleg, and farmers suffered increased disease losses. The growth of the industry was being limited by a lack of suitable varieties.

The first rapeseed-breeding program in Australia was set up in Victoria in 1970, followed by Western Australia and New South Wales in 1973. Their initial objectives were to develop varieties that were blackleg-resistant and low in erucic acid and glucosinolates while maintaining or increasing yields. Blackleg became a major problem in the early 1970s, and the disease was soon widespread. In Western Australia, where the disease was most severe, yield losses of up to 80% resulted in plantings crashing from 49,000 ha in 1972 to 3,200 ha in 1974.

Although resistant varieties were developed, the Western Australian industry did not produce significant quantities of canola again until the early-mid 1990s. The first Australian varieties were Wesreo (released 1978) and Wesway (released 1979), which were low-erucic-acid, blackleg-resistant varieties from Western Australia. In Australia, canola is used to denote varieties with erucic acid level <2% and total glucosinolates <40 μ mol/g. The first canola-quality *B. napus* varieties to be released were Wesroona, in Western Australia in 1980, and Marnoo, from Victoria in 1980. Marnoo was higher yielding and had much lower glucosinolate levels than earlier varieties and so became a popular variety, particularly in Victoria.

However, Marnoo's limited blackleg resistance was a handicap in New South Wales. Growers there had been growing mainly Span, and quickly adopted Jumbuck (*B. rapa* variety, released 1982) because of its better yield, quality and disease resistance. In





1987, with the release of Maluka and Shiralee (both *B. napus*) from New South Wales, high-quality canola varieties became available. These were the first varieties to combine canola quality with blackleg resistance and high yields. They also resulted in a trend back to *B. napus* varieties.

The first hybrid canola, Hyola 30, was released by Pacific Seeds in 1988, followed by Hyola 42 in 1991. Triazine-tolerant (TT) canola was first commercialised with the release of the variety Siren in 1993. Siren was late maturing with low yield and oil content but was useful where cruciferous weeds reduced the chances of success with canola. New TT varieties rapidly followed, both early (Karoo and Drum) and midseason (Clancy and Pinnacle) maturity. This led to the rapid adoption of TT canola across Australia, especially in Western Australia, where TT canola now comprises ~90% of the total crop.

The TT varieties continue to have a yield disadvantage of 10–15%, and about 3–5% lower oil content than conventional, Roundup Ready and Imi-tolerant varieties, but they are accepted by farmers because they allow canola to be grown where it could not previously.

Since the early 1990s, canola production has extended into lower rainfall areas in all states, even where rainfall is as low as 325 mm/year. This expansion has caused plant breeders to select earlier maturing varieties, with the release of Monty in 1998 and Mystic in 1999.⁷

The first imidazolinone-tolerant (Clearfield[®]) variety was released in 1999, further expanding weed-control options. Genetically modified glyphosate-tolerant varieties, incorporating the Roundup Ready[®] trait, were grown commercially for the first time in 2008 in New South Wales and Victoria. High oleic, low linolenic acid varieties were grown commercially for the first time in 1999. These varieties differ from conventional canola in the fatty acid profile of the oil, which increases its uses, especially for deep frying. ⁸

In Victoria, the main production area is the south-west but the crop is important across the grainbelt. The release of earlier maturing cultivars has extended canola's range into the Mallee. $^{\rm 9}$

A.1.3 Hybrids

A hybrid is a plant created by cross-pollinating male and female parents of different inbred lines. A hybrid has the benefit of heterosis (hybrid vigour). Hybrid canola generally has higher yield potential than traditional, inbred, open-pollinated varieties. This improved yield is achieved through a combination of superior traits such as larger seeds, leading to early vigour, and better stress tolerance. However, hybrid seed should never be retained for sowing because it will not produce true copies of the original hybrid plant.¹⁰

Although the first canola hybrid was released in 1988, only recently have hybrids been grown on a large scale. Canola breeding of the future will focus more on hybrids. The major global producers are China, the European Union, Canada and India.

A.1.4 Global production

The major global canola producers are China, the European Union, Canada and India. Canada is the major exporter and Japan and the European Union are the major importers. Australian canola competes with Canadian product in the international



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⁷ B. Colton, T. Potter. History. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/______data/</u> assets/pdf_file/0010/2701/Chapter_1_- History.pdf

⁸ D McCaffrey (2009) Introduction. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/</u> <u>GRDC Canola Guide All 1308091.pdf</u>

⁹ DEPI (2012) Growing canola. Department of Environment and Primary Industries Victoria, AG0750, updated July 2012. <u>http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/growing-canola</u>

¹⁰ GRDC (2010) Growing hybrid canola. GRDC Canola Fact Sheet, August 2010, <u>https://www.grdc.com.au/~/</u> media/D4B939DB8790453FB2D6CBD04CA11B78.pdf





Canola industry in South Australia

marketplace. Canola is the third most important winter grain crop in Australia, behind wheat and barley. ¹¹

A.1.5 Domestic production

Australian canola production has averaged ~1.4 Mt/year, ranging from 512,000 t to 2.46 Mt. The total Australian oilseed crush capacity is ~1.1 Mt, with much of this in the eastern states. Some 550,000–650,000 t of canola is crushed annually, with the main export markets for surplus seed being Japan, Pakistan, Bangladesh, China and the European Union.

The vast majority of canola oil is used in the food industry: about one-third in spreads and cooking oil, and two-thirds in the commercial food-service sector (Figure 2). About 20–25% of Australian canola oil is exported. Canola meal, the main byproduct of crushed canola, is used as a high-protein feed for intensive livestock, mainly in the pig, poultry and dairy industries.



Figure 2: Most of Australia's canola oil is used in the food-service sector.

The challenge for growers and the industry over the next few years will be to continue to improve productivity by adopting best practice management and being responsive to climate variability to ensure a stable supply of high-quality oilseed for domestic and international markets. ¹² Table 1 shows production in four states for 2014–15 and estimated production for 2015–16.

Table 1: Canola production in New South Wales, Victoria, South Australia and Western Australia Sources: industry estimates, GIWA, PIRSA

	Final 2013–14		Estimate 2014–15	;
	Harvested area (ha)	Production (t)	Area planted (ha)	Production (t)
NSW	575,000	835,000	510,000	816,000
Vic	483,000	647,000	380,000	456,000
SA	302,000	314,000	221,000	287,000
WA	1,247,000	1,635,000	1,143,000	1,446,000
Total	2,607,000	3,431,000	2,254,000	3,005,000

¹¹ D McCaffrey (2009) Introduction. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

¹² D McCaffrey (2009) Introduction. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>





December 2015

SECTION 1

Planning/Paddock preparation



Agriculture Victoria: Growing canola

IPNI: Juncea canola in the low rainfall zones of Victoria and South Australia

NSW DPI: Juncea canola in the low rainfall zone of south-western NSW

Bayer Crop Science: Canola talk

PIRSA: Mid North Region—land use potential for canola

Research paper: Canola industry in South Australia

1.1 Paddock selection

In addition to early preparation and good crop management, success with canola cropping depends on careful paddock selection. The major considerations when selecting a paddock to grow canola in rotation with other crops are:

- soil type
 - potential disease problems
- previous herbicide use
- broadleaf weeds

Choosing more reliable and weed-free paddocks is the best option (Figure 1). When coming out of the pasture phase it is desirable to soil-test during the previous summer and autumn and then to initiate pasture and fallow management by spring to control broadleaf and grass weeds, and establishment pests such as redlegged earth mites.

In a continuous cropping rotation, aim to keep weed numbers low through the use of fallow, hay or green/brown manure crops. Integrated weed management strategies including crop competition, crop-topping and harvest weed seed management should also be adopted.¹



Figure 1: Choosing more reliable and weed-free paddocks is the best option for canola.

P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>



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1.1.1 Soil types

Canola generally grows best in fertile soils. In mixed livestock and cropping areas, it is ideally grown immediately after pasture. High yields can also be obtained after a fallow or a cereal, provided adequate nitrogen (N) fertiliser is used, and after green manure crops if soil water is not limiting. Canola will not perform well in low-fertility paddocks. Generally, the best wheat-growing soils will produce the best canola crops. Paddocks with a uniform soil type will permit more even sowing depth and seedling emergence and more even crop ripening.

Avoid growing canola where the following problems occur: ²

Hardpans

Although canola is a tap-rooted plant, it is not strong enough to penetrate some tight hardpans and can still suffer from 'J' rooting problems. Paddocks should be checked 12 months in advance by using a soil probe or by digging a small pit to visually assess a suspected problem and determine the depth of working or ripping that may be required to break up any hardpan. ³

Many soils of southern New South Wales (NSW) appear to have sufficient cracks and biopores to enable root penetration through all but the hardest compaction layers. Deep ripping is not recommended as a standard tool for overcoming hardpans prior to sowing canola crops. Studies have rarely found significant yield responses to deep ripping.⁴

Crusting soils

The surface of a soil can crust after rainfall and reduce plant establishment if it is poorly structured with low organic matter levels, or a sodic clay that disperses after wetting. The use of gypsum and/or stubble retention on hardsetting sodic clay soils can improve seedling emergence and early growth. ⁵

Acid soils

Canola is more susceptible to low pH and aluminium (AI) toxicity than most other crops. If you expect the pHCa to be <5.0, have the prospective canola paddock soil-tested. If acidic subsoil is suspected, take split samples of soil depths 0–10 and 10–20 cm.

The depths of the deeper segments probably depend on individual soils, so limiting to a second 10-cm segment could be inconclusive.

Agronomist's view

Where a pHCa <4.7 is combined with exchangeable AI level of \geq 3%, do not grow canola before obtaining specific advice. Other indicators of acidity problems are poor growth in barley and lucerne, or if oats and triticale grow better than wheat. Consider using lime when the topsoil pHCa drops to <5.0. ⁶

Provided the surface soil is not acid, canola appears relatively tolerant of subsurface acidity, except where exchangeable AI exceeds 20%, where there is manganese

- ⁴ G Poile <u>et al.</u> (2012) Canola and subsoil constraints Technical Bulletin April 2012. EH Graham Centre, <u>https://www.csu.edu.au/___data/assets/pdf__file/0003/922764/Canola_-and-__subsoil_constraints.pdf</u>
- ⁵ P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> au/uploads/documents/GRDC Canola Guide All 1308091.pdf
- ⁶ P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>



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P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

³ P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>



toxicity, or where the acid 'throttle' is more than 20 cm deep. Typical subsurface acidity can be managed by liming the surface to pH Ca 5.5. 7

Waterlogging

1 More information

<u>GRDC: Canola best</u> <u>practice management</u> <u>guide for south-eastern</u> <u>Australia</u> Soils become waterlogged when rainfall exceeds their infiltration capacity. It is most common in soils with a sodic clay subsoil of low permeability. However, hardpans can also induce waterlogging. A sodic subsoil problem can be identified by a simple soil-testing procedure (dispersion test) backed up by laboratory chemical analysis. Avoid these soils unless they have a good depth of well-drained topsoil, which allows for adequate root growth even after heavy rainfall. Use of raised beds has been a successful strategy for reducing the impact of waterlogging in high-rainfall areas of south-western Victoria and Western Australia. ⁸

1.2 Rotations and paddock history

Canola is an excellent choice to enhance or extend a crop rotation. It produces a high yield and can be a profitable crop in its own right as well as an excellent fit with cereals and pulses.

The average yield of canola across Victoria between 2002 and 2007 was 1.3 t/ha, which includes three drought years. Yields of >4 t/ha are achieved by some farmers in better years, especially in higher rainfall regions such as south-western Victoria and sometimes under irrigation. Cereal yields after canola are often enhanced because of the 'disease cleaning' that occurs when an unrelated crop type, such as canola, is alternated with cereals and is kept free of grassy weeds.

Canola in the rotation allows farmers to improve management of weeds because canola is a broadleaf crop and there are different herbicide-tolerant varieties of canola. 9

Canola can reduce but not eliminate the incidence of some cereal root and crown diseases, such as crown rot, take-all and cereal cyst nematodes. Research has shown canola to be the most effective winter crop for reducing levels of crown rot in subsequent wheat crops.

Canola can have both positive and negative effects on subsequent crops. Canola is non-mycorrhizal, and so levels of arbuscular mycorrhizal fungi (AMF) can fall under canola. This may disadvantage subsequent crops that are highly dependent on AMF. Crops affected include all commonly grown summer crops (sorghum, cotton, maize, sunflowers and the summer pulses) as well as faba beans and chickpeas.

Wheat, barley and oats have a low dependence on AMF, and so they can be readily grown in rotation with canola.

Research has shown that wheat yield increases of \sim 0.6–1.0 t/ha can be expected when following canola compared with following wheat.

No-tillage, which retains more stubble, is increasing the carryover of many of the main cereal diseases, such as crown rot, in NSW. Canola fits well into this system by allowing an additional season for cereal stubble breakdown to occur, therefore reducing the carryover of disease.

Maintaining a rotation of one canola crop every 4 years also minimises the potential for disease build-up in the canola.

The use of triazine-tolerant (TT) varieties of canola has helped to control difficult weeds such as mustards, wild radish and sow thistle.



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M Conyers et al. (2010) Canola yield decline in south-eastern Australia. Grassroots Agronomy, <u>http://www.grassrootsag.com.au/CiD%20low%20res.pdf</u>

⁸ P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

⁹ S Holden (2010) Growing canola. AG0750. (Revised 2012 by F Prichard, C Bluett). Agriculture Victoria, <u>http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/growing-canola</u>





GRDC: Over the bar with better canola agronomy

<u>GRDC: Canola best</u> practice management guide for south-eastern <u>Australia</u>



AOF: Canola volunteer control guide Rutherglen bugs may be present in large numbers on canola stubble around harvest time. These can readily move into neighbouring summer crops or crops planted directly into the canola stubble, causing serious damage. ¹⁰

1.3 Fallow weed control

Weeds can affect crop yield either through direct competition or possibly as hosts for pathogens such as *Sclerotinia*. In particular, for canola, a number of *Brassica* weeds can cause significant problems.

Growers should be aware of the following important *Brassica* weeds when selecting a paddock for canola:

- charlock (Sinapis arvensis)
- wild radish (Raphanus raphanistrum)
- wild or Mediterranean turnip (Brassica tournefortii)
- wild cabbage or hare's ear (Conringia orientalis)

Each of these weeds has a seed size similar to canola and they cannot be easily removed from canola grain samples. Because they contain ~50 times more erucic acid in the oil and ~10 times more glucosinolates in the seed than found in canola, any contamination could result in the crop being rejected at delivery because of the impact on oil and meal quality.

Other problem *Brassica* weeds have smaller seed than canola and they are usually removed during harvesting. These include shepherd's purse (*Capsella bursa-pastoris*), turnip weed (*Rapistrum rugosum*), musk weed (*Myagrum perfoliatum*) and the mustards (*Sisymbrium* spp.). These weeds reduce yield through competition; for example, shepherd's purse may be a problem weed of canola grown after a pasture phase.

If sowing canola into paddocks where any of these *Brassica* weeds are present, select an appropriate, herbicide-resistant variety. Growing TT, Clearfield[®] or Roundup Ready[®] canola allows problem broadleaf weeds to be managed. However, eradicating problem weeds or reducing their seed populations prior to sowing is preferable.¹¹

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

Benefits of fallow weed control are significant:

- Conservation of summer rain and fallow moisture is integral to winter cropping in the southern region, particularly so as the climate moves towards summerdominant rainfall. Long fallow is undertaken in more marginal areas of the south.
- Modelling studies show that the highest return on investment in summer weed control is for lighter soils or in situations where soil water that would support continued weed growth is present.¹²

- ¹¹ P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>
- ¹² GRDC (2012) Make summer weed control a priority. Southern Region. Summer Fallow Management Fact Sheet, GRDC January 2012, <u>http://www.grdc.com.au/GRDC-Manual-SummerFallowWeedManagement</u>



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¹⁰ L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/ data/assets/pdf file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>

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1.4 Fallow chemical plant-back periods

Canola is particularly susceptible to a range of residual herbicides. Under dry seasonal conditions or in alkaline soils, residues from herbicide applied to a previous pulse or cereal crop can persist into the next cropping season. For example, the sulfonylurea group (e.g. chlorsulfuron, sulfosulfuron) used in cereal crops have a canola plant-back period of 24–30 months. Similarly, some herbicides registered in pulse crops can have plant-back periods ranging from 9 months (simazine) to 24 months (flumetsulam) to 34 months (imazethapyr). The use of these herbicides can therefore restrict crop options and prevent the sowing of canola for up to 3 years. The use of various herbicides (triazines or Group B herbicides) can restrict crop-selection options in the following year. Plant-back periods are provided on herbicide labels for sensitive crops under these conditions. ¹³

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of a subsequent crop. Many plant backs also have rainfall requirements in addition to the time period.

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, as is the case for sulfonylureas (chlorsulfuron). Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate heading or under 'Protection of crops etc.' in the 'General Instructions' section of the label.¹⁴

1.5 Seedbed requirements

Seed-soil contact, especially under dry conditions, is crucial for helping moisture to diffuse into the canola seed. Emergence of canola seedlings can be reduced by the formation of soil crusts in hardsetting, sodic or dispersing soils. Sodic or dispersing soils that surface-seal will reduce the emergence of canola seedlings.

A firm, moist seedbed provides uniform seed germination and rapid seedling growth. Adequate soil moisture at the seedling and elongation stages promotes the development of a strong, healthy plant less prone to lodging and with maximum leaf growth by the end of July. ¹⁵

Sowing canola into raised beds has proven very successful in southern Victoria. Many soil types in this region (heavy duplex soils and impervious clay subsoils) are prone to severe waterlogging in winter. Raised-bed cropping provides a relatively inexpensive and practical drainage solution, enabling growers to successfully produce canola and other crops and obtain much higher yields. Research in southern Victoria has demonstrated yield improvements of 60% where canola was sown on narrow raised beds (1.5–2.0 m wide and 25 cm high) compared with canola sown on much wider beds (20–30 m wide and 20 cm high). Root development and trafficability after rainfall events were also improved, and in subsequent years, indications are that the soil structure of raised beds starts to improve. Raised beds have also been adopted in some of the



Australian Pesticides and Veterinary Medicines Authority

NSW DPI: Using preemergent herbicides in conservation farming systems

NSW DPI: Weed control in winter crops

Research paper: Sulfonylurea spray contamination damage to canola crops



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¹³ P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

¹⁴ B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf</u>

¹⁵ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf__file/0004/516181/Procrop-canola-growth-and-development.pdf</u>





GRDC: Canola best practice management guide for south-eastern Australia wetter areas of the south-west of Western Australia. They have been trialled in southern NSW, but a string of dry years has reduced grower interest. ¹⁶

1.6 Soil moisture

Soil moisture is vital for both germination and emergence. Canola must absorb a high percentage of its weight in water before germination begins. It will germinate when the seed moisture content has risen to ~24%.

Water absorption is a passive process. The ability of seeds to absorb water depends on the difference in water potential between the seed and the surrounding soil. Seeds can absorb water even at very low soil-water potentials, but low water potentials may induce secondary dormancy.

Seed size influences the rate of water absorption. Small seeds have a high surface-tovolume ratio, which means that less time is required to absorb adequate moisture for germination.

In soils with a low moisture content, the germination rate will be lower and emergence slower (Table 1).

Table 1: Effect of soil moisture content on final emergence percentage and days to 50% emergence

Source: Modified from Canola Council of Canada (2003)

Total soil water content (% weight)	Final emergence percentage	Days to 50% emergence
18%	82%	9
15%	59%	12
13%	45%	13
11%	4%	-

The trial was established in a growth chamber at constant day–night temperatures of 8.5° C–10°C. In summary:

- The higher the total soil water content, the higher the final germination percentage.
- The higher the soil water content, the quicker the time to 50% seedling emergence. ¹⁷

Water is essential for plant growth. Adequate soil moisture:

- promotes root growth
- · promotes a large, abundant leaf area
- · helps plants to retain their leaves longer
- · lengthens the flowering period
- increases the numbers of branches per plant, flowers forming pods and seeds per pod
- increases seed weight and seed yield

Moisture stress is more important during podfill than at the vegetative stage. However, too much or too little water at any growth stage reduces yield potential. Factors that may limit yield include:

- · the amount of moisture stored in the soil over summer
- the rate and duration of rainfall during the growing season
- · the ability of the soil to absorb water, store it, and make it available for plants



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¹⁶ P Parker (2009) Crop rotation and paddock selection. Ch. 4. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

¹⁷ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/______data/assets/pdf__file/0004/516181/Procrop-canola-growth-and-development.pdf</u>

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IREC: Is there a place for canola on irrigation?

Research paper: Yield of wheat and canola in the high rainfall zone of south-western Australia in years with and without a transient perched water table



DAWR: A change in climate

DOE: Climate change

BOM: Climate change and variability

Agriculture Victoria: Weather and climate

NSW DPI: NSW climate summary

QAAFI: Seasonal crop outlook (wheat)

<u>GRDC: Grain</u> marketing—wheat, canola and barley outlook

Rabobank: Agribusiness Outlook 2015 Modifying some of these factors can improve moisture availability and efficiency of water use.

When soil water and nutrients are abundant, the balance of root to stem and leaf growth typically shifts in favour of stem growth at the expense of roots. When water is limited, the opposite usually occurs. Roots account for ~25% of plant dry matter at stem elongation in moisture-stressed canola, compared with ~20% in unstressed plants.

1.6.1 Moisture stress during rosette formation and elongation

Canola has limited ability to withstand severe drought. To avoid dehydration, the plant closes its stomata and rapidly sheds leaves.

Moisture stress during the early vegetative stages reduces the ability of stomata to conduct carbon dioxide and therefore slows photosynthesis. This in turn reduces leaf area expansion and dry matter production. It also limits root growth, which reduces nutrient uptake. More severe water deficits inhibit photosynthesis because of cell and chloroplast shrinkage.

This is important in seasons with dry winters. It is also important in low-rainfall areas where the period of crop growth is restricted at the start of the season by lack of rainfall and at the end of the season by water deficits and high temperatures.

Plants under early-season moisture stress will usually recover normal growth with subsequent rainfall or irrigation. Stressed plants are able to recover leaf area, form flowers, set pods and fill seeds when water becomes available, but with hastened development rates, crops have early maturity and lower yields. The worst time for drought stress in canola is during stem elongation or flowering.

Long periods of drought will reduce yields more than frequent, short periods of drought. The impact will be greatest on coarse-textured soils and shallow soils with low waterstorage capacity.

Adequate soil moisture tends to lengthen the number of days to maturity by up to 10 days. Additional soil moisture will result in no further increase in yield and may cause yield reductions through poor soil aeration and/or increased lodging and diseases.¹⁸

1.7 Yield and targets

1.7.1 Seasonal outlook

The NSW Department of Primary Industries provides a seasonal outlook to assist grain growers. The <u>Seasonal Conditions and Climate Change Summary e-newsletter</u> will let you know as soon as the monthly report is published. <u>Subscribe now</u>.

The Victorian Government produces 'The Break' newsletter, which allows grain growers to access seasonal climate risk information. The newsletter describes credible seasonal outlooks, generates potential crop yields from decision-support computer tools, provides links and highlights topical climate-risk information. The Break is produced as part of the Future Farming Strategy.

<u>Click here</u> to view previous issues of The Break and The Fast Break, as well as subscribe to future newsletters.

1.7.2 Fallow moisture

Like wheat, canola will benefit from stored subsoil moisture. Strict summer fallow management is critical to achieving yield potential in all areas. The stored soil moisture

¹⁸ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf</u>



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allows earlier sowing and moisture reserves through the season in no-till systems. Fallows should be managed efficiently to maximise the amount of moisture at sowing.¹⁹

1.7.3 Nitrogen- and water-use efficiency

Nitrogen fertiliser can increase the water-use efficiency (WUE) of early-sown canola (Table 2). The additional N enables the crop to cover the ground quicker and develop a dense leaf canopy, resulting in reduced soil evaporation and better WUE.

However, because the N promotes vegetative growth, there is a risk that the crop could become water-stressed during pod-filling if reserves of soil moisture have been depleted and there is little rainfall (Table 3). ²⁰

A University of Adelaide study in 2013 of canola under different water regimes with N showed that grain yield was mainly driven by biomass production. It also revealed that the timing of N had little impact on yield; however, split application improved oil content. Canola crops extracted water to 60–80 cm, and addition of N increased the drying of the profile by maturity but had little effect on total water use relative to nil N. Both N-use efficiency and WUE were improved by additional water availability.²¹

Grains Research and Development Corporation-funded research in Victoria estimated the WUE of plot-grown canola to be 18 kg/mm.ha and evaporation 112 mm. In seasons when growing season rainfall exceeds 375 mm, canola WUE is likely to decrease because of waterlogging.²²

Kirrily Condon from Grassroots Agronomy says: We use a target WUE of 8 kg/ ha.mm for canola. From our benchmarking in 2014 of 102 canola paddocks, 36% achieved this target, 49% achieved between 6 and 8 kg/ha.mm.

A practical WUE equation for farmers to use, fine-tuned by James Hunt (CSIRO), is:

WUE = (yield x 1000)/available rainfall

where available rain = (25% November–March rain) + (growing season rainfall) – 60 mm evaporation

Agronomist's view

Table 2: Effects of nitrogen fertiliser on yield and water-use efficiency of canola in the Victorian Wimmera

Note that increasing fertiliser rate improves yield per unit water use at the expense of yield per unit N

Nitrogen rate (kg N/ ha)	Grain yield (t/ha)	Shoot dry matter (t/ha)	Water use (mm)	Soil evaporation (mm)	Dry matter per unit water use (kg/ ha.mm)	Yield per unit water use (kg/ ha/mm)	Yield per unit nitrogen fertiliser (kg grain per kg N)
0	1.6	5.2	307	128	17.1	5.3	
70	2.5	8.8	349	112	25.3	7.1	35.3
140	2.5	8.7	344	91	25.2	7.3	17.9
210	2.8	9.5	335	87	28.4	8.4	13.4

¹⁹ L Jenkins (2009) Crop establishment. Ch. 5. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC Canola Guide All 1308091.pdf</u>

P Hocking, R Norton, A Good (1999) Crop nutrition. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/______data/assets/pdf__file/0013/2704/Chapter_4_-_Canola_Nutrition.pdf</u>

- A Riar, G McDonald, G Gill (2013) Nitrogen and water use efficiency of canola and mustard in Mediterranean environment of South Australia. GRDC Update Papers, 13 February 2013, <u>https://www.grdc.com.au/</u> <u>Research-and-Development/GRDC-Update-Papers/2013/02/Nitrogen-and-water-use-efficiency-of-canolaand-mustard-in-South-Australia</u>
- ²² D Grey (1998) Water-use efficiency of canola in Victoria. 9th Australian Agronomy Conference, <u>http://www.regional.org.au/au/asa/1998/5/181grey.htm</u>



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Table 3: Difference in yield and water-use efficiency of cereal and oilseed crops (source: Norton and Wachsmann 2006)

Cereals have a much greater water-use efficiency than oilseed crops. This reflects the low energy cost of starch relative to fat as main products stored in grain

Season	Water regime	Crop	Water use (mm)	Yield (t/ha)	Yield per unit water use (kg/ha.mm)
2000–01	Rainfed	Wheat	237	2.05	8.6
	Rainfed	Canola	252	1.19	4.7
2001–02	Rainfed	Wheat	337	4.18	12.4
	Rainfed	Canola	256	1.75	6.8
2001–02	Irrigated	Wheat	401	6.04	15.1
	Irrigated	Canola	387	3.44	8.9

1.7.4 Estimating maximum yield per unit water use by location and nitrogen

Researchers propose a three-step procedure to derive the 'slope' parameter representing maximum yield per unit water use accounting for N and location.

Step 1

Use the data in Figure 2*a* to account for the effect of N on maximum yield per unit water use. For severely limited crops (N supply <50 kg N/ha), maximum yield per unit water use would be ~5–6 kg grain/ha.mm. For crops with abundant N supply (>200 kg N/ha), the parameter approaches 24 kg grain/ha.mm. For intermediate N supply, maximum yield per unit water use can be estimated graphically using this curve.

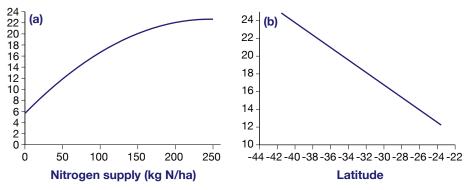


Figure 2: Maximum yield per unit water use (kg/ha.mm) as a function of (a) nitrogen and (b) location.

Step 2

Use the line in Figure 2*b* to correct for location. For a latitude of -41.5° (Launceston, the southernmost location in this study), maximum yield per unit water use would be ~24–25 kg grain/ha.mm. For a latitude of -23.5° (Emerald, the northernmost location), maximum yield per unit water use would be ~12 kg grain/ha.mm. For intermediate locations, maximum yield per unit water supply can be estimated from the graph (Figure 2*b*).

Step 3

Select the lowest value from steps 1 and 2. For example, if we want to estimate the maximum yield per unit water use for Dalby (latitude -27.1°) with intermediate N supply (100 kg N/ha), the location correction would return 14.7 kg/ha.mm and the N correction would return 16.6 kg/ha.mm. We therefore select the lowest value, 14.7 kg/ha.mm, as a benchmark for this combination of location and N supply.²³

²³ V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. GRDC Integrated Weed Management Hub, <u>http://www.grdc.com.au/GRDC-Booklet-WUE</u>



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Table 4: Water-use efficiency based on total biomass (WUEdm) or grain yield (WUEgy) of different crops

Water-use efficiency is based on the biomass or yield per mm of crop water use. Values are mean and range.

Crop	Region	WUEdm	WUEgy	Source
		(kg/ha	a.mm)	
Canola	Victoria	24.0 (17.1-28.4)	6.8 (4.7-8.9)	Norton and Wachsmann 2006
Canola*	NSW		13.4	Robertson and Kirkegaard 2005
Chickpeas	Western Australia	16.0 (11.1-18.3)	6.2 (2.6-7.7)	Siddique et al. 2001
Lentils		12.7 8.5-16.7)	6.7 (2.4-8.5)	
Lupins		17.3 (9.3-22.3)	5.1 (2.3-8.3)	
Faba beans		24.2 (18.7-29.6)	10.4 (7.7-12.5)	
Peas		26.2 (17.6-38.7)	10.5 (6.0-15.9)	
Vetch		18.2 (13.4-22.4)	7.5 (5.6-9.6)	
Chickpeas	Tel Hadya, Syria	13.7 (9.4-18.1)	3.2 (2.1-5.2)	Zhang et al. 2000
Lentils		8.7 (5.0-14.2)	3.8 (1.9-5.5)	
Wheat	South Australia	36.1 (21.2-53.1)	15.9 (9.2-23.2)	Sadras et al. (unpublished)
	South-east Australia		9.9 (max =22.5)	Sadras and Angus 2006

*Based on simulated estimate of crop water use

There are intrinsic differences in the WUE of crops (Table 4), with wheat more water-use efficient than grain legumes or canola, in terms of both total biomass production and grain yield. Differences in the composition of the grain—it is more energy efficient to produce starch than oil or protein—partially explain the higher grain yield per unit water use of wheat than of oilseed crops and pulses.

Further, canola and the grain legumes are grown at lower plant densities and/or have less vigorous seedlings than wheat, contributing to greater early losses of moisture through soil evaporation, and hence to lower WUE. The amount of winter growth made by the crop is therefore an important factor in determining crop WUE.²⁴

1.8 Potential disease problems

Blackleg is the major disease of canola in Australia and can significantly reduce yields, especially in higher rainfall districts. Research has shown that 95–99% of blackleg spores originate from the previous year's canola stubble.

Spores can travel >1 km on the wind but most travel shorter distances, so selecting a paddock as far away as possible from the previous season's canola stubble will help to reduce disease pressure. Where possible, a buffer distance of 500 m is recommended.

On larger farms, it may be possible to implement a system of block farming whereby blocks of several paddocks of a particular crop type are rotated around the farm to maintain an adequate buffer distance. Reducing canola stubble by raking and burning provides only limited benefits in reducing the disease level because not all of the infected stubble and old roots are destroyed.

Use of blackleg-resistant varieties in combination with an appropriate fungicide treatment, if necessary, is the best way to minimise yield losses. Careful paddock selection can also assist in reducing the impact of another potentially serious canola disease, Sclerotinia stem rot (caused by *S. sclerotiorum*).

Sclerotinia stem rot is an intermittent problem in many canola-growing districts, particularly central and southern NSW. Agronomists report that it is also present in south-western and north-eastern Victoria. It has a wide host range of broadleaf plants

²⁴ V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. GRDC Integrated Weed Management Hub, <u>http://www.grdc.com.au/GRDC-Booklet-WUE</u>



GRDC: Water use efficiency of grain crops in Australia: principles, benchmarks and management

<u>GRDC: Nitrogen and</u> <u>water use efficiency of</u> <u>canola and mustard</u> <u>in Mediterranean</u> <u>environment of South</u> <u>Australia</u>

Research paper: Nitrogen use efficiency in canola

<u>CSIRO: A guide</u> <u>to consistent</u> <u>and meaningful</u> <u>benchmarking of yield</u> <u>and reporting of wateruse efficiency</u>

Research paper: Wateruse efficiency of canola in Victoria





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and weeds, including lupins, chickpeas, field peas, faba beans, sunflowers, cape weed and Paterson's curse. Growing canola after any of these crops or in paddocks that have had large populations of these weeds can increase the risk of Sclerotinia stem rot, especially when canola is grown under irrigation or in higher rainfall areas.²⁵

1.9 Nematode status of paddock

Canola has hosting ability of root-lesion nematodes of low-medium for *Pratylenchus thornei* and medium-high for *P. neglectus*.

Testing soil is the only reliable way to determine whether root-lesion nematodes are present in a paddock. Before planting, soil tests can be carried out by PreDicta B (SARDI Diagnostic Services) through accredited agronomists, to establish whether crops are at risk and whether alternative crop types or varieties should be grown. Growing-season tests can be carried out on affected plants and associated soil; contact local state departments of agriculture and PreDicta B.²⁶

To organise testing and sending of soil samples, visit the PreDicta B website.

For more information, see GrowNotes Southern Canola. Section 8. Nematodes.



GRDC (2015) Root-lesion nematodes. GRDC Tips and Tactics, February 2015, <u>http://www.grdc.com.au/</u> <u>TT-RootLesionNematodes</u>



GRDC: Variety choice and crop rotation key to managing root lesion nematodes

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Pre-planting



Agriculture Victoria: Victorian winter crop summary

Agriculture Victoria: What is canola and GM canola?

<u>GRDC: National Variety</u> <u>Trials. 2015 Canola</u> <u>mudmaps</u>

<u>GRDC: National Variety</u> <u>Trials. Variety brochures</u>

SARDI: Canola variety sowing guide 2015

GRDC: NVT Victorian winter crop summary 2015

BCG: The agronomic, environmental, economic and coexistence impacts of GM canola

BCG: Playing it safe: clethodim (Select) use in canola



GRDC: Crop variety guides

MFMG: Canola variety trials

Baker Seed Co. Newsletter

Australian Grain: Optimal canola establishment to maximise yields



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2.1 Varietal performance and ratings yield

The main features to consider when selecting a variety are maturity, yield, oil content, herbicide tolerance and blackleg resistance. Early-maturing varieties are generally more suited to drier areas, and mid-season types are suited to higher rainfall growing areas.¹

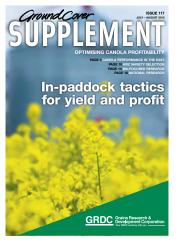
New variety listings for 2015 were:

- Clearfield[®]—Hyola 970CL, Pioneer 44Y89(CL)
- Triazine-tolerant-Pioneer Atomic TT
- Triazine-tolerant high stability—Monola 515TT
- Roundup Ready[®]—Hyola 600RR, DG550RR, IH51RR, IH52RR, Pioneer 44Y26(RR), Pioneer 45Y25(RR)
- Roundup Ready[®] and triazine-tolerant—Hyola 725RT

Varieties removed in 2015:

- Clearfield[®]—Carbine, Hyola 971CL, Pioneer 43C80(CL)
- Triazine-tolerant—ATR-Snapper, Hyola 656TT, Hyola 555TT, Crusher TT, Thumper TT
- Triazine-tolerant high stability—Monola 413TT
- Roundup Ready[®]—GT Cobra, GT Viper, Pioneer 45Y22(RR)
- Roundup Ready[®] and triazine-tolerant—Fusion HT-RR





L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-Canola-Northern-NSW-Planting-Guide.pdf</u>

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2.1.1 Varieties for Victoria

For detailed information on varieties available in Victoria in 2015 (Table 1), visit Agriculture Victoria's Victorian winter crop summary.

Table 1: Canola varieties being marketed in Victoria in 2015²

Blackleg ratings are from the 2014 GRDC Blackleg Management Guide (revised September 2014); the Australian Oilseeds Federation published updated ratings in March 2015; est, estimate by marketing company (yet to be rated by Australian Oilseeds Federation). R, Resistant; MR, moderately resistant; MS, moderately susceptible; S, susceptible (Jockey® seed dressing contains fluquinconazole). Blackleg resistance group refers to the combinations of blackleg resistance genes carried by each variety.

Variety	Maturity	Year of release	Blackleg resistance rating bare seed	istance resistance ng bare rating +		Open pollinated or hybrid	Marketer
Conventional varietie							
AV-Garnet	mid	2007	MR		А	open	Nuseed
AV-Zircon mid		2011	MR			open	Nuseed
Hyola 50	early-mid	2007	R		A, D	hybrid	Pacific Seeds
Nuseed Diamond	early-mid	2013	R-MR	R-MR	A, B, F	hybrid	Nuseed
SF Brazzil	late	2013	R-MR		B, C	open	Seed Force
SF Sensation	very late	2013	R-MR			hybrid	Seed Force
Conventional high st	ability						
Victory V3002	early-mid	2011	R-MR	R	A, B, F	hybrid	Cargill/AWB
Herbicide tolerant Cl	earfield varietie	s					
Archer	mid	2012	MR-MS	R-MR	А	hybrid	Heritage Seeds
Edimax CL*	Late	2014	R-MR		С	hybrid	AGF Seeds
Hyola 474CL	mid-early	2011	R		B, F	hybrid	Pacific Seeds
Hyola 575CL	mid	2010	R		B, F	hybrid	Pacific Seeds
Hyola 577CL	mid	2013	R	R		hybrid	Pacific Seeds
Hyola 970CL	late	2014	R			hybrid	Pacific Seeds
Pioneer 43Y85(CL)	early	2011	MR	R-MR	А	hybrid	Pioneer Hi-Bred
Pioneer 44C79(CL)	early	2008	MR-MS		С	open	Pioneer Hi-Bred
Pioneer 44Y84(CL)	early- early mid	2010	MS	MR	А	hybrid	Pioneer Hi-Bred
Pioneer 44Y87(CL)	early-mid	2013	MR	R-MR	А	hybrid	Pioneer Hi-Bred
Pioneer 44Y89(CL)	early-mid	2014	R-MR		B, C	hybrid	Pioneer Hi-Bred
Pioneer 45Y86(CL)	mid- mid early	2012	MR-MS	R-MR	AB	hybrid	Pioneer Hi-Bred
Pioneer 45Y88(CL)	mid	2013	R-MR	R-MR	А	hybrid	Pioneer Hi-Bred
Clearfield juncea car	nola varieties						
XCEED OASIS CL	early	2008	R	G		open	Seednet
Triazine tolerant varie	eties						
Pioneer Atomic TT	mid	2012	MS	MR	А, В	hybrid	Pioneer Hi-Bred
ATR-Bonito	early- early mid	2013	MR	R-MR	А	open	Nuseed
ATR-Gem	early-mid	2011	MR	R-MR	А	open	Nuseed
ATR-Stingray	early	2011	MR	R	С	open	Nuseed

² Agriculture Victoria (2015) Victorian winter crop summary. 2015 edition. (Ed. K Holloway) Department of Economic Development, Jobs, Transport and Resources Victoria, <u>http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/victorian-winter-crop-summary</u>





December 2015

Variety	Maturity	Year of release	Blackleg resistance rating bare seed	Blackleg resistance rating + Jockey®	Blackleg resistance group	Open pollinated or hybrid	Marketer
ATR-Wahoo	mid	2013	MR	R-MR	А	open	Nuseed
Hyola 450TT	early-mid	2013	R	R	A, B, D	hybrid	Pacific Seeds
Hyola 559TT	mid	2012	R	R	A, B, D	hybrid	Pacific Seeds
Hyola 650TT	mid-late	2013	R	R	A, B, E	hybrid	Pacific Seeds
Pioneer Sturt TT	early	2012	MS	MR		open	Pioneer Hi-Bred
Triazine tolerant high	n stability varie	ties					
Monola 314TT	early-mid	2013	MR	R-MR	open		Nuseed
Monola 515TT	mid	2015			open		Nuseed
Monola 605TT	early-mid	2011	R		open		Nuseed
Roundup Ready vari	eties						
DG 550RR	mid	2014	R-MR	R	А, В	hybrid	Seednet
GT-41	early	2012	R-MR	R-MR	A, B, F	hybrid	Nuseed
GT-50	early-mid	2012	R-MR		A, B, F	hybrid	Nuseed
Hyola 400RR	early-mid	2013	R		A, B, D	hybrid	Pacific Seeds
Hyola 404RR	early-mid	2010	R-MR	R	A, B, D hybrid		Pacific Seeds
Hyola 500RR	mid	2013	R		A, B, D	hybrid	Pacific Seeds
Hyola 505RR	mid-early	2010	R	R	D	hybrid	Pacific Seeds
Hyola 600RR	mid-late	2014	R-MR (est)	R (est)		hybrid	Pacific Seeds
IH30 RR	early	2013	R-MR	R	А, В	hybrid	Bayer
IH50 RR	mid	2012	R-MR	R	А	hybrid	Bayer
IH51 RR	mid	2014				hybrid	Bayer
IH52 RR	mid	2014	R-MR	R	А, В	hybrid	Bayer
Pioneer 43Y23 (RR)	early	2012	R-MR	R	В	hybrid	Pioneer Hi-Bred
Pioneer 44Y24 (RR)	mid-early	2013	R-MR	R	С	hybrid	Pioneer Hi-Bred
Pioneer 44Y26 (RR)	early-mid	2014	R-MR		A, B, S	hybrid	Pioneer Hi-Bred
Pioneer 45Y25 (RR)	mid	2014	R-MR		B, C	hybrid	Pioneer Hi-Bred
Roundup Ready high	n stability varie	ties					
Monola 513GT	mid	2012	MR	R-MR		open	Nuseed
Victory V5002RR	mid	2011	MR	R	А, В	hybrid	Cargill/AWB
Roundup Ready and	Triazine Tolera	ant					
Hyola 525RT	mid	2013	R-MR	R	A, B, D	hybrid	Pacific Seeds
Hyola 725RT	mid-late	2014	R-MR (est)			hybrid	Pacific Seeds



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2.1.2 Varieties for South Australia

For detailed information on varieties available in SA in 2015 (Table 2), visit <u>SARDI's</u> <u>Canola variety sowing guide 2015</u>.

Table 2: South Australian mid-season long-term canola yields and agronomic information ³ Data source SARDI/GRDC NVT and District Canola Trials; 2009–13 MET data analysis by National Statistics Program. Oil, Average of 2013 SA midseason NVT trials, adjusted to 6% moisture (number of trials in parentheses). OP, Open-pollinated; Spec. oil, high-stability specialty oil; E, early; M, mid; L, late; R, resistant; MR, moderately resistant; MS, moderately susceptible; S, susceptible (Jockey® seed dressing contains fluquinconazole). Blackleg resistance group refers to the combinations of blackleg resistance genes carried by each variety

					Lowe	rEP_	Yorke Penin	sula_	Mid north		Aid north South east					
Variety	Licensee	Release year	Туре^	Mat- urity	% of site mean	no. trials	Oil (%)*	Blackleg rating (bare)	Blackleg rating (+jockey)	Blackleg resistance group						
Convention	al															
AV Garnet	Nuseed	2007	OP	М	108	10	106	6	108	8	110	14	46.3 (6)	MR	-	А
AV Zircon	Nuseed	2011	OP	ML	104	6	105	2	104	2	109	8	46.8 (6)	MR	-	unknown
Hyola [®] 50	Pacific Seeds	2006	Hybrid	М	112	10	114	6	112	8	116	14	46.5 (6)	R	-	AD
Nuseed Diamond	Nuseed	2013	Hybrid	E	113	3	-	-	-	-	-	-	47.0 (3)	R-MR	R-MR	ABF
Victory® V3002	Cargill/ AWB	2012	OP - Spec. Oil	Μ	111	2	-	-	-	-	113	6	46.3 (6)	R-MR	R	ABF
TT Site Mean Yeild (t/ha)					2.09		2.71		2.21		2.17					
Clearfield																
Archer	Heritage Seeds	2012	Hybrid	ML	105	4	106	3	105	11	108	10	44.9 (8)	MR-MS	R-MR	Nil
Carbine	Heritage Seeds	2012	Hybrid	EM	102	4	101	3	103	7	96	6	46.0 (8)	MR-MS	R-MR	A
Hyola® 474CL	Pacific Seeds	2011	Hybrid	ME	102	6	104	3	101	9	109	8	46.3 (8)	R	-	BF
Hyola® 575CL	Pacific Seeds	2010	Hybrid	М	104	8	104	5	103	12	112	11	46.2 (8)	R	-	BF
Hyola® 577CL	Pacific Seeds	2013	Hybrid	М	104	2	-	-	102	2	110	2	46.8 (7)	R	R	unknown
Pioneer® 43Y85 (CL)	DuPont Pioneer	2012	Hybrid	Е	96	2	94	2	95	3	95	3	N/A	MR	R-MR	А
Pioneer® 44Y87 (CL)	DuPont Pioneer	2013	Hybrid	EM	104	2	-	-	105	3	100	3	N/A	MR	R-MR	A
Pioneer® 45Y86 (CL)	DuPont Pioneer	2012	Hybrid	М	107	8	108	5	108	12	106	11	46.2 (8)	MR-MS	R-MR	AB
Pioneer® 45Y88 (CL)	DuPont Pioneer	2013	Hybrid	М	108	4	106	2	108	6	110	5	44.4 (8)	R-MR	R-MR	A
Clearfield Site Mean Yeild (t/ ha)					2.11		2.14		2.30		2.8					
Triazine Tole	erant															
Atomic HT	NPZ Australia		Hybrid	EM	-	-	102	2	104	6	98	5	44.5 (7)			
ATR Bonito	Nuseed	2013	OP	EM	105	4	98	2	104	6	101	5	47.3 (8)	MR	R-MR	A
ATR Gem	Nuseed	2011	OP	EM	101	6	96	2	100	8	101	7	46.4 (8)	MR	R-MR	А



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					Lowe	rEP	Yorke Penin		Mid n	orth	South	east				
Variety	Licensee	Release year	Type^	Mat- urity	% of site mean	no. trials	Oil (%)*	Blackleg rating (bare)	Blackleg rating (+jockey)	Blackleg resistance group						
ATR Stingray	Nuseed	2011	OP	Е	98	8	94	5	98	12	94	11	46.3 (8)	MR	R	С
ATR Wahoo	Nuseed	2013	OP	ML	101	4	94	2	100	6	101	5	46.3 (8)	MR	R-MR	А
Crusher TT	Pacific Seeds	2010	OP	М	105	8	100	5	104	12	103	11	44.1 (7)	MR-MS		А
Hyola® 450TT	Pacific Seeds	2013	Hybrid	ME	103	2	-	-	103	3	107	2	46.9 (8)	R	R	ABD
Hyola® 559TT	Pacific Seeds	2012	Hybrid	М	107	5	106	2	107	7	107	5	46.4 (8)	R	R	ABD
Hyola® 650TT	Pacific Seeds	2014	Hybrid	ML	-	-	-	-	107	2	-	-	45.9 (4)	R	R	ABE
Hyola® 750 TT	Pacific Seeds	2015	Hybrid	L												
Monola® 314TT	Nuseed	2014	OP - Spec. Oil	E	87	2	-	-	88	2	82	2	44.0 (7)	MR	R-MR	unknown
Sturt TT	NPZ Australia	2012	OP	Е	-	-	92	2	94	7	87	2	43.6 (4)	MS	MR	Nil
Thumper TT	Pacific Seeds	2011	OP	ML	97	8	90	4	94	11	103	11	46.2 (8)	R		E
Triazine Tolerant Site Mean Yeild					1.90		2.5		2.10		1.8					

(t/ha)

2.1.3 Oil

Canola was developed from rapeseed to produce an oilseed crop with improved nutritional composition. The aim was to produce a crop that had low levels of glucosinolates in the meal and low levels of erucic acid in the oil. ⁴

Oil is extracted by mechanically crushing the seed. The oil is then processed by using heat and/or chemicals. Approximately 73% of canola in Australia is processed by addition of solvents, 25% by expeller treatment and 2% by cold-pressing.

The seed typically has an oil content of 35–45%. The oil content is generally expressed as a percentage of the whole seed at 8% moisture content. The oil contains:

- 10–12% linolenic acid (omega-3)
- <0.1% erucic acid</p>
- 59–62% oleic acid

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• 12-22% linoleic acid

Canola oil is high in unsaturated fats (93%) and has no cholesterol or trans-fats. It has the lowest saturated fat content (7%) of any common edible oil. 5

2.1.4 Seed meal

The seed meal is what is left over after the oil is removed. It contains proteins, carbohydrates, minerals and fibre. The exact composition of seed meal depends on the oil extraction method. The protein content varies each season and increases as the



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R Mailer (2009) Grain quality. In Canola best practice management guide for eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC Canola_Guide_All_1308091.pdf</u>

⁵ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf__file/0004/516181/Procrop-canola-growth-and-development.pdf</u>



oil content decreases. Typically, seed meal consists of 36–39% protein, 1.5–2.0% fat, 11–13% fibre and <10 μ mol glucosinolate/g.

The minimum protein content of seed meal, as determined by the AOF (Australian Oilseeds Federation) is 36%, measured at 12% moisture. ⁶

2.2 Varieties

2.2.1 Conventional varieties

AV-Garnet: a mid-maturing to mid-early-maturing variety. Medium height. Moderatehigh oil content. Widely adapted. Blackleg resistance rating 2014, MR; resistance group A. Tested in NVT trials 2006–14. Bred by Department of Environment and Primary Industries (DEPI) Victoria. Marketed by Nuseed Pty Ltd.

AV-Zircon: a mid-maturing variety. Medium height. Moderate oil content. Blackleg resistance rating 2014, MR; resistance group currently unknown. Tested in NVT trials 2011–14. Bred by DEPI Victoria and Nuseed Pty Ltd. Marketed by Nuseed Pty Ltd.

Hyola[®] **50:** mid-maturing to mid-early-maturing hybrid. High oil content. Widely adapted. Blackleg resistance rating 2014, R; resistance group AD. Tested in NVT trials 2005–14. Bred by Canola Breeders International. Marketed by Pacific Seeds.

Nuseed® Diamond: new release (coded NCH1203C). Early-maturing hybrid. Medium height. High oil content. Suited to low-medium rainfall zones. Blackleg resistance rating 2014, R–MR; resistance group ABF. Tested in NVT trials 2012–14. Bred and marketed by Nuseed Pty Ltd.

SF Brazzil™: late-maturing, winter, dual-purpose, open-pollinated variety. Suited to early sowing and winter grazing in very high-rainfall zones. Blackleg resistance rating 2014, R–MR; resistance group BC. Not tested in NVT trials. Marketed by Seed Force.

SF Sensation™: very late-maturing, winter, dual-purpose hybrid. Suited to early sowing and winter grazing in very high-rainfall zones. Blackleg resistance rating 2014, R–MR; resistance group currently unknown. Not tested in NVT trials. Marketed by Seed Force.

Victory[®] **V3002:** early–mid-maturing conventional specialty (high stability oil) hybrid, slightly later than Victory V3001. Moderate–high oil content. Blackleg resistance rating 2014, R–MR; resistance group ABF. Tested in NVT trials 2011–14. Bred by Cargill and DEPI Victoria. Marketed by AWB Ltd in a closed-loop program.⁷

2.2.2 Triazine-tolerant varieties

Triazine-tolerant (TT) varieties can have lower yield and oil content than some Roundup Ready varieties. However, they can give good yields in weedy paddocks, when sprayed with atrazine and/or simazine herbicides.

ATR-Bonito: an early-maturing to early-mid-maturing variety. High-very high oil content. Plant height slightly shorter than ATR-Gem. Blackleg resistance rating 2014, MR; resistance group A. Tested in NVT trials 2012–14. Bred by Nuseed Pty Ltd and DEPI Victoria. Marketed by Nuseed Pty Ltd. An EPR (end-point royalty) applies.

ATR-Gem: a mid–early-maturing variety. High–very high oil content. Slightly shorter plant height than Tawriffic TT. Blackleg resistance rating 2014, MR; resistance group A. Tested in NVT trials 2011–14. Bred by Nuseed Pty Ltd and DEPI Victoria. Marketed by Nuseed Pty Ltd.



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J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf</u>

⁷ Agriculture Victoria (2015) Victorian winter crop summary. 2015 edition. (Ed. K Holloway) Department of Economic Development, Jobs, Transport and Resources Victoria, <u>http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/victorian-winter-crop-summary</u>



ATR-Stingray: an early-maturing variety. High oil content. Short plant height. Blackleg resistance rating 2014, MR; resistance group C. Tested in NVT trials 2010–14. Bred by Nuseed Pty Ltd and DEPI Victoria. Marketed by Nuseed Pty Ltd.

ATR-Wahoo: a mid-maturing variety, similar to ATR-Marlin. High–very high oil content. Plant height similar to ATR-Gem. Blackleg resistance rating 2014, MR; resistance group A. Tested in NVT trials 2012–14. Bred by Nuseed Pty Ltd and DEPI Victoria. Marketed by Nuseed Pty Ltd. An EPR applies.

Hyola[®] **450TT:** early-maturing to mid–early-maturing hybrid. High–very high oil content. Medium plant height. Suited to low-rainfall to medium–high-rainfall areas. Blackleg resistance rating 2014, R; resistance group ABD. Tested in NVT trials 2013 and 2014. Bred and marketed by Pacific Seeds.

Hyola® 559TT: mid-maturing to mid-early-maturing hybrid. High oil content. Medium plant height. Suited to medium-very high-rainfall areas. Blackleg resistance rating 2014, R; resistance group ABD. Tested in NVT trials 2012–14. Bred and marketed by Pacific Seeds.

Hyola[®] **650TT:** mid-maturing to mid–late-maturing hybrid. High oil content. Medium–tall plant height. Suited to medium–high-rainfall areas. Blackleg resistance rating 2014, R; resistance group ABE. Tested in NVT trials 2013 and 2014. Bred and marketed by Pacific Seeds

Monola® 314TT: early–mid-maturing, open-pollinated, specialty oil variety. Moderate oil content. Medium plant height. Blackleg resistance rating 2014, MR. Tested in NVT trials 2013 and 2014. Bred and marketed by Nuseed Pty Ltd. Nuseed.

Monola® 515TT: new release (coded NL805). Mid-maturing, open-pollinated specialty oil variety. Moderate-high oil content. No published GRDC blackleg resistance rating or resistance group for 2014. Tested in NVT trials for the first time in 2014. Bred and marketed by Nuseed Pty Ltd.

Pioneer® Sturt TT: early-maturing to early-mid-maturing, open-pollinated variety. Moderate oil content. Short-medium plant height. Adapted to low-medium-rainfall zones. Blackleg resistance rating 2014, MS. Tested in NVT trials 2011–14. Bred by NPZ Australia Pty Ltd. Marketed by DuPont Pioneer. An EPR applies.

Pioneer® Atomic TT: mid-maturing hybrid. Medium height. Moderate oil content. Suited to medium-rainfall zones. Blackleg resistance rating 2014, MS; resistance group AB. Tested in NVT trials 2012–14. Bred by NPZ Australia Pty Ltd. Marketed by DuPont Pioneer. ⁸

2.2.3 Clearfield[®] (imidazolinone-tolerant) varieties

These varieties are tolerant to Intervix[®] imidazolinone herbicide and are part of the Clearfield[®] Production System.

Archer: mid–late-maturing hybrid. High oil content. Medium–tall plant height. Blackleg resistance rating 2014, MR–MS. Tested in NVT trials 2011–14. Marketed by Heritage Seeds.

Carbine: early–mid-maturing hybrid. Moderate–high oil content. Medium plant height. Blackleg resistance rating 2014, MR–MS. Tested in NVT trials 2011–13. Marketed by Heritage Seeds.

Hyola® 474CL: mid-maturing to mid-early-maturing hybrid. High oil content. Mediumtall plant height. Suited to medium-low-rainfall to high-rainfall areas. Blackleg resistance rating 2014, R; resistance group BF. Tested in NVT trials 2011–14. Bred and marketed by Pacific Seeds.



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P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/</u> pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf



Hyola® 575CL: mid-maturing hybrid. High–very high oil content. Medium plant height. Suited to medium–very high-rainfall areas. Blackleg resistance rating 2013, R; resistance group BF. Tested in NVT trials 2010–14. Bred and marketed by Pacific Seeds.

Hyola® 577CL: mid-maturing hybrid. High–very high oil content. Medium–tall plant height. Suited to medium–high-rainfall areas. Blackleg resistance rating 2014, R. Tested in NVT trials 2013 and 2014. Bred and marketed by Pacific Seeds.

Hyola® 970CL: late-maturing, winter graze and grain hybrid. Pacific Seeds indicate high-very high biomass, good grain yield and oil content. Early-mid autumn and spring sowing, graze and grain option for very high-rainfall zones. No published GRDC blackleg resistance rating or resistance group for 2014. Released 2014. Not tested in NVT trials. Bred and marketed by Pacific Seeds.

Hyola® 971CL: late maturing, winter graze and grain hybrid. Pacific Seeds indicate high-very high biomass, good grain yield and oil content. Early-mid autumn and spring sowing, graze and grain option for very high-rainfall zones. Blackleg resistance rating 2014, R-MR; resistance group A. Released 2012. Not tested in NVT trials. Bred and marketed by Pacific Seeds.

Pioneer® 43C80(CL): an early-maturing variety. Adapted to low-rainfall areas. Medium plant height. Blackleg resistance rating in 2013, MR–MS. Tested in NVT trials 2008–09 and 2011–12. Bred and marketed by DuPont Pioneer.

Pioneer® 43Y85(CL): early-maturing hybrid. Short–medium plant height. Moderate oil content. Suited to medium–low-rainfall areas. Blackleg resistance rating 2014, MR; resistance group A. Tested in NVT trials 2011–14. Bred and marketed by DuPont Pioneer.

Pioneer[®] **44C79(CL):** an early-maturing to early-mid maturing variety. Medium plant height. Blackleg resistance rating in 2013, MS. Tested in NVT trials in 2008, 2009 and 2011. Bred and marketed by DuPont Pioneer.

Pioneer[®] **44Y84(CL):** early-maturing to early-mid-maturing hybrid. High-very high oil content in 2013 trials. Medium-tall plant height. Blackleg resistance rating 2014, MS; resistance group A. Tested in NVT trials 2009–13. Bred and marketed by DuPont Pioneer.

Pioneer[®] **44Y87(CL):** early–mid-maturing hybrid. Moderate–high oil content. Medium plant height. Suited to medium-rainfall areas. Blackleg resistance rating 2014, MR; resistance group A. Tested in NVT trials 2012–14. Bred and marketed by DuPont Pioneer.

Pioneer® 44Y89(CL): new release (coded PHI-1305). Early–mid-maturing hybrid. High oil content. Short–medium plant height. Suited to low–medium-rainfall areas. Blackleg resistance rating 2014, R–MR; resistance group BC. Tested in NVT trials 2013 and 2014. Bred and marketed by DuPont Pioneer.

Pioneer® 45Y86(CL): mid-maturing hybrid. High–very high oil content. Medium– tall plant height. Suited for dual-purpose (graze and grain) option in full-season environments. Blackleg resistance rating 2014, MR–MS; resistance group AB. Tested in NVT trials 2010–2014. Bred and marketed by DuPont Pioneer.

Pioneer® 45Y88(CL): mid-maturing hybrid. Moderate–high oil content. Medium plant height. Suited to high-rainfall areas. Blackleg resistance rating 2014, R–MR; resistance group A. Tested in NVT trials 2012–14. Bred and marketed by DuPont Pioneer.

SF Edimax CL: new release. Late-maturing, dual-purpose winter hybrid. Undergoing BASF Clearfield registration. Suited to early sowing and spring sowing in high-rainfall areas. Blackleg resistance rating 2014, R–MR; resistance group C. Not tested in NVT trials. Marketed by AGF Seeds.



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2.2.4 Roundup Ready[®] varieties

DG 550RR: new release (coded VT-WZ-11-2685). Mid-maturing hybrid. High oil content. Blackleg resistance rating 2014, R–MR; resistance group AB. Tested in NVT trials 2013 and 2014. Bred and marketed by Seednet.

Hyola® 400RR: early-maturing to mid–early-maturing hybrid. Very high oil content. Medium plant height. Suited to low–medium-rainfall areas. Blackleg resistance rating 2014, R; resistance group ABD. Tested in NVT trials 2013 and 2014. Bred and marketed by Pacific Seeds.

Hyola® 404RR: early-maturing to mid–early maturing hybrid. Very high oil content. Medium plant height. Suited to low–high-rainfall areas. Blackleg resistance rating 2014, R–MR; resistance group ABD. Tested in NVT trials 2010–14. Bred and marketed by Pacific Seeds.

Hyola[®] **500RR:** mid-maturing hybrid. Medium-tall plant height. High oil content. Suited to medium-high-rainfall areas. Blackleg resistance rating 2014, R; resistance group ABD. Tested in NVT trials 2013 and 2014. Bred and marketed by Pacific Seeds.

Hyola[®] **600RR:** new release. Mid-maturing to mid–late-maturing hybrid. Very high oil content. Medium–tall plant height. Suited to medium–high-rainfall to very high-rainfall areas. No published GRDC blackleg resistance rating or resistance group 2014. Tested in NVT trials for the first time in 2014. Bred and marketed by Pacific Seeds

IH30RR: early-maturing hybrid. High oil content. Suited to low-medium-rainfall areas. Blackleg resistance rating R-MR; resistance group AB. Tested in NVT trials 2012–14. Bred and marketed by Bayer.

IH51RR: new release (coded AN13R9003). Mid-maturing hybrid with Bayer's new pod shatter reduction trait. High oil content. Suited to later windrow timings or direct harvesting in medium–high-rainfall areas. No published GRDC blackleg resistance rating or resistance group for 2014. Tested in NVT trials for the first time in 2014. Bred and marketed by Bayer.

IH52RR: new release (coded AN11R5201). Mid-maturing hybrid. High oil content. Suited to medium–high-rainfall areas. Blackleg resistance rating 2014, R–MR; resistance group AB. Tested in NVT trials 2013 and 2014. Bred and marketed by Bayer.

Monola[®] 513GT: early-mid-maturing, open-pollinated, specialty oil variety. Very high oil content. Medium plant height. Blackleg resistance rating 2014, MR. Tested in NVT trials 2012–14. Bred and marketed by Nuseed Pty Ltd.

Monola® G11: new release (coded NMH13G011). Early–mid-maturing, specialty oil hybrid. Very high oil content. Medium plant height. Blackleg resistance rating 2014, R–MR; resistance group ABS. Tested in NVT trials 2013 and 2014. Bred and marketed by Nuseed Pty Ltd.

Nuseed® GT-41: early-maturing hybrid. High oil content. Medium plant height. Blackleg resistance rating 2012, R–MR; resistance group ABF. Tested in NVT trials 2012–14. Bred and marketed by Nuseed Pty Ltd.

Nuseed® GT-50: mid-maturing hybrid. High-very high oil content. Medium-tall plant height. Blackleg resistance rating 2014, R–MR; resistance group ABF. Tested in NVT trials 2012–14. Bred and marketed by Nuseed Pty Ltd.

Pioneer[®] **43Y23(RR):** early-maturing hybrid. Moderate–high oil content. Blackleg resistance rating 2014. R–MR; resistance group B. Tested in NVT trials 2011–14. Bred and marketed by DuPont Pioneer.

Pioneer[®] **44Y24(RR):** early–mid-maturing hybrid. High oil content. Medium plant height. Suited to medium–high-rainfall areas. Blackleg resistance rating 2014, MR; resistance group C. Tested in NVT trials 2011–14. Bred and marketed by DuPont Pioneer.

Pioneer® 44Y26(RR): new release (coded PHI-1311). Early–mid-maturing hybrid. High–very high oil content. Medium–tall plant height. Suited to medium–high-rainfall areas.



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Blackleg resistance rating 2014, R–MR; resistance group ABS. Tested in NVT trials 2013 and 2014. Bred and marketed by DuPont Pioneer.

Pioneer® 45Y25(RR): new release (coded PHI-1306). Mid-maturing hybrid. High–very high oil content. Medium plant height. Suited to medium–high-rainfall areas. Blackleg resistance rating 2014, R–MR; resistance group BC. Tested in NVT trials 2012–14. Bred and marketed by DuPont Pioneer. ⁹

2.2.5 Roundup Ready[®]-triazine-tolerant varieties

New varieties are being developed that combine two herbicide tolerance traits, allowing improved weed control in paddocks where weeds have developed resistance to other herbicide chemistries.

Hyola[®] **525RT**[®]: mid-maturing, RT[®] dual-herbicide-tolerant hybrid. High–very high oil content. Medium plant height. Suited to medium–high-rainfall areas. Blackleg resistance rating 2014, R–MR; resistance group ABD. Tested in NVT trials 2013 and 2014. Bred and marketed by Pacific Seeds.

Hyola® 725RT®: new release. Mid–late-maturing, RT® dual-herbicide-tolerant hybrid. Highvery high oil content. Medium–tall plant height. Suited to medium–high-rainfall to very highrainfall areas. No published GRDC blackleg resistance rating or resistance group for 2014. Tested in NVT trials for the first time in 2014. Bred and marketed by Pacific Seeds.

2.2.6 Juncea canola (Brassica juncea)

Juncea canola is adapted to low-rainfall areas (300–400 mm) and dry conditions. It has oil quality similar to canola, but still requires segregation and has designated delivery sites.

XCEED™ VT Oasis CL: first herbicide-tolerant Clearfield[®] juncea canola in Australia. Early–mid-maturing, open-pollinated variety. High oil content. Suitable for direct harvesting. Blackleg resistance rating R and resistance group G. Tested in NVT trials 2008–13. Bred by DEPI Victoria/Viterra. Marketed by Seednet. An EPR applies. ¹⁰

2.3 Planting seed quality

2.3.1 Seed size

Canola seeds are smaller than other grains such as wheat, barley or lupins. They weigh only 3 mg each. The 1000-seed weight of canola is typically 3–6 g. Seed size varies according to the growing conditions. There are also varietal differences. Generally, hybrid varieties have larger seeds (Figure 1).

Seed size plays an important role in crop establishment. Larger seeds produce seedlings that are more vigorous and give improved crop establishment. There is also an interaction with sowing depth. Larger seeds establish more plants, particularly if sown at depth of \geq 3 cm. ¹¹

In practice, we target 2–3 cm sowing depth (3 cm if marginal moisture at surface). Larger seeds tend to have better establishment, so hybrids are sown at lower sowing rates (1.5–2 kg), compared with up to 3.5 kg for smaller seeded open-pollinated varieties.

Agronomist's view

- Agriculture Victoria (2015) Victorian winter crop summary. 2015 edition. (Ed. K Holloway) Department of Economic Development, Jobs, Transport and Resources Victoria, <u>http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/victorian-winter-crop-summary</u>
- ¹⁰ Agriculture Victoria (2015) Victorian winter crop summary. 2015 edition. (Ed. K Holloway) Department of Economic Development, Jobs, Transport and Resources Victoria, <u>http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/victorian-winter-crop-summary</u>
- J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/516181/Procrop-canola-growthand-development.pdf



Monsanto: What is Roundup Ready[®] canola?





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December 2015



Figure 1: Dr Abed Chaudhury cross-pollinating canola flowers. Following their discovery of two genes that control the size of plant seeds, CSIRO Plant Industry researchers are investigating how that knowledge can be used to produce larger seeds across a wide range of crops. (Photo: Carl Davies)

Birchip Cropping Group (BCG) trials at Horsham and Quambatook in 2013 showed that retaining hybrid seed could result in lost yield.

Key points:

- Retaining hybrid canola from one season to the next incurred a yield penalty of 0.3 t/ha at Quambatook. There was a general penalty of 0.2 t/ha for retained seed in the mean yield of all varieties (including open-pollinated) at Horsham.
- Oil content and test weights of retained seed were lower at Quambatook, but not at Horsham.
- Retaining hybrid seed compromises plant vigour, disease resistance and herbicide tolerance. The yield advantages (0.2–0.3 t/ha) from hybrid varieties, particularly within the Clearfield hybrid varieties, significantly outweigh the initial seed cost of \$44/ha at 2 kg/ha sowing rate. ¹²

There are a lot of data to suggest retaining open-pollinated seed has very little impact on yield and oil provided seed quality is good.

Agronomist's view

² BCG (2013) Retaining hybrid canola. Trial Details. Birchip Cropping Group, <u>http://www.bcg.org.au/view_trial.php?trial_id=918&src=trial_docs.php</u>



BCG: Retaining hybrid canola

<u>GRDC: Seed size</u> matters for canola establishment

<u>GRDC: Trial shows</u> commercial hybrids deliver higher returns

GRDC



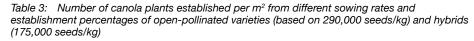


<u>GRDC: Canola</u> establishment; does size matter?

2.3.2 Canola establishment

Check the seed size every year—it can vary depending on how well the seed crop finished in the previous spring.

For *B. napus*, the range is 250,000–350,000 seeds/kg for open-pollinated varieties and 150,000–200,000 for hybrids. Table 3 shows the large difference in plant establishment rates for a given seeding rate between open-pollinated varieties and hybrids. ¹³



Sowing rate	Establi	Establishment percentage									
(kg/ha)	40%	50 %	60%	70%	80%	90%					
Open-pollinated	1										
2.0	23	29	35	41	46	52					
3.0	35	44	52	61	70	78					
4.0	46	58	70	81	93	104					
5.0	58	73	87	102	116	131					
Hybrid											
2.0	14	18	21	25	28	32					
3.0	21	26	32	37	42	47					
4.0	28	35	42	49	56	63					
5.0	35	44	53	61	70	79					

2.3.3 Seed germination and vigour

Seed quality is important for good establishment. Canola seed should have a germination percentage >85%. Planting high-quality seed is essential for rapid, even crop establishment.

Early seedling growth relies on stored energy reserves in the seed. Good seedling establishment is more likely if the seed is undamaged, stored correctly, and from a plant that has had adequate nutrition.

Seed moisture content, age of seed, seed size and germination percentage all contribute to seed quality. There can be substantial differences in the performance of commercial certified seed lots from different sources, and these differences can be as great as differences among varieties.

Several factors can greatly affect germination, including seed size, seed handling and harvest timing. $^{\rm 14}$

The larger the seed, the larger the cotyledon and the lipid reserves. Although seed size does not affect germination, larger seeds have earlier and faster emergence than medium-sized and small seeds. This is because larger seeds germinate more rapidly and produce longer roots than smaller seeds. Under adequate moisture, medium-sized seeds will emerge in 5–6 days.

Seed size is usually measured by weighing 1000 grains; this is known as the 1000-seed weight. The 1000-seed weight differs among varieties and from season to season. As a result, sowing rates should be altered according to seed weight to achieve the desired plant population. ¹⁵



¹³ L Jenkins (2009) Crop establishment. In Canola best practice management guide for eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

¹⁴ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/______data/assets/pdf__file/0004/516181/Procrop-canola-growth-and-development.pdf</u>

¹⁵ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf__file/0004/516181/Procrop-canola-growth-and-development.pdf</u>



Harvest timing

The timing of windrowing can also affect germination. If the crop is not windrowed at the correct time, seed development can stop, resulting in unripe seeds with reduced germination ability.

Seed chlorophyll

High levels of seed chlorophyll can reduce seedling vigour and increase seedling mortality. Chlorophyll levels <35 mg/kg are desirable. Canola seed harvested from plants suffering frost or severe moisture stress during seed-filling may have elevated chlorophyll levels.

Seed handling

Germination can also be affected by seed-handling procedures. Care needs to be taken when harvesting canola seed to ensure that it is not cracked. Cracking can reduce germination. ¹⁶

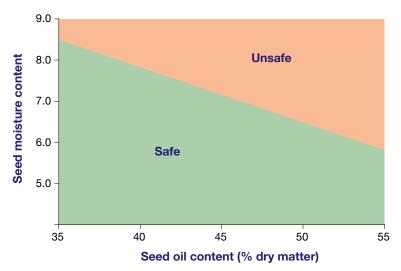
2.3.4 Seed storage

The aims of storage are to preserve the viability of the seed for future sowing and to maintain its quality for market. Canola is more difficult to store than cereals because of its oil content. The oil content makes canola more prone to deterioration in storage. For this reason, canola should not be stored on-farm for more than one summer.

The rate at which canola deteriorates in storage depends on:

- storage temperature
- · seed moisture content
- seed oil content
- relative humidity
- storage time
- · percentage of green or immature seeds in the sample
- amount of weathering after physiological maturity

Monitoring of seed moisture of canola is necessary during storage, because a moisture content of 6.0–8.5% can be unsafe, depending on the seed oil content (Figure 2).



¹⁶ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf</u>





High temperatures or moisture levels can cause a number of reactions in the seed, resulting in:

- increased levels of free fatty acids, causing off-flavours in the oil
- oxidation and browning reactions, which taint the oil
- changes to the oil profile of the seed, due to reactions involving chlorophylls, carotenoid pigments, flavonoids and phenols

Canola should be stored at ${\leq}8\%$ moisture and at temperatures ${<}25^{\circ}C$ (but preferably ${<}20^{\circ}C$).

Safe storage limits are determined by the oil and moisture content of the seed. Canola falling into the potentially unsafe area above the line in Figure 2 should not be stored for any length of time unless appropriate action is taken, such as lowering the moisture content and seed temperature. ¹⁷

2.3.5 Safe rates of fertiliser sown with the seed

Fertiliser at high rates is best separated from the seed at sowing, by banding. The risk of seed damage from fertiliser increases:

- with narrow sowing tines or discs, particularly at wider row spacing, where fertiliser becomes more concentrated close to the seed
- in more sandy soils
- in dry soils

BCG trials in 2012 at Sea Lake showed that applying urea with the seed, even deepbanded, can affect establishment and slow growth and development.

Key points included:

- There was no advantage in applying nitrogen (N) at sowing (deep-banded).
- The effects of seed burn on canola are much greater on sandier soils than on clay. Dry soils are also more susceptible than wet soils. If applying N up-front, rates should not exceed 10 kg N/ha (22 kg urea/ha) on 30 cm spacing, and seed should be separated by at least 3–4 cm from the N fertiliser. ¹⁸
- However, this research should not discourage growers from applying adequate N fertiliser. NSW Department of Primary Industries research shows for every 1 t/ha of expected yield of canola, 80 kg N/ha needs to be made available through a combination of available mineral N at sowing, fertiliser application and mineralisation.¹⁹



IPNI: Care with fertiliser and seed placement

GRDC: Fertiliser toxicity

GRDC: Canola best practice management guide for south-eastern Australia



BCG: Are canola and nitrogen good 'seed bed' fellows?

<u>GRDC: Ground Cover</u> <u>Optimising-canola-</u> <u>profitability</u>



¹⁷ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf</u>

BCG (2012) Are canola and nitrogen good 'seed bed' fellows? Trial Details. Birchip Cropping Group, <u>http://www.bcg.org.au/view_trial.php?trial_id=874&src=</u>

¹⁹ GRDC (2015) Optimising canola profitability. Ground Cover Supplement Issue 117, July–August 2015. GRDC, <u>http://www.grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-117-Optimising-canola-profitability</u>



SECTION 3 Planting

3.1 Seed treatments

3.1.1 Insecticide treatments

Imidacloprid products, such as Gaucho[®] 600 or Picus, are registered for use on canola seed, for protection against redlegged earth mite, blue oat mite and aphids.

These chemicals work through repellency and anti-feeding action, rather than by directly killing earth mites or aphids. They will protect emerging seedlings for 3–4 weeks after sowing. As well as the direct effects of controlling aphids, the use of imidacloprid may also reduce the incidence and spread of aphid-transmitted virus diseases during this period. This product can be applied only by registered operators. All seed companies can supply seed pre-treated with imidacloprid. Fipronil (e.g. Cosmos[®]) is registered for control of redlegged earth mite in canola. It should be used as part of an integrated pest management approach to redlegged earth mite.

Fipronil can be applied either on-farm or off-farm by a contractor or seed company.¹

3.1.2 Fungicide treatments

Fluquinconazole products (e.g. Jockey[®]) can be used in high-risk situations as a seed dressing to help minimise the effects of blackleg disease. These products may shorten the hypocotyl length of canola. To avoid the possibility of reduced emergence, do not sow treated seed deeper than 20 mm or in soils prone to crusting. Ensure that treated seed is sown in the season of treatment.

Fludioxonil + metalaxyl-M (Maxim[®] XL) is a fungicidal seed dressing that provides suppression of blackleg as well as protection against seedling diseases caused by *Pythium* spp. and *Rhizoctonia solani*. It will not cause shortening of the hypocotyl or affect seed viability.

Flutriafol products (Impact[®]) are in-furrow fungicide treatments that are mixed and sown with the fertiliser to assist in minimising the effects of blackleg disease. In situations of high blackleg pressure, research has shown flutriafol products to be superior to other fungicides for controlling blackleg disease.²

3.2 Seed placement

Sow canola seed into the soil, rather than dropping it on the soil surface and harrowing it in. Drilled seed is more accurately placed in contact with moisture and will germinate more uniformly.

Deep furrow planting, which allows sowing into subsurface moisture through the dry surface soil, is a proven technique in these soils, where rainfall is summer dominant and surface seedbeds are often dry at sowing time. When deep furrow planting, it is critical



Oilseeds WA: Assessment of fungicide efficacy against blackleg disease

Research paper: Evaluation of fungicides for the control of downy mildew

Bayer CropScience: <u>Prosaro®—the most</u> effective foliar fungicide treatment against blackleg and sclerotinia



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¹ L Jenkins (2009) Crop establishment. Ch. 5. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC_Canola_Guide_All_1308091.pdf</u>

L Jenkins (2009) Crop establishment. Ch. 5. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC Canola Guide All 1308091.pdf</u>



that moist soil is firmed around the seed but only 2–3 cm of moist soil is covering the seed.

On lighter, sandier soils moisture seeking points in conjunction with 'V' shaped press wheels give excellent results. When sowing into wet soils, take care to avoid a smearing action by the moisture seeking points, which could reduce crop emergence.

Broadcasting seed through the seeder's small seeds box is unreliable and usually results in staggered germination. Thoroughly clean the seeder out after sowing to prevent seed residue from contaminating other crops sown later in the season.³

3.3 Time of sowing

Sowing time is a compromise between sowing too early, which may increase the risk of frost damage and lodging, and sowing too late, which increases the risk of the crop undergoing seed development in increasingly hot and dry conditions, reducing the yield potential and oil content of the grain.

For each week that sowing is delayed, yields drop by ~5% in South Australia and Victoria. The yield penalty can be even higher in seasons with a dry finish.

In general, sowing at the earliest time within the optimum window pays off in a number of ways. Earlier sown crops have the following advantages:

- They generally have higher seed and oil yields with the crop finishing under cooler, moister, conditions. A premium is paid for oil content >42%.
- They allow for better coordination of sowing and harvesting, because these operations for canola are well ahead of main wheat season.
- They grow faster initially and so compete better with weeds.
- Earlier sown crops normally have fewer problems with insect pests, such as aphids, in spring.

Because canola seed is very small, it takes longer to establish than cereals. Late sowing into cold soils further reduces plant growth, making canola seedlings more vulnerable to disease, insects, slugs and other constraints.

Late sowing also results in canola maturing when the weather is typically warmer and drier. Hot weather during the flowering–pod-set stages may cause pod abortion, fewer seeds per pod, and reduced oil content.

Canola usually flowers for 3–5 weeks, and frost damage is greatest if frost occurs towards the end of flowering and through podfill. Early-maturing varieties sown at the beginning of May would be subject to frosts in the late-flowering and pod-filling stages, whereas midseason varieties will flower and fill pods later, reducing the risk of frost damage.

Ideally, the small seeds of canola need to be sown no more than 5 cm deep in selfmulching clays (2–3 cm in red soils) into well-prepared, moist seedbeds.

Good seed–soil contact, to help ensure uniform establishment, is aided by the use of rollers, cultipackers and press-wheels. The crop is suited to conventional and no-till systems.

Heavy stubble loads may reduce emergence, and should not be left over the sowing row. Triazine-tolerant (TT) varieties are less vigorous; therefore, planting methods are more critical for even establishment. ⁴



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L Jenkins (2009) Crop establishment. Ch. 5. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC Canola Guide All 1308091.pdf</u>

⁴ L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>





BCG: Timing is everything: of barley and canola timing of sowing

Hart Field Trials: Canola growth and development—impact of ToS and seasonal conditions



<u>GRDC: Growing hybrid</u> <u>canola</u>

Hart Field Trials: Retaining hybrid canola seed

<u>GRDC: Canola</u> establishment; does size matter?

NSW DPI: Canola time of sowing, Cowra

AOF: Canola response to time of sowing in the Victorian Mallee

GRDC: Turning sowing times on their head with winter habit canola and wheat

<u>GRDC: Canola growth</u> <u>and development —</u> <u>impact of time of sowing</u> (TOS) and seasonal <u>conditions</u> The Birchip Cropping Group conducted trials in 2012 showing that early-sown canola gave the highest yields and gross returns. The early-sown crops were able to withstand frosts and avoid the worst of the dry spring. $^{\rm 5}$

Trials conducted by the Hart Field Site Group in 2014 and funded by Grains Research and Development Corporation (GRDC) found that early-sowing opportunities may maximise canola yield, but selection of the correct variety is important.

Understanding the drivers behind canola development will help to improve canola management and variety selection. Researchers noted that varietal maturity ratings do not always correlate with varietal phenology. They found that the way each canola variety develops could have a large influence on the resulting yield, when planted at different times and in different environments. ⁶

3.3.1 Retained seed

Some growers are interested in retaining hybrids from one season to the next, as they have traditionally done with open-pollinated (OP) varieties. Retaining hybrids to the second generation (F2) will produce seed of inconsistent quality. Depending on how different the parent lines were in certain traits, the F2 generation may vary greatly from the original hybrid. Such variations may occur in herbicide tolerance, blackleg resistance and maturity (see GRDC Fact Sheet: <u>Growing hybrid canola</u>). Those differences may greatly affect the overall yield and financial returns to growers to the point that the initial savings from retaining the seed are outweighed.

3.3.2 Canola growth and development—impact of time of sowing (TOS) and seasonal conditions

This project has three take-home messages:

- Understanding the drivers behind canola development will help to improve canola management and variety selection.
- Varietal maturity ratings do not always correlate with varietal phenology.
- Early sowing opportunities may provide a great opportunity to maximise canola yield, but selection of the correct variety is important.

CSIRO first conducted some pre-trial modelling using the best available information on variety development prior to 2014, and the APSIM model. This explored the potential for planting canola early at a number of locations across Australia and the potential yields that could be achieved by planting cultivars with differing maturity, at a number of sowing times.

Table 1 summarises this work and shows the potential for longer season varieties to be planted in locations such as Cummins and have an improved yield potential; however, the opportunity for successfully sowing these varieties occurs in only 15% of years (where sufficient summer rainfall occurs).⁷

⁶ A Ware, S Noack, S Sheriff (2104) Canola growth and development—impact of ToS and seasonal conditions. Hart Field Site, <u>http://www.hartfieldsite.org.au/media/2014%20Trial%20Results/2014 Results</u> <u>Canola growth and development impact of ToS and seasonal conditions.pdf</u>



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BCG (2012) Timing is everything: barley and canola time of sowing. Birchip Cropping Group, <u>http://www.</u> bcg.org.au/view_trial.php?trial_id=863&src=trial_docs.php

A Ware, R Brill, J Kirkegaard, S Noack, A Pearce, L Davis (2015) Canola growth and development—impact of time of sowing (TOS) and seasonal conditions. GRDC Update Papers, 10 February 2015, <u>http://grdc.com.</u> <u>au/Research-and-Development/GRDC-Update-Papers/2015/02/Canola-growth-and-development-impactof-time-of-sowing-TOS-and-seasonal-conditions</u>

Table 1: Example of possible output from APSIM modelling: showing summary of potential yield for four cultivar phenotypes in four locations (Source: J. Lilley, CSIRO)

Shaded area shows safest sowing window (balance between frost- and heat-stress risk); percentage value is the sowing opportunity (% of years where rainfall allows sowing in this window)

	Cultivar			Sowing-window intervals							
Location	phenology type	8 March	22 March	5 April	19 April	3 May	17 May	31 May	14 June	28 June	potential yield (t/ha)
Cummins,	CB™ Taurus	10	1%								4.1
SA	CBI406		159	%							4.0
	46Y78					70)%				3.9
	Hyola [®] 50					70)%				3.7
Naracoorte,	CB™ Taurus	15	5%								3.6
SA	CBI406			42%							3.5
	46Y78					85%					3.4
	Hyola [®] 50					77	%				3.4

This process highlighted a number of gaps in the understanding of many of the canola varieties currently being grown, and led to the 2014 trial program.

Methodology

As part of the GRDC Optimising Canola Profitability project, three preliminary trials were established in South Australia in 2014: at Yeelanna (Lower Eyre Peninsula), Hart (Mid North) and Lameroo (Mallee). Each trial featured the same six varieties (selected for a range of maturity times); three of the varieties were planted at two establishment rates (15 and 45 plants/m²). Each variety treatment was sown at four sowing times, ranging from when the earliest seed was available (mid-April) through to mid-June. Development stages were recorded throughout the season, and grain yield was determined.

A further two trials, part of a canola establishment project funded by *South Australian Grain Industry Trust* (SAGIT), are also reported. These trials were at Minnipa (Upper Eyre Peninsula) and Wanilla (Lower Eyre Peninsula) and had four sowing times but a limited number of cultivars.

Description of varieties used in 2014 time of sowing trials

ATR Gem(*b*: early–mid-maturity TT variety. High oil content. Medium plant height. Blackleg resistance rating of MR (resistance group A). Tested in National Variety Trials (NVT) trials 2011–14. Bred and marketed by Nuseed Pty Ltd.

ATR Stingray(): early-maturing triazine-tolerant variety. Short height. Moderate-high oil content. Blackleg resistance rating MR (resistance group C). Tested in NVT trials 2010–14. Bred by Nuseed Pty Ltd and DPI Victoria. Marketed by Nuseed Pty Ltd.

Pioneer® 44Y87 (CL): early–mid-maturing Clearfield® hybrid. Moderate–high oil content. Medium plant height. Suited to medium-rainfall areas. Blackleg resistance rating MR (resistance group A). Tested in NVT trials 2012–14.

Pioneer® 45Y88 (CL): mid-maturing Clearfield® hybrid. Moderate–high oil content. Medium plant height. Suited to medium–high-rainfall areas. Blackleg resistance rating R–MR (resistance group A). Bred and marketed by DuPont Pioneer. Tested in NVT trials 2012–14.

Hyola[®] **559TT:** mid–early-maturing TT hybrid. High oil content. Medium plant height. Ideally fits medium–low-rainfall areas right through to high-rainfall areas. Blackleg resistance rating R (blackleg rotation groups A, B, D). Tested in NVT trials in 2012–14. Bred and marketed by Pacific Seeds.

Hyola® 575CL: mid-maturing Clearfield® hybrid. High oil content. Medium plant height. Blackleg resistance rating R (resistance groups B, F). Tested in SA NVT trials in 2010– 14. Bred and marketed by Pacific Seeds.



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Hyola® 971CL: late-maturing winter Grain n Graze Clearfield® hybrid. Extremely high biomass, good grain yield and oil content. Autumn and spring sowing grain-and-graze option for very-high-rainfall areas or irrigated zones. Provisional blackleg rating of R-MR (resistance group A). Not tested in NVT trials. Marketed by Pacific Seeds.

Results and discussion

Results for 50% flowering dates in 2014 (Table 2) show that when planted early, Hyola[®] 575CL reaches flowering considerably earlier (up to 2 weeks) than the other varieties tested. Hyola[®] 971CL, when planted in mid-April, failed to reach flowering prior to 1 October at all sites where it was trialled. The other varieties generally flowered within a few days of each other, with any differences becoming smaller by the last time of sowing.

Table 2: Dates of 50% flowering recorded for each variety and each time of sowing (TOS) at four sites in 2014

Location a	nd variety	Date of 50%	flowering		
	TOS:	15 April	30 April	13 May	29 May
Minnipa	ATR StingrayP	9 July	30 July	19 Aug.	6 Sept.
	Hyola [®] 559TT	31 July	10 Aug.	28 Aug.	6 Sept.
	TOS:	15 April ^a	5 May	2 June	19 June
Yeelanna	Pioneer [®] 44Y87CL	8 Aug.	7 Aug.	12 Sept.	15 Sept.
	Pioneer [®] 45Y88CL	1 Aug.	9 Aug.	12 Sept.	15 Sept.
	ATR GemP	1 Aug.	10 Aug.	15 Sept.	15 Sept.
	Hyola [®] 559TT	5 Aug.	18 Aug.	12 Sept.	15 Sept.
	Hyola [®] 575CL	10 July	11 Aug.	12 Sept.	19 Sept.
	Hyola [®] 971CL	-	-	-	-
	TOS:	14 Apr.	1 May	16 May	2 June
Hart	Pioneer [®] 44Y87CL	15 July	20 Aug.	2 Sept.	8 Sept.
	Pioneer [®] 45Y88CL	16 July	17 Aug.	4 Sept.	9 Sept.
	ATR GemP	6 July	10 Aug.	3 Sept.	10 Sept.
	Hyola [®] 559TT	6 July	8 Aug.	1 Sept.	8 Sept.
	Hyola [®] 575CL	29 June	2 Aug.	31 Aug.	6 Sept.
	Hyola [®] 971CL	2 Oct.	1 Oct.	4 Oct.	7 Oct.
	TOS:	14 Apr.	9 May	5 June	20 June
Lameroo	Pioneer [®] 44Y87CL	28 July	27 Aug.	8 Sept.	17 Sept.
	Pioneer [®] 45Y88CL	30 July	29 Aug.	13 Sept.	23 Sept.
	ATR GemP	27 July	27 Aug.	11 Sept.	19 Sept.
	Hyola [®] 559TT	26 July	25 Aug.	6 Sept.	16 Sept.
	Hyola [®] 575CL	8 July	28 Aug.	7 Sept.	19 Sept.
	Hyola [®] 971CL	-	-	-	-

^ASown and irrigated with 8 mm through dripper hose.

Table 3 shows the responses in grain yield to two different establishment rates (15 and 45 plants/m²) at Yeelanna, Hart and Lameroo. At Yeelanna, the higher establishment rate (45 plants/m²) produced significantly higher yields at each time of sowing. This reflects other work from the SAGIT canola establishment project on this soil type. At the Hart site, establishment rate became significant only at the third and fourth times of sowing (16 May and 2 June), where the higher seeding rate improved yields. This shows that although canola has great ability to compensate for poor establishment, in some situations, a poorly established crop will cost yield and this needs to be factored into management.



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Table 3: Grain yield of canola comparing two different establishment rates (15 and 45 plants/m²) at three sites over four sowing times (TOS) in 2014

Location		Yield (t/h	a)		
	TOS:	15 April ^a	5 May	2 June	19 June
Yeelanna	15 plants/m ²	1.72	1.90	0.91	No harvest
	45 plants/m ²	2.14	2.19	1.23	No harvest
	l.s.d. (P = 0.05)				0.17
	TOS:	14 Apr.	1 May	16 May	2 June
Hart	15 plants/m ²	1.70	1.89	1.69	1.28
	45 plants/m ²	1.70	1.94	1.94	1.62
	l.s.d. (P = 0.05)				0.17
	TOS:	14 Apr.	9 May	5 June	20 June
Lameroo	15 plants/m ²	0.50	0.19	0.14	0.14
	45 plants/m ²	0.43	0.22	0.18	0.11

^ASown and irrigated with 8 mm through dripper hose

Table 4 shows that the variety Pioneer® 45Y88CL yielded the highest at Yeelanna, Hart and Lameroo when planted in mid-April. The early May sowing showed very similar yield of all varieties, with the exception of ATR Gem() and Hyola® 971CL. The Hart trial did not show any yield reduction when seeding was delayed to mid-May (third time of sowing) compared with early May; however, significant yield reductions occurred at the Wanilla site when comparing similar sowing times. This may reflect differences in soil water-holding capacity of these two soils. The results from these trials in the context of yield data from all South Australian NVT trials is shown in Table 5.

Table 4:Grain yield from canola sown at four sowing times (TOS) and five South Australian sites in2014

Location and rainfall	Cultivar	Grain yie	eld (t/ha)		
	TOS:	15 Apr.	30 Apr.	13 May	29 May
Minnipa	ATR StingrayP	2.12	1.62	1.26	0.34
(Jan.–Mar. 102 mm, Apr.–Oct. 290 mm)	Hyola [®] 559TT	1.63	1.51	1.12	0.43
Api. 001. 200 minij	P-value				<0.001
	l.s.d. (P = 0.05)				0.18
	TOS:	30 Apr.	6 May	16 May	28 May
Wanilla	Hyola [®] 575CL	1.41	1.49	0.91	0.65
(Jan.–Mar. 83 mm, Apr.–Oct. 399 mm)	Pioneer [®] 45Y88CL	1.41	1.50	0.70	0.51
	P-value				<0.001
	l.s.d. (P = 0.05)				0.14
	TOS:	15 April ^A	5 May	2 June	19 June
Yeelanna (Jan.–Mar. 89 mm,	Pioneer [®] 44Y87CL	1.96	2.06	1.38	No harvest
Apr.–Oct. 346 mm)	Pioneer [®] 45Y88CL	2.26	2.17	1.13	
	ATR GemP	1.64	1.82	0.73	
	Hyola [®] 559TT	1.89	2.07	1.08	
	Hyola [®] 575CL	2.21	2.34	1.18	
	Hyola [®] 971CL	0.54	0.27	0.20	
	P-value				<0.001
	l.s.d. (P = 0.05)				0.30





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Location and rainfall	Cultivar	Grain yi	eld (t/ha)		
	TOS:	14 Apr.	1 May	16 May	2 June
Hart (Jan.–Mar. 84 mm,	Pioneer [®] 44Y87CL	1.62	1.80	1.89	1.82
Apr.–Oct. 289 mm)	Pioneer [®] 45Y88CL	1.98	1.96	1.89	1.42
	ATR GemP	1.29	1.52	1.56	1.15
	Hyola [®] 559TT	1.76	1.84	1.74	1.32
	Hyola [®] 575CL	1.49	2.06	2.05	1.61
	Hyola [®] 971CL	0.37	0.40	0.49	0.25
	P-value				<0.001
	l.s.d. (P = 0.05)				0.24
	TOS:	14 Apr.	9 May	5 June	20 June
Lameroo (Jan.–Mar. 62 mm,	Pioneer [®] 44Y87CL	0.59	0.36	0.28	0.23
Apr.–Oct. 189 mm)	Pioneer [®] 45Y88CL	0.72	0.31	0.24	0.12
	ATR GemP	0.46	0.12	0.08	0.10
	Hyola [®] 559TT	0.56	0.22	0.30	0.22
	Hyola [®] 575CL	0.51	0.25	0.23	0.13
	Hyola [®] 971CL	0.00	0.00	0.00	0.00
	P-value				<0.001
	l.s.d. (P = 0.05)				0.18

^ASown and irrigated with 8 mm through dripper hose.



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Table 5: South Australian canola variety NVT trial of yield performance (2014, expressed as % of site average yield)

	LOW	ER EP		PER EP	YOF PENIN		М	ID NOF	TH		SOUTH	EAST	
	Ν	Лid	E	arly	Mid	Early		Mid		Early		Mid	
		014	2	014	20	14		2014			201	14	
Variety	Mt Hope	Yeelanna	a Lock	Minnipa	Arthurton	Minlaton	Spalding	Riverton	Turretfield	Keith	Bordertown	Frances	Moyhall
AV Garnet	99	88	96	rial	90	rial	82	Trail	rial	76	73	85	97
AV Zircon	91	94	75	No Trial	93	No Trial	82	No T	No Trial	55	86	102	94
Hyola 50	106	113	106	2	101	2	104	2	2	85	109	108	115
Hyola 635CC	94	104	77		108		111			74	101	86	96
Nuseed Diamond	100	102	146		109		122			210	132	121	112
Victory V3002	94	97			99		98			-	99	98	86
Site av yield (t/ha)	2.32	1.6	0.96		2.83		2.46			0.59	1.35	1.46	1.76
LSD (%)	6	15	6		6		8			16	8	12	18
Archer	99	91	-	-	100	105	104	89	94	sult	89	97	102
Hyola 474CL	99	107	106	110	97	102	97	109	103	No valid result	-	-	-
Hyola 575CL	98	111	107	110	99	109	95	107	103	valic	85	92	94
Hyola 577CL	95	96	-	-	96	-	103	105	105	٩	77	88	104
Pioneer 43Y85(CL)	-	-	88	-	-	93	-	-	-		-	-	-
Pioneer 44Y87(CL)	99	103	101	96	99	103	101	97	95		97	111	96
Pioneer 44Y89(CL)	102	102	116	109	98	108	105	106	103		122	101	109
Pioneer 45Y86(CL)	101	97	-	-	100	-	98	86	97		108	100	92
Pioneer 45Y88(CL)	98	93	-	-	102	-	103	93	98		91	103	93
Site av yield (t/ha)	2.23	2.2	0.95	1.84	2.7	2.29	2.17	2.67	2.23		1.2	1.36	1.5
LSD (%)	6	11	7	5	6	7	10	4	6		10	13	22
ATR Bonito	-	-	91	95	97	94	104	103	93	result	101	103	ult
ATR Gem	96	96	-	-	96	97	-	100	99	d res	92	100	No valid result
ATR Stingray	93	85	120	105	80	98	100	-	118	No valid	-	-	valic
ATR Wahoo	93	81	-	-	-	-	-	101	95	Р	73	94	No
Hyola 450TT	103	114	114	101	108	108	-	-	-		-	108	
Hyola 559TT	-	-	111	104	117	113	110	111	107		133	113	
Hyola 650TT	108	103	-	-	110	-	108	117	110		120	99	
Hyola 750TT	103	89	-	-	117	-	110	101	102		120	97	
Monola 314TT	-	-	-	-	-	-	93	87	96		99	114	
Monola 515TT	-	-	-	-	84	81	83	92	92		85	83	
Pioneer Atomic TT	-	-	104	93	-	107	106	90	-		-	-	
Pioner Sturt TT	95	95	84	91	-	97	-	-	-		-	-	
Site av yield (t/ha)	2.06	1.62	0.76	1.61	2.34	2.06	2.42	2.57	1.97		0.81	1.12	
LSD (%)	7	15	9	6	7	8	9	4	7		14	17	
Date sown	30 Apr	30 Apr	1 May	30 May	7 May	7 May	6 May	5 May	5 May	15 May	15 May	20 May	19 May

Jan-Mar/ Apr-Oct rf (82) 359

(80) 318

229 *Comparisons cannot be made across chemistry types as the trials were not structured to allow this. (Source:

(32) (96) 275 88 (322) (87) 250 (82) 304 (99) 376 (137) 347 (40) 226 (30) 222 (67) 242 (57) 275

GRDC/NVT).

Some of the differences in yields and plant development observed in the time-of-sowing trials can in part be explained by the drivers behind the development of each canola cultivar. There are three main considerations in the development of canola cultivars: vernalisation response, photoperiod response and basic temperature response. Each of these will play a different role in every variety.

Vernalisation affects canola from sowing to floral initiation. Varietal response to vernalisation will manifest as reduced time from sowing to floral initiation as well as a reduced number of leaves at floral initiation. Early sowing of canola into a relatively



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warm period (i.e. sowing in early April *v*. mid-May) is expected to lead to a delay in the accumulation of vernalisation, which will exacerbate the differences in flowering dates of varieties with different vernalisation requirements.

Varietal response to photoperiod occurs between emergence and floral initiation. Canola is a long-day plant, meaning that the duration from sowing to floral initiation is reduced in situations of extended daylight hours. In recent studies, varieties commonly responded to daylength in the range of 11–16 h. For canola plants emerging in mid-April after an early-April sowing, some of the photoperiod requirement could be met in autumn when daylength is longer than in mid-winter.

The basic temperature response is essentially the response of a variety to thermal time (degree-days) when both photoperiod and vernalisation requirements are met. Although there are differences in the basic temperature response amongst commercial varieties in terms of time taken to floral initiation, this is generally less important than the differences resulting from vernalisation or photoperiod response. The basic temperature response is, however, the main driver of development after floral initiation.

Using the data collected from the South Australian and New South Wales trials in 2014, we can draw some conclusions about how some of the varieties develop.

Hyola[®] 971CL has a high vernalisation requirement. When this variety was sown in mid-April in the low-medium-rainfall area of South Australia in 2014, flowering did not commence until the first week in October. Dry conditions through spring in all locations led to this variety being the lowest yielding in all trials.

Hyola[®] 575CL appears to have a relatively flat thermal-time requirement, regardless of when it is sown. This resulted in Hyola[®] 575CL being the first variety to commence flowering when sown early. Results from the first time of sowing in all trials show that the yield of Hyola[®] 575CL was lower than that of Pioneer[®] 45Y88CL, meaning that it was a disadvantage to plant Hyola[®] 575CL early in 2014. The variety description of Hyola[®] 575CL indicated it should have a mid-season maturity, similar to Pioneer[®] 45Y88CL.

For Pioneer[®] 44Y87CL, as sowing was delayed thermal-time requirement was reduced. Further research is needed to understand why this occurred but it may have been due to a greater vernalisation requirement of Pioneer[®] 44Y87CL than of Hyola[®] 575CL, with early sowing taking longer to accumulate vernalisation than later sowing dates. This may have helped Pioneer[®] 44Y87CL to avoid some damage from early frost events.

Information generated by trials such as this in the future will add value to other trial results such as NVT and help to explain differences in varietal adaptation and performance as a starting point to growing more profitable canola.

Conclusion

The manner in which each canola variety develops can have a large influence on the resulting yield when planted at different times and in different environments. The future challenge for this project is to develop and deliver information on new varieties in a way that is timely and relevant to growers and advisers. Growers and advisers will be able to use this information to aid selection of a suite of varieties suited to the sowing opportunities that most often occur in their district and to capitalise on early or delayed sowing opportunities as the seasons dictate. ⁸

A Ware, R Brill, J Kirkegaard, S Noack, A Pearce, L Davis (2015) Canola growth and development—impact of time of sowing (TOS) and seasonal conditions. GRDC Update Papers, 10 February 2015, <u>http://grdc.com.</u> <u>au/Research-and-Development/GRDC-Update-Papers/2015/02/Canola-growth-and-development-impactof-time-of-sowing-TOS-and-seasonal-conditions</u>



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AQ 3.4 Targeted plant population

Crop establishment counts should be carried out within 4 weeks of emergence to review the success of the sowing operation, which will help to decide whether the seed rate or equipment needs to be adjusted for next year's crop. The impact of establishment pests (such as earth mites, aphids, slugs or soil-dwelling pests) can also be assessed at this time.

For narrow row spacing (up to 30 cm), use a square quadrat (0.5 m by 0.5 m, 0.25 m²); for a wider row spacing, a 1-m ruler placed along the row is more convenient. Count as many sites as possible (minimum of 20) across a widely representative area of the whole crop.

In Victoria, ideal plant populations (no. of plants/m²) are:

- 30-50 for the Mallee, Wimmera, northern, north-east districts
- 40-60 (up to 75 if sown late) for northern irrigation districts
- 50–75 for southern Victoria

In South Australia, optimum plant population (no. of plants/m²) varies with rainfall:

- 40–70 for areas of low rainfall (250–350 mm)
- 50–80 for areas of medium rainfall (350–500 mm) ⁹

Plant population, which is determined by sowing rate, germination percentage and establishment percentage, is an important determinant of biomass at flowering and therefore of yield.

Low-density crops can compensate with increased pod and seed production per plant; however, they are more vulnerable to disease, pests, weed competition and environmental stress.¹⁰

Experience has shown that crops with ~10 plants/m² can still yield to their waterlimited potential.

Agronomist's view

Evenness of plant population, both within the row and across the paddock, is more important than having an ideal population. Where plant populations are low, plants compensate by producing extra branches. Sowing rate for open-pollinated varieties is generally 2–3 kg/ha, subject to seed size. Sowing rate for hybrids is usually 1.5–2.5 kg/ha, because of high seed costs.

Many growers have reduced the sowing rate for open-pollinated varieties to 2 kg/ha, but only after they have gained experience in the skills and machinery refinements required to produce consistent establishment of the crop under a range of seasonal conditions. The trend towards hybrids with superior seedling vigour over open-pollinated varieties is allowing experienced growers to reduce seeding rates to 1.5–2.0 kg/ha. Excessively high seeding rates, for example 6–8 kg/ha cause crops to grow too tall, with weak, spindly stems, making them susceptible to lodging in spring during flowering and pod development.

It is advisable to sow an extra 1.0–1.5 kg/ha when seedbed conditions are not ideal, such as when sowing late into cold, wet soils or when no-till sowing into dense stubbles. Within the recommended plant population range, it is better to have too



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³ L Jenkins (2009) Crop establishment. Ch. 5. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC_Canola_Guide_All_1308091.pdf</u>

¹⁰ P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>



many canola plants than too few, although high plant densities have been linked to an increased incidence of Sclerotinia stem rot.

Typically, about 40–60% of sown seeds establish as plants. However, if conditions are favourable, establishment can be as high as 80%. Check the seed size every year; it can vary depending on how well the seed crop finished in the previous spring. For *Brassica napus*, the range is 250,000–350,000 seeds/kg for open-pollinated varieties and 150,000–200,000 for hybrids. Table 6 shows the large difference in plant establishment rates for a given seeding rate between open-pollinated varieties and hybrids. ¹¹

Table 6: Number of plants established per m² from different sowing rates and establishment percentages of open-pollinated varieties of canola (based on 290,000 seeds/kg) and hybrids (based on 175,000 seeds/kg)

Sowing rate	Establish	Establishment percentage:									
(kg/ha)	40%	50%	60%	70%	80%	90%					
Open-pollinated canola											
2.0	23	29	35	41	46	52					
3.0	35	44	52	61	70	78					
4.0	46	58	70	81	93	104					
5.0	58	73	87	102	116	131					
Hybrid canola											
2.0	14	18	21	25	28	32					
3.0	21	26	32	37	42	47					
4.0	28	35	42	49	56	63					
5.0	35	44	53	61	70	79					

Increasing the sowing rate increases competition between plants, creating thinner main stems and fewer, less productive branches. Reducing the sowing rate creates plants with thicker main stems and more branches, delays leaf-area development, reduces biomass at flowering, and ultimately reduces yield.

3.4.1 Calculating seed requirements

Correct seed rates are critical in ensuring that target plant density is reached. The calculation of seeding rates for canola is different from that for wheat.

Suppliers usually provide canola seed as number of seeds per kg (e.g. 200,000 seeds/ kg). To determine the seeding rate based on this, the following formula assumes that plant density and germination are known:

Sowing rate (kg/ha) = (target plant density x 1,000,000)/(seeds/kg x expected germination)

Example

Pioneer[®] 44Y84 has a seed count of 211,400 seeds/kg. We want to achieve a target plant density of 40 plants/m² and assume that 85% of the seeds will germinate.

Thus, the seeding rate = $(40 \times 1,000,000)/(211,400 \times 85)$

= 40,000,000/17,969,000

= 2.23 kg/ha 12

¹¹ L Jenkins (2009) Crop establishment. Ch. 5. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC_Canola_Guide_All_1308091.pdf</u>

² BCG (2015) Calculating canola seeding rates. News article. Birchip Cropping Group, <u>http://www.bcg.org.au/cb_pages/news/</u> <u>Thetimeforsowingcanolaisuponusmakingitimportanttorevisitourunderstandingonseedingrates.Gettingthisri.</u> <u>php</u>



AOF: Over the bar with better canola agronomy

AOF: Better oilseeds trial: Canola variety x row spacing x plant population trial (2009)



Seeding rate calculators

Pacific Seeds: Canola seed planting rate calculators

GRDC



December 2015

3.4.2 Row spacing

Canola is usually sown at spacings of 22.5–30.5 cm, with the adoption of stubble retention and no-till farming systems resulting in a trend to wider row spacing and the possibility of inter-row sowing using GPS guidance systems. Now there is a trend back to narrower row spacings (17.5–25 cm) for improved crop competition and yield potential in cereals. Precision planting equipment also makes this possible.

Experiments in southern New South Wales have shown that widening row spacing in canola does appear to reduce yield when the row space is increased to 35 cm. ¹³ Densities as low as 15 plants/m², if consistent across a paddock, can still result in profitable crops when sown early and plants have time to compensate. Seed size varies between and within varieties and hybrids. Check seed size to calculate the correct number of seeds to be sown per m².

Establishment can be significantly reduced by sowing too deep, sowing late into cold, wet soils, and no-till sowing into dense stubble. Use a higher seed rate, consider sowing the seed at a shallower depth, or select a variety or hybrid with high vigour in these situations. Hybrids are generally more vigorous than open-pollinated varieties, primarily because of larger seed size. Where seed is retained on-farm, grade the seed and keep the largest seed for sowing.

High plant densities, combined with suitable environmental conditions, can increase the risk of Sclerotinia stem rot during flowering. High plant densities can also increase the risk of moisture deficit during grainfill in dry spring conditions, potentially reducing yields.¹⁴

3.4.3 Managing low plant establishment

Plant populations as low as 20 plants/m² can still produce good yields; however, such crops are more susceptible to weed competition. In addition, the variable pod development on these plants makes timing of windrowing difficult to determine, especially if germination has been staggered. At densities <15 plants/ m², the crop is likely to be patchy and lower yielding. Before re-sowing or abandoning a crop, always check with an experienced agronomist or grower, because plants can compensate remarkably well and the yield potential may be equal to, or higher than, a better established but later sown crop. ¹⁵

3.5 Sowing depth

Where conditions allow, aim to drill seed through the main seed box to 1.5–3 cm deep and as deep as to 5 cm in self-mulching clays. Where there is moisture below 1.5–3 cm, a reduced but viable establishment may still be achieved by sowing deeper, provided large seed is sown. This strategy can be used to sow some of the crop on time in seasons of good summer rainfall followed by drying surface seedbeds in autumn. Success with this strategy depends on soil type, soil structure and the amount and timing of follow-up rainfall. ¹⁶

Sowing depth has a major influence on seedling vigour, which subsequently affects seedling establishment and crop performance.



Research paper: Growing canola on raised beds in southwest Victoria



¹³ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf</u>

P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>

¹⁵ L Jenkins (2009) Crop establishment. Ch. 5. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC_Canola_Guide_All_1308091.pdf</u>

P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/</u> pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf



Deep seed placement increases the risk of failed emergence. Deeper sowing reduces light availability, and the hypocotyl (the shoot that emerges from the seed) responds to this by elongating, reducing the chance of seedling emergence. Seeds planted >2 cm deep or into >5 t/ha of stubble develop elongated hypocotyls. This elongation depletes the seed reserves more quickly than in seeds with shorter hypocotyls. The longer hypocotyls are also thinner, with decreased tissue density, and are more susceptible to mechanical damage and collapse.

Plants with longer hypocotyls have smaller root systems, smaller leaf area from an early stage, and less leaf and root biomass. Leaves are slower to expand, which reduces dry matter. As a result, plants that allocate more resources to the hypocotyls at the expense

of leaves and roots have lower relative growth rates. ¹⁷ This effect can contribute to slower growth of plants in surface-mulch treatments, and the slower growth can be compounded by low temperatures.

3.6 Sowing equipment

Canola can be sown by using no-till techniques and most canola is now sown into retained stubble with a disc or knifepoint–press-wheel system. Stubble handling is more difficult in a tine system but growers are adapting by mulching stubbles after harvest, inter-row sowing or using double-break crops (pulse then canola).

When sowing into cereal stubble, ensure that straw and header trash is pushed away from the sowing row. Stubble covering the row can reduce canola emergence and early plant growth, to reduce yield significantly. Use rollers, cultipackers or press-wheels to improve seed–soil contact where appropriate, ensuring that the pressure applied by these devices is low. ¹⁸

Sow seed through the main seed box or small seeds box of standard wheat-sowing equipment. The air-seeder or combine should be in good condition and the level adjusted (from side to side, front to back, and tine to tine) to ensure sowing at a uniform depth. Regulate groundspeed to avoid tine bounce, which will cause an uneven sowing depth. Diffusers are fitted to the sowing tines of air-seeders to stop seed from being blown from the seed row. A maximum sowing speed of 8–10 km/h is suggested for most soils.

Several options are available to level the seedbed and help to compact moist soil around the seed. These include the use of press-wheels or a rubber-tyred roller, coil packers (flexi-coil roller), or trailing light harrows or mesh behind the planter. Knifepoints with press-wheels are the preferred option. Avoid heavy harrows with long tines and prickle chains because they can disturb seed placement.

The seed box on most modern air-seeders and combines can be calibrated for low seeding rates. Check calibrations from year to year, because seed size can change and affect actual sowing rate.

Checklist for sowing equipment:

- Ensure accurate calibration for sowing rate.
- Ensure even wear of points for accurate seed placement.
- Use narrow points to reduce ridging.
- Keep front and rear rows of tines level.
- Sow slower rather than faster, to avoid overly shallow depth, seed bounce, or increased soil-throw by tines, which effectively results in front-tine seed being sown too deep.



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1 More information

AOF: Over the bar with better canola agronomy

DAFWA: Deep seeding in canola

¹⁷ L Jenkins, R Brill (2013) Improving canola profit in central NSW: effect of time of sowing and variety choice. GRDC Update Papers 25 February 2013, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Improving-canola-profit-in-central-NSW-effect-of-time-of-sowing-and-variety-choice</u>

¹⁸ J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf</u>





NSW DPI: Row spacing of winter crops in broad scale agriculture in southern Australia

http://www.Research paper: Canola in rotations

- Ensure level ridges behind the seeder. If using harrows, heavy harrows may be too severe and finger harrows too light.
- Avoid seed–superphosphate mixes that contain excess rates of nitrogen. ¹⁹

3.6.1 Alternative sowing techniques

The use of wider row spacing to conserve moisture in low-rainfall areas has seen an expansion of the areas in which canola is grown. Other techniques, such as dry sowing, aerial sowing and the use of raised beds, have been further refined, which can reduce sowing delays caused by unseasonably dry or wet conditions.²⁰



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¹⁹ L Jenkins (2009) Crop establishment. Ch. 5 In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC_Canola_Guide_All_1308091.pdf</u>

²⁰ L Jenkins (2009) Crop establishment. Ch. 5 In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC Canola Guide All 1308091.pdf</u>



SECTION 4

Plant growth and physiology

4.1 Canola types

Almost all canola grown commercially in Australia is the Swede rape type of *Brassica napus*. *Brassica juncea* (brown or Indian mustard), which has the same quality as canola, is also grown but in much smaller quantities.

The 10 oilseed rape types grown throughout the world are mainly annual and biennial forms of *B. napus* and *B. campestris*. In Canada, both species are important; in Europe and the Indian subcontinent, *B. napus* is the dominant species. Each species has an optimum set of environmental and growing conditions.

4.1.1 Conventional

The first rapeseed varieties were introduced into Australia from Europe and Canada in 1969. Under Australian conditions, these varieties were late flowering (and so restricted to the higher rainfall zones) and very susceptible to blackleg.

From 1970 to 1988, conventional breeding techniques were used to improve yield, adaptation, blackleg resistance and seed quality (low erucic acid, low glucosinolates). These varieties were based on *B. rapa* (formerly known as *B. campestris*). They had earlier maturity and tolerance to pod shattering.

In 1988, the first varieties were released that combined blackleg resistance with higher yield. These varieties were based on *B. napus* material from Asia and Europe. From this time, there was a complete change of trend to breeding *B. napus* varieties.

Brassica napus is thought to have originated from natural crosses (hybridisation) of *B. rapa* and *B. oleracea*. It is distinguished from other species by the shape of the upper leaves; the lower part of the leaf blade half-grasps the stalk. ¹

4.1.2 Triazine-tolerant canola

Triazine-tolerant (TT) varieties were first commercialised in 1993, with the release of the variety Siren. Genes for tolerance to the triazine group of herbicides were bred into conventional canola varieties. This enabled the control of *Brassica* weeds, which were previously unable to be controlled in standard canola varieties.

The TT trait is associated with reduced conversion of sunlight into biomass (i.e. reduced radiation-use efficiency). TT varieties are therefore generally less vigorous as seedlings and produce less biomass than conventional varieties. This results in 10–15% lower yields and 1–3% lower oil contents than in conventional varieties; however, the effective weed control available in these varieties means that actual yield is often higher than in conventional varieties competing with weeds. Another effect of the TT trait is a delay in plant development. ²



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J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/</u> <u>documents/GRDC_Canola_Guide_All_1308091.pdf</u>

J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/</u> <u>documents/GRDC Canola Guide All 1308091.pdf</u>



4.1.3 Hybrids

Hybrids were first released in 1988. Hybrid varieties are produced by using controlled pollination of a female parent by a male parent (the source of pollen). The progeny (the F1 hybrid) may contain the best characteristics of both parents, and typically exhibit 'hybrid vigour'. Hybrid varieties are usually associated with larger seeds, strong seedling vigour and greater biomass production. ³

4.1.4 Specialty canola: high oleic–low linolenic

Specialty canola varieties were bred by traditional means to increase the content of the monounsaturated fat oleic acid and decrease the level of the polyunsaturated fat linolenic acid in the oil (hence, high oleic–low linolenic (HOLL) canola). This oil from HOLL canola is more stable at higher temperatures and more suited for deep-frying than other canola oils. ⁴

4.1.5 Imidazolinone-tolerant canola

Canola varieties have been bred that are tolerant to imidazolinones (IMIs), the active ingredient of herbicides such as OnDuty[®] and Intervix[®]. They are grown as part of the Clearfield[®] production system. IMI-tolerant canola varieties were developed by selection of naturally occurring mutations from conventional canola varieties. Unlike the TT gene, the gene for IMI tolerance is not associated with a yield penalty. ⁵

4.1.6 Condiment (Indian) mustard

Condiment mustards are varieties of *B. juncea* grown for their hot, peppery taste. Although related to juncea canola (see below), condiment mustards have different meal and oil qualities. The level of glucosinolates in the meal after crushing is much higher in condiment mustard and is responsible for the hot and spicy taste of table mustard; however, the erucic acid level is sufficiently low to make it suitable for human consumption. The oil has a distinctive 'nutty' flavour. Indian mustard is the preferred oilseed in many parts of South Asia, northern and western China, and eastern Russia. It has a reputation for having greater drought and shattering tolerance than canola. ⁶

4.1.7 Juncea canola (*Brassica juncea*)

Juncea canola is the name given to plants bred from *B. juncea* to have all of the oil and meal quality specifications of canola. The oil has high levels of oleic acid and low levels of erucic acid, and the meal has low levels of glucosinolates (Table 1). The meal can be substituted for canola meal in animal diets. Juncea canola has the same market enduse as canola.

Juncea canola is being developed as a drought- and heat-tolerant alternative to canola for the low-rainfall zone. It also has excellent seedling vigour (similar to that of hybrid canola) and is more tolerant of shattering than canola. Because it is a relatively new crop, breeding, selection and agronomic research have not progressed as far as with canola. The first commercial varieties were grown in 2007.



³ J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC Canola Guide All 1308091.pdf</u>

⁴ J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC_Canola_Guide_All_1308091.pdf</u>

⁵ J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/ documents/GRDC Canola Guide All 1308091.pdf</u>

J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/</u> <u>documents/GRDC Canola Guide All 1308091.pdf</u>

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Feedback



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Table 1: Typical seed quality characteristics for canola, juncea canola and condiment mustard when grown in the low-rainfall zone (source: NSW DPI)

	· ·		
Characteristic	Canola	Juncea canola	Condiment mustard
Oil (%)	36–42	34–40	34–40
Oleic acid (% of total oil)	57–63	57–63	Variable
Linoleic acid (% of total oil)	18–25	18–25	Variable
Linolenic acid (% of total oil)	8–13	8–13	Variable
Erucic acid (% of total oil)	<1	<1	1–20
Glucosinolate in meal (µmol/g at 10% moisture content)	<30	<30	110–160
Allyl glucosinolate in meal (µmol/g at 10% moisture content)	0	<1	Not available

4.1.8 Roundup Ready[®] canola

Roundup Ready[®] varieties have been bred by genetic modification technology to be tolerant of the herbicide glyphosate. This allows glyphosate to be sprayed over canola in the early stages of growth without affecting the development of the crop. The first varieties were grown commercially in 2008.

4.1.9 Industrial mustard

Industrial mustard is a *B. juncea* type that is not suitable for either of the edible markets because of its high levels of erucic acid and/or glucosinolates. Industrial mustard is grown for use in several industrial products, including biodiesel.

4.1.10 Winter types for grazing

Unlike the other canola varieties, which are spring types, winter types require a period of cold (vernalisation) before they will flower. This makes them suitable for a dual-purpose role. They can be grazed during winter, then locked up for harvest in late spring. In 2015 there are four winter types commercially available.⁷

4.2 Canola development

The life cycle of the canola plant is divided into seven principal stages. By recognising the beginning of each stage, growers can make more accurate management decisions on timing of weed-control operations, introduction and removal of grazing livestock in crops managed as dual-purpose, timing of fertiliser applications, timing of irrigation, and timing of pest-control measures.

Each growth stage covers a developmental phase of the plant. However, the beginning of each stage is not dependent on the preceding stage being finished, which means growth stages can overlap.

The beginning of each growth stage from budding is determined by looking at the main (terminal) stem. In the literature, it is referred to as a decimal code, similar to the Zadoks code for wheat growth stages (Figure 1.) ⁸



Revisiting canola management can lift returns

<u>Canola growth and</u> <u>development—impact</u> <u>of time of sowing (TOS)</u> and seasonal conditions

Canola: phenology, physiology and agronomy

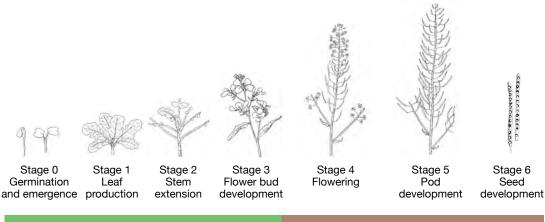
Canola crop phenology for advisors



http://www.dpi.nsw.gov.au/ data/assets/pdf file/0004/516181/Procrop-canola-growth-and-development. pdf

³ T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>





	Vegetativ	e		Reproductive				
			Flowe	ering	6 wee	ks		
					Podfill	4 weeks		
			24 weeks					
April	May	June	July	August	September	October		

Figure 1: Canola growth stages. (Source: NSW DPI)

infocus

4.2.1 Why know about canola development?

- Understanding the drivers behind canola development will help to improve canola management and variety selection.
- · Varietal maturity ratings do not always correlate with varietal phenology.
- Early sowing opportunities may provide a means to maximise canola yield, but selection of the correct variety is important.

Despite the success of canola in Australian cropping systems, significant gaps remain in the underlying knowledge of canola physiology and agronomy, a situation exacerbated by its expansion into new areas and the release of new technologies, including vigorous hybrid varieties with herbicide tolerance.

Although growers recognise the high profit potential and the farming-system benefits of canola, a perceived risk of growing canola remains, largely due to the high level of input required (e.g. seed, nitrogen (N) fertiliser, sulfur fertiliser, herbicides, windrowing). There is a need to determine the level of investment appropriate for these inputs on a regional scale and the agronomic management practices (for example sowing date decisions) that reduce the overall risk and increase the profitability of canola.

Sound, tactical agronomic decisions require improved understanding of the physiology of yield and oil formation in canola, and of how they are affected by variety, environment and management, and the interaction ($G \times E \times M$).

Maximising canola yield and profit will be achieved through an increased understanding of canola physiology. This will occur by taking the following steps:

- 1. Identify the optimum flowering window to minimise heat and frost risk at specific sites.
- 2. Identify the variety–sowing date combinations that achieve the optimum flowering window.



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 Manage the trajectory of biomass accumulation (of specific varieties) to maximise water-use efficiency, optimise N-use efficiency and minimise the risk of highinput costs (e.g. seed costs, N fertiliser, herbicide types, harvest strategies).

Having optimised these steps, further investigation may reveal specific varietal adaptations that provide yield advantage under specific stress (heat, drought, frost) or provide further G x E x M synergies.

As a first step to improve the understanding of G x E x M interactions in current varieties, CSIRO conducted pre-field-experiment modeling by using the best available information on variety development prior to 2014 trials, and the APSIM model. This modeling explored the potential for planting canola early at locations across Australia and the potential yields to be achieved by planting cultivars with differing maturity at a range of sowing times. The results show that potential exists for longer season varieties to be planted in locations such as Cummins, South Australia, and to have improved yield potential. However, the opportunity for successful sowing of these varieties occurs in only 15% of years (when sufficient summer rainfall occurs).

The manner in which each canola variety develops can have a large influence on yield, when planted at different times and in different environments. The challenge for researchers is to develop and deliver information on new varieties in a way that is timely and relevant to growers and advisers. Growers and advisers will be able to use this information when selecting a set of varieties suited to the sowing opportunities that most often occur in their district and to capitalise on early or delayed sowing opportunities as the seasons dictate. ⁹

4.3 Plant growth stages

4.3.1 Germination and emergence (stage 0 [0.0–0.8])

Emergence occurs after the seed absorbs moisture and the root (radicle) splits the seed coat and the shoot (hypocotyl) pushes through the soil, pulling the cotyledon leaves upward and in the process shedding the seed coat (Figure 2). When exposed to light, the cotyledons part and become green. ¹⁰

After sowing, the seed adsorbs moisture and the various biochemical processes begin, resulting in the production of the first root and shoot. The root grows downward and develops root hairs, which anchor the developing seedling. The hypocotyl begins growing up through the soil, pushing the cotyledons or seed leaves. Emergence takes 6–15 days depending on soil temperature, moisture and sowing depth.

As well as an energy source to fuel the biochemical processes, the developing plant needs oxygen for respiration. Waterlogging results in oxygen being driven from the soil, as well as cooling the soil, resulting in slower growth rates.

At this stage, all of the energy required for the cotyledons to emerge is provided by the seed reserves. Deep sowing, small seed or any other factor that requires the plant to expend more energy in getting the first leaf through to the surface (e.g. crusting) will, apart from delaying emergence, result in weaker and smaller seedlings that may be more prone to weed and pest competition. ¹¹



<u>Canola growth and</u> <u>development—impact</u> of time of sowing (TOS) and seasonal conditions

Improved understanding of thresholds of armyworm in barley and aphids in canola



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A Ware *et al.* (2015) Canola growth and development—impact of time of sowing (TOS) and seasonal conditions. GRDC Update Papers, 10 February 2015, <u>http://grdc.com.au/Research-and-Development/</u><u>GRDC-Update-Papers/2015/02/Canola-growth-and-development-impact-of-time-of-sowing-TOS-and-seasonal-conditions</u>

^o T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

¹¹ Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>



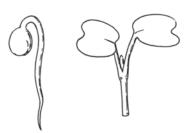


Figure 2: Canola germination and emergence, stage 0-0.8.

4.3.2 Leaf production (stage 1 [1.00–1.20])

A well-grown canola plant normally produces 10–15 leaves. Each leaf is counted when most of its surface is exposed to light (Figure 3). Early leaves may drop from the base of the stem before leaf production is complete. ¹²

The growing point of canola is above the soil, between the two cotyledons. The exposed growing tip makes canola seedlings more susceptible than cereals to insect damage. At 4–8 days after emergence, the seedling develops its first true leaf. Subsequent leaves are produced at a rate determined by temperature. No definite number of leaves is produced by a canola plant. A canola plant under good growing conditions normally produces 9–30 leaves on the main stem depending on variety and growing conditions.

As the shoots continue to develop, a similar process is happening with the root system. Canola plants have a taproot system. The root system continues to develop, with secondary roots growing outward and downward from the taproot. Root growth is due to cell division and enlargement at the tip of the root. Root development is relatively constant, averaging nearly 2 cm/day as long as good soil moisture exists.

Roots do not grow in search of water or nutrients; they intercept water and nutrients present in the soil pore space that they happen to contact. Factors limiting root penetration through the soil include dry soil, soil compaction, weed competition for moisture and nutrients, salinity and cold soil temperatures.¹³



Figure 3: Canola leaf production, stage 1.

4.3.3 Stem elongation (stage 2 [2.00–2.20])

Stages of stem elongation are defined according to how many detectable internodes (minimum length 5–10 mm) are found on the stem (Figure 4). A leaf is attached to the stem at each node. Each internode is counted. A well-grown canola plant normally produces 10-15 internodes.¹⁴

¹⁴ T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>



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¹² T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

¹³ Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>



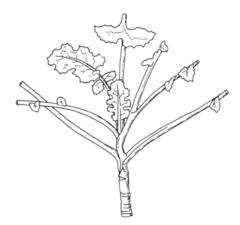


Figure 4: Stem elongation, stage 2.

4.3.4 Flower bud development (stage 3 [3.0–3.9])

Initially, flower buds remain enclosed during early stem elongation and they can only be seen by peeling back young leaves. As the stem emerges, they can be easily seen from above but are still not free of the leaves; this is described as the green bud stage (Figure 5). As the stem grows, the buds become free of leaves and the lowest flower stalks extend so that the buds assume a flattened shape. The lower flower buds are the first to become yellow, signaling the yellowing bud stage. ¹⁵



Figure 5: Canola flower bud development, stage 3.

4.3.5 Flowering (stage 4 [4.1–4.9])

Flowering starts when one flower has opened on the main stem and finishes when no viable buds are left to flower (Figure 6). $^{\rm 16}$



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¹⁵ T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

¹⁶ T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

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Figure 6: Flowering, stage 4.

4.3.6 Pod development (stage 5 [5.1–5.9])

Podding development starts on the lowest one-third of the branches on the main stem and is defined by the proportion of potential pods that have extended to >2 cm long (Figure 7).¹⁷



Figure 7: Pod development, stage 5.

4.3.7 Seed development (stage 6 [6.1–6.9])

Seed development is also seen on the lowest one-third of branches on the main stem (Figures 8, 9). The stages are assessed by seed colour as follows:

- 6.1, seeds present
- 6.2, most seeds translucent but full size



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¹⁷ T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All_1308091.pdf</u>



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- 6.3, most seeds green
- 6.4, most seeds green-brown mottled
- 6.5, most seeds brown
- 6.6, most seeds dark brown
- 6.7, most seeds black but soft
- 6.8, most seeds black but hard
- 6.9, all seeds black and hard

Seed oil concentration in Australian crops increases through seed development following an 'S'-curve pattern, which starts 20 days after flowering and reaches a plateau ~60 days after flowering, the time when seed dry weight is ~70% of its final value (Figure 10). Final seed oil concentrations usually vary between 30% and 50% (as received). In general, high temperatures during grain filling, terminal water stress, and high N supply depress final seed oil concentration. Variety has a significant impact, with TT varieties typically having lower oil concentrations than conventional varieties because of their less efficient photosynthetic system. The growth stage when the crop is physiologically mature is important and one that growers should learn to recognise. It occurs when the seeds have reached their maximum dry weight and the crop can be windrowed. At this time, 40-60% of seeds have started to change from green to their mature colour (growth stage 6.4–6.5). Seed moisture content is 35–40% and most seeds are firm enough to roll between the thumb and forefinger without being squashed. It is a period of rapid change, when all seeds can develop from translucent to black over a 12-day period. It is important not to windrow too early; windrowing before physiological maturity will reduce yields by 3-4% for each day too early, because of incomplete seed development. Oil content will also be reduced. Canola can be harvested when the moisture content of mature seed is 8%. 18

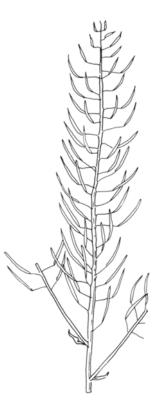


Figure 8: Seed development, stage 6.



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¹⁸ T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

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Figure 9: Seed pods.

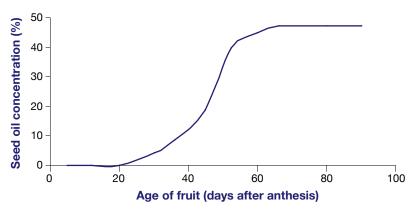


Figure 10: Seed oil concentration in Australian crops increases throughout seed development and reaches a plateau at ~60 days after flowering. (Source: P. Hocking and L. Mason)

4.3.8 Environmental stresses impacting yield and oil content

Frost, moisture stress and heat stress can all have an impact on grain yield, oil content and oil quality. Frost can occur at any time during the growth of the canola plant, but frosts are most damaging when pods are small. Pods affected at this time have a green to yellowish discoloration, then shrivel and eventually drop off. Pods affected later may appear blistered on the outside of the pod and usually have missing seeds (Figure 11).



Figure 11: Frost damage before the watery seed stage results in either missing seeds or very shrivelled seeds. Frost damage at this time may or may not affect oil content. (Photo: T. Potter, SARDI)

Moisture and heat stress are linked, in that the plant will suffer heat stress at a lower temperature if it is also under moisture stress. Flower abortion, shorter flowering period, fewer pods, fewer seeds per pod and lighter seed weight are the main effects, occurring



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either independently or in combination (Figure 12).¹⁹ Hail damage to pods can also affect seed development (Figure 13).



Figure 12: Severe moisture stress during pod filling results in seeds being underdeveloped and small. (Photo: D. McCaffery, NSW DPI)



Figure 13: Hail damage may penetrate through the pod wall and affect seed development. (Photo: D. McCaffery, NSW DPI)

4.4 The drivers of plant phenology

4.4.1 Temperature

Temperature influences plant development principally via effects on rate of growth and developmental phases.

Temperature and vegetative growth

Generally, plant vegetative growth increases as temperature increases. There are upper and lower temperature limits at which growth ceases. The lower limit, or base temperature, for growth in Australia is generally accepted as 3°C, although studies have shown a broader range of lower limits from 0°C to 5°C.

Optimal temperature for growth is in the range 20–25°C.

The upper limit is generally regarded as 35°C, but crops have been shown to acclimatise if they have previously been exposed to high temperatures.



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¹⁹ T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All_1308091.pdf</u>



The concept of degree-days was developed to quantify the influence of temperature on crop growth and it is used to predict crop growth stage. Degree-days are calculated by taking the daily average temperature (maximum plus minimum divided by 2) and subtracting the base temperature.

For example, if the daily maximum was 20°C and the minimum 10°C, then the average daily temperature was 15°C; after subtracting the base temperature of 3°C, the crop therefore experienced 12 degree-days for growth. ²⁰

Development of the plant in response to temperature

Germination and emergence

Germination is the process whereby the seed imbibes moisture and produces the first root and shoot, which emerge from the seed coat. The coleoptile (e.g. wheat) or cotyledons (e.g. canola) push through the soil surface and the first leaves appear. Temperature, moisture and oxygen are needed to instigate this process.

An estimate of the time needed for the crop to germinate can be calculated using degree-days, with the range being 80–100 degree-days, or if the soil temperature is 16° C, then ~7 days. ²¹

Vegetative growth

Following emergence, the plant then produces leaves at a rate determined by temperature. The appearance of one leaf to the next is a constant in thermal time, accepted as 80 degree-days. This period is also known as the phyllochron. There are variations to this value, influenced by sowing date, but for most crops sown from late April to mid-June, the phyllochron is 80 degree-days.

If the daily mean temperature is 15°C as per the previous calculation, then a leaf will appear every 6.7 days, or if it is cooler and the daily mean is 10°C, then it will take 11.5 days for the next leaf to emerge. This information can be used to predict leaf timing for herbicide operations.

The transformation from vegetative to reproductive growth occurs ~500–800 degreedays after emergence. ²²

Flowering and podfill

High temperatures (>32°C) at flowering will hasten the plant's development, reducing the time from flowering to maturity. High temperatures during flowering shorten the time for which the flower is receptive to pollen, as well as the duration of pollen release and its viability.

High temperature can decrease total plant dry matter, the number of pods that develop, number of seeds per pod and seed weight, resulting in lower yields. Very hot weather combined with drought and high winds may cause bud blasting, where the flower clusters turn brown and die, resulting in serious yield losses.

Although temperature is the key driver of plant development, the plant's response is modified by vernalisation and daylength. ²³

Vernalisation

Vernalisation is the requirement to be exposed to cold temperatures in order for the reproductive phase to begin. Temperatures of ~0°C are needed to meet this requirement depending on varietal characteristics. Canola varieties that have little or no vernalisation requirement are often referred to as spring types, and temperatures in the range of

²¹ Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>



²⁰ Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>

²² Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>

²³ Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>



 $7-18^{\circ}$ C for brief periods will be sufficient for vernalisation. Canola varieties with strong vernalisation requirements are called winter types, and lower temperatures of $0-7^{\circ}$ C for several weeks are needed for vernalisation.

Vernalisation is an adaptation that gives the plant an environmental cue for when is the most suitable time to transform to the reproductive phase, so offering a wider sowing window.

Spring types simply go through the vegetative phase and transform to reproductive phase based on the temperatures and/or daylength experienced by the plant. ²⁴

Daylength

Canola develops and flowers more rapidly when grown under long day conditions. Canola is not an obligate-daylength plant (i.e. a plant that will not commence the reproductive phase until a certain daylength requirement is met), but the change to reproductive phase can be delayed if the daylength is too short. Although varieties have differing responses, a daylength longer than ~11 h is required by the canola plant to trigger reproductive development.

This results in an autumn-sown canola crop remaining in the vegetative phase during the winter, accumulating biomass and, hence, yield potential, as well as delaying flowering until the risk of frosts is reduced. However, early-sown canola may experience the 11-h photoperiod shortly after emergence, which may result in the plant flowering prematurely.

Daylength requirement is a desirable characteristic because it allows flexibility in sowing dates. $^{\mbox{\tiny 25}}$

What does all this mean?

When growing a canola crop, the aim is to have the crop grow sufficient biomass to flower late enough to reduce the risk of a major frost event but early enough to ensure that grainfill is not adversely affected by either moisture or temperature stress. Therefore, the optimum flowering window is generally known for each district. However, getting a crop to flower in this period is not easy, because many variables such as sowing date, seasonal temperatures and available moisture influence crop phenology.

Canola varieties already possess the characteristics that give a reasonable sowing window to allow flowering at the optimal time for maximising grain yields. A key advantage of canola over many crops is the much longer flowering period, so whereas a frost may kill the flowers for that day, there will be new flowers the next day to compensate.

A characteristic such as vernalisation allows canola to be sown at the first opportunity early in the season, and the grower can be confident that it will remain vegetative until its temperature requirements are met for flowering in late spring. In a high-rainfall zone where summer rain is assured, theoretically, spring sowings will remain vegetative until late winter. In lower rainfall areas, the delay to the reproductive phase can mean that flowering occurs too late for the optimum conditions for grainfill.

Similarly, a variety that is sensitive to daylength has a wider sowing window because the vegetative period is extended, developing biomass and yield potential, and the flowering period is delayed until the optimum time. ²⁶



²⁴ Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>

²⁵ Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>

²⁶ Canola crop phenology for advisors. CropPro, <u>http://www.croppro.com.au/cb_pages/canola_crop_phenology.php</u>



FAC Nutrition and fertiliser



GRDC Update Papers: Economics and management of P nutrition and multiple nutrient decline

IPNI: Nitrogen and sulfur for wheat and canola protein and oil

GRDC Update Papers: CropPro.com.au diagnostic agronomy for the southern region

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NSW DPI: Soil testing

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Canola requires high inputs per tonne of grain for the major (macro-) nutrients nitrogen (N), phosphorus (P) and sulfur (S) compared with other crops (Table 1). However, on a per-hectare basis, the nutritional requirements of canola are similar to cereals, because yields are usually about half those of wheat.¹

Table 1: Comparison of the average quantity of major nutrients removed (kg/ha) per tonne of grain and stubble for a range of crops, including canola and wheat.

	Nitrogen		Phospho	Phosphorus		um	Sulfur	
	Grain	Stubble	Grain	Stubble	Grain	Stubble	Grain	Stubble
Canola	40	10	7	2	9	26	3.5-5	3.2
Wheat	21	8	3	0.7	5	21	1.5	1.5
Barley	20	7	2.5	0.7	4.5	18	1.5	1.5
Oats	20	7	2.5	0.6	4.5	18	2	1
Lupins	51	10	4.5	0.4	9	16	3	2.5

5.2 Soil testing

In Australia, canola is not recommended for sowing on soils of pHCa (measured in CaCl2 solution) <4.5, and preferably not <4.7 if exchangeable aluminium (Al) levels exceed 3%. Many soils where canola is grown have a pH <5.0; some have pH as low as 4.0. Although most of these soils were naturally acidic, their acidity has been increased by agricultural activities. The acidity may occur in the surface soil or subsoil, or in both. Soil tests for pH are recommended before growing canola. Samples are taken from the surface (0–10 cm), as well as at depth (10–30 cm) to check for subsoil acidity.

Where the soil pH is \leq 5, Al and manganese (Mn) toxicities can be a problem for canola. Aluminium is much more detrimental than Mn because it kills root tips, the sites of root growth. Plants with Al toxicity have a shallow, stunted root system that is unable to exploit soil moisture at depth. The crop does not respond to available nutrients, and seed yield is drastically reduced. Severe Mn toxicity reduces yield because entire leaves become chlorotic and distorted. Mild to severe Mn toxicity is often seen sporadically or in patches and often associated with waterlogged parts of fields.²

5.3 Nitrogen

Canola has a high demand for N, twice that of wheat per tonne. A canola crop of 1 t/ha will remove ~40 kg N/ha; however, the crop will require at least twice this amount of N supplied (Figure 1). A crop with a targeted yield of ~2 t/ha crop will require ~160 kg N/ ha. This can be supplied through soil reserves, but additional N fertiliser will be needed in many cases. Depending on the amount of soil N available to the crop, ~80–100 kg/ha



P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/</u> <u>uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

² P Hocking, R Norton, A Good (1999) Crop nutrition. In 10th International Rapeseed Congress, GCIRC, <u>http://www.regional.org.au/au/gcirc/canola/p-05.htm</u>



More information

GRDC Update Papers: Nitrogen and water-use efficiency of canola and mustard in South Australia

<u>GRDC Update Papers:</u> <u>Nitrogen decision —</u> <u>Guidelines and rules of</u> <u>thumb</u>

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GRDC Update Papers: Managing subsoil constraints—crop and varietal tolerance rotations fallow management crop responses

GRDC Update Papers: Meeting the cropping system's demand for nitrogen—can we do it and manage the profit risk? of fertiliser N could be needed. In general, a canola crop requires an amount of N similar to a high-protein wheat crop.

Deep soil testing for N and S is recommended for all growers, particularly first-time growers. This will allow N budgeting.



Figure 1: Canola is highly responsive to nitrogen. (Photo: P. Hocking, CSIRO)

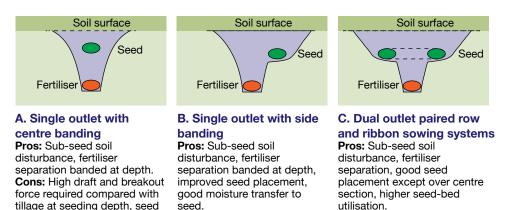
Canola seed is very sensitive to fertiliser burn. No more than 10 kg/ha of N should be in direct contact with the seed at sowing in narrow (18-cm) rows, and proportionally less at wider row spacings. Most of the N should be either drilled in before sowing or banded 2–3 cm below and beside the seed at sowing (Figure 2). An alternative is to apply N to the growing crop. Application timing should aim to minimise losses from volatilisation; that is, time the topdressing for when the crop has good groundcover and before a rain event. Losses can be high on dry, alkaline soils. ³



L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>







Cons: High draft and breakout force required, higher soil and residue disturbance influencing seeding depth uniformity.

Feedback

Figure 2: Three arrangements of split seed and fertiliser banding with tillage below the seeding point, illustrating the different types of seed and fertiliser separation achieved.

force required, potentially higher soil and residue

Cons: High draft and breakout

seed.

disturbance.

placement quality variable.

The N content of a canola plant (expressed as a percentage of dry matter) is highest at the full rosette stage, and this is when deficiency symptoms are often visible. Generally, the older leaves become pale green to yellow, and may develop red, pink or purple colours (Figure 3). Plants will be stunted and the crop will not achieve full groundcover by 8-10 weeks after sowing. Once stem elongation commences, a deficiency is then characterised by a thin main stem and restricted branching. This results in a thin and open crop. Flowering will occur over a shorter period, reducing the number of pods per unit area.





DAFWA: Diagnosing nitrogen efficiency in canola

Figure 3: Nitrogen deficiency symptoms show as smaller leaves, which are more erect, and leaf colours from pale green to yellow on older leaves and pinkish red on others. (Photo: S. Marcroft, MGP)

Some visual symptoms are similar to other nutrient deficiencies (e.g. P and S), and this can result in incorrect diagnosis. ⁴ Nitrogen deficiency affects older leaves first, whereas S deficiency affects younger leaves first. 5

5.3.1 Estimating nitrogen requirements

Canola is ideally grown in soils of high N fertility, for example, as the first or second crop following several years of legume-dominant pasture. However, paddock fertility is

P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/ uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

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





often inadequate, so additional N is required to produce both high yields and good seed quality.

Although canola removes 40 kg N/t grain, the crop can require up to three times this amount of N to produce the yield (referred to as the efficiency factor). This is because the plants must compete for N with soil microorganisms, and some of the N taken up by the plants is retained in the stubble and senesced leaves and roots. A good canola crop will produce twice as much stubble as grain (by weight), giving a harvest index of ~33%.

The best way to determine a crop's potential N requirement is through a combination of N removal (total N in the estimated grain yield x efficiency factor) and the amount of N estimated to be available in the soil. Deep soil tests (to a depth of 60 or 90 cm) can be taken prior to sowing. Most deep soil tests are taken to 60 cm in the major canola-producing areas. They can also be done during the growing season to determine whether topdressing is required.

Example

Available soil N (calculated from deep N test + estimate of in-crop mineralisation) = 125 kg/ha

Nitrogen requirement calculator

Nitrogen removed in grain = target yield x 40 (kg N/t grain)

Total N required = N removed in grain x 2.5 (efficiency factor of 40%)

In the example:

Estimated target yield = 2 t/ha N removal in grain 2 x 40 kg N/t = 80 kg N/ha Total N required = 80 x 2.5 kg N/ha = 200 kg N/ha ⁶

Nitrogen fertiliser rates

Fertiliser N required for crop = total N required – available soil N (kg N/ha)

Using the example:

Available soil N (calculated from deep N test + in-crop mineralisation) = 125 kg/haFertiliser N required for crop = 200 - 125 kg N/ha

= 75 kg N/ha (or 163 kg/ha of urea)

As the above calculations indicate, ~75 kg/ha of additional N is required as fertiliser to achieve the anticipated yield. The N can be applied in several combinations pre-sowing, at sowing or as topdressing(s) before stem elongation during the season.

Other formulae are available for calculating N requirements; however, these need more detailed inputs, which can be provided by consultants or agronomists.⁷

5.3.2 Diagnosing nitrogen deficiency in canola

Nitrogen deficiency is the most common nutrient deficiency in canola, especially during cold, wet conditions and in sandy soils in high-rainfall areas. Some hybrid varieties can display leaf purpling with adequate nutrient levels (Figure 4).



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P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>



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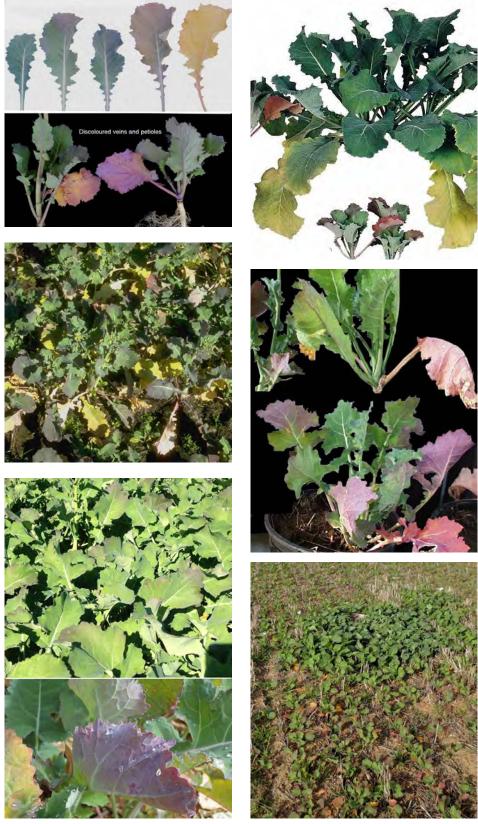


Figure 4: Images of nitrogen deficiency in canola. (Photos: DAFWA)



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What to look for

Paddock

- Plants are smaller and less branched with red to purple or yellow leaves.
- Symptoms are worse in wetter seasons, on lighter soil areas and sometimes on non-legume header rows.

Plant

- Mildly deficient plants are smaller with paler green and more erect leaves. Deficient seedlings have reddened cotyledons.
- Oldest leaves develop whitish purple veins and mild purple pigmentation, which starts at the end of the leaf and progresses to the base on both sides of the leaf. (See Table 2 for conditions with similar leaf symptoms.)
- The whole leaf then turns yellow or pinkish purple. Developing leaves are narrow and more erect.
- Established plants that become N-deficient develop yellowing on leaf margins that spreads in toward the midrib between the veins. The midrib becomes discoloured then the leaf dies.
- From stem elongation, the main stem is thinner and branching is restricted. Flowering time and pod numbers are reduced.

What else could it be?

Table 2: Conditions that result in symptoms in canola similar to nitrogen deficiency

Condition	Similarities	Differences
<u>Beet western yellow virus in</u> <u>canola</u>	Purple-red colours spreading from end of oldest leaves	Affected plants are stunted rather than smaller and thinner as in N deficiency
Damping off in canola	Reddened cotyledons and older leaves of seedlings	Damping off causes stunted plants with pinched roots or hypocotyls. Often plant death occurs
Sulfur deficiency in canola	Purple leaves	Sulfur deficiency affects younger leaves the most
Phosphorus deficiency in canola	Purplish older leaves	Phosphorus-deficient plants have purpling on leaf margin, then the leaf turns bronze

Where does it occur?

Nitrogen deficiency can occur on most soils but is most common in the following situations:

- · cold, wet conditions that slow N mineralisation and uptake of N
- soils with very low organic matter
- after high rainfall on sandy soils, which can result in N leaching

Management strategies

- Nitrogen fertiliser or foliar spray can be applied. However, only some N can be absorbed through the leaf, so you will still be reliant on rainfall to move the N into the root-zone. The economics of liquid v. solid fertilisers should be taken into account.
- There is a risk of volatilisation loss from urea or nitrate sources of N. Loss is greatest from dry alkaline soils with dewy conditions, but recent GRDC-funded research shows this may not be as high as traditionally thought. ⁸



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³ G Schwenke (2014) Nitrogen volatilisation: Factors affecting how much N is lost and how much is left over time. GRDC Update Papers, 25 July 2014, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Factors-affecting-how-much-N-is-lost-and-how-much-is-left-over-time</u>



 The yield potential for canola is established during stem elongation and the budding stage, so all N should be applied before this stage of growth (8–10 weeks).

Tissue test

- Use a whole top-of-plant test to diagnose suspected deficiency. Critical N levels vary with plant age and size, but as a rough guide, 2.7% (seedling) to 3.2% (rosette) indicates deficiency.
- Models that combine nitrate, ammonium, soil organic carbon, soil type and legume history are valuable for N fertiliser calculation.
- Leaf-colour symptoms are not a reliable guide for hybrid varieties.⁹

5.4 Phosphorus

5.4.1 Role and deficiency symptoms

Phosphorus plays an important role in the storage and use of energy within the plant. Lack of P restricts root development (resulting in weaker plants) and delays maturity (Figure 5), both of which affect yield potential and seed oil content, particularly in dry spring conditions. Low levels of P also restrict the plant's ability to respond to N. Even a mild deficiency can significantly reduce plant growth without any symptoms. In cases of severe deficiency, the older leaves will often appear dull blue or purple (Figure 6). Phosphorus is a very mobile nutrient within the plant, and if a deficiency occurs, P moves rapidly from older leaves to the young leaves or developing pods.¹⁰



Figure 5: Severe phosphorus deficiency showing plant stunting and delayed maturity. (Photo: R. Colton, NSW DPI)



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

¹⁰ P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/</u> uploads/documents/GRDC Canola Guide All 1308091.pdf





Figure 6: Phosphorus deficiency shows as distinct pink-purpling of the tips and margins of older leaves. (Photo: P. Hocking, CSIRO)

Fertiliser placement

In the soil, P is immobile, so fertiliser should be banded close to the seed at sowing. This ensures that the developing seedling is able to take up a good supply during the early growth stage when requirement for P is at its highest. Many soils (particularly if exchangeable AI is present) are able to tie up P, making it unavailable to plants. Banding the fertiliser can reduce the amount of P tied up because less fertiliser is in contact with the soil than occurs with broadcasting.

Phosphorus fertiliser banded above and below the seed gives better yield responses than P broadcast before sowing. In sandy soils, which are prone to drying in the surface layer, banding some of the fertiliser below the seed at sowing may improve the efficiency of P uptake.¹¹

Phosphorus requirements

If a wheat crop responds to P application, then a rate at least equivalent should be used when sowing canola at that site. Topdressing is ineffective, so it is important to achieve the correct P rate at sowing. A maintenance application of 7–8 kg P/ha is needed for every tonne of canola you expect to harvest.

If a soil test indicates a high soil P level, then lower rates of P could be applied. In some situations, where soil P levels are very high, it may be uneconomic to apply P. If more is applied than is removed by the grain, it will be added to the soil P bank and may be available for following crops or pastures to utilise. However, a significant proportion (up to 50%) of applied fertiliser P can ultimately become 'fixed' into organic and inorganic forms that are largely unavailable for crop uptake in the short-medium term but can add to the P pool in the longer term, with a proportion of the P becoming available over time.

Depending on your location, several laboratory analyses are available for P. The Olsen P test (bicarbonate) is often recommended for acid soils, whereas the Colwell P test is more useful on alkaline clay soils. However, each of these tests measures only a proportion of the P status of a soil. The phosphorus buffering index (PBI) is also important because it can indicate how available the P in the soil is to plants. Acid-extractable P (BSES-P) is recommended as a baseline of the pool P status. A qualified soil-nutrition advisor will help you to decide which tests are applicable on your soil type.

If tests indicate <20 mg/kg, then P is considered low (depending on soil type and rainfall) and a response is likely. If the soil P level is high (>40 mg P/kg) a response to P is less likely, unless the soil is acidic (pHCa <4.8) and has a low cation exchange



P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/</u> uploads/documents/GRDC Canola Guide All 1308091.pdf





GRDC Update Papers: Economics and management of P nutrition and multiple nutrient decline capacity (<5 cmol(+)/kg); in such cases, significant yield responses have been obtained in southern New South Wales. Soil P tests are less reliable in low-rainfall zones or on alkaline soils, where a nutrient budget is better for making P fertiliser decisions. A Colwell P level of ~40 mg/kg provides opportunity for some seasonal adjustment to fertiliser rates. ¹²

5.5 Sulfur

5.5.1 Role and deficiency symptoms

Sulfur is crucial for canola in the synthesis of oil and protein as well as for the plant's vegetative development. Sulfur is needed in the formation of chlorophyll in leaves, and therefore for growth. Canola has a much higher requirement for S than wheat or legume crops.

Sulfur deficiency symptoms include the following:

- Leaves are pale and mottled in plants from early rosette to stem elongation; leaves may be cupped, with a purple margin (very deficient crops) (Figure 7).
- Flowers are pale yellow to cream (Figure 8).
- Podset is poor and there is pod abortion; pods that do form are short and bulbous.
- During podset, stems of affected plants are purple-brown and ripen to a brown rather than a straw colour.
- Affected plants are slow to ripen, continuing to flower until moisture runs out, after the rest of the crop has dried off sufficiently for windrowing.

Low levels of S will cause yield loss, even if the above symptoms are not obvious. 13



Figure 7: Sulfur-deficiency symptoms appear in the rosette stage as pale mottled leaves, which may be cupped and have purple margins. (Photo: H. Burns, NSW DPI)



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¹² P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

¹³ P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/</u> uploads/documents/GRDC Canola Guide All 1308091.pdf

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Figure 8: Trials ca. 1990 confirmed paddock observations of the late 1980s of canola's high requirement for sulfur. Flowers are a pale yellow. (Photo: A. Good, Incitec)

5.5.2 Soil sulfur

Most sulfur is held in soil organic matter. Cropped soils tend to have low levels of organic matter, so their reserves of S are also often low. The most popular high-analysis fertilisers such as mono- and di-ammonium phosphate (MAP and DAP) contain very little S. The release of organic S by bacteria occurs through a process similar to mineralisation of N, and in some years, seasonal conditions can cause low mineralisation rates. Dry conditions in summer and autumn can reduce mineralisation of S, and wet conditions during winter can cause leaching of S below plant roots. No-till farming systems result in reduced levels of S mineralisation.

All paddocks sown to canola should receive 20 kg S/ha in the form of available sulfate. On lighter soils with a history of deficiency symptoms, increase rates to 30 kg/ha.

We're finding that paddocks with a history of canola now have high residual S levels in the subsoil and rates can be reduced to 5-10kg/ha.

Agronomist's view

Sulfur can be applied before sowing (as gypsum or sulfate of ammonia where N is also required), at sowing (as single superphosphate or a high-analysis fertiliser containing sulfate-S) or topdressed during the vegetative stages (sulfate of ammonia).

Where higher rates of S are required, it is most cost-effective to apply gypsum presowing. Fertilisers amended with elemental S can assist with S requirements, but elemental S needs to be converted to sulfate-S before plant uptake can occur. This can delay availability to the growing seedling.

Do not underestimate crop requirements. Sulfur deficiency has occurred in paddocks that have been topdressed in the pasture phase with single superphosphate. Sulfur deficiency can also be induced in paddocks with high yield potential where high rates of N and P have been used.¹⁴

5.6 Potassium

An adequate supply of potassium (K) is important to provide plants with increased resistance to disease, frost and drought, as well as for promoting increased

¹⁴ P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>



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carbohydrate production. Canola crops take up large amounts of K during growth, but most of it remains in the stubble, with only a small proportion removed in the grain.

Although soil tests, especially the balance of exchangeable cations, can provide a guide to the level of K, tissue tests are the most reliable method to determine whether K fertiliser is needed. Avoid sowing K fertiliser with the seed; it could affect germination. ¹⁵

Recent research shows:

- Potassium deficiency has been confirmed in South Australia in grain cropping regions.
- As K reserves are drawn down with higher yields, K replacement may need to be more widely addressed, as it has been in Western Australia.
- The first evidence could be seen as good growth in windrows.
- Soil tests are reliable on sandy soils but less so on heavy soils.
- Potassium at 50–100 kg/ha banded below the seed at seeding where soil tests are below critical concentrations should give economic responses.¹⁶

5.7 Boron

5.7.1 Role and toxicity and deficiency symptoms

Canola requires boron (B) in small amounts; however, it can cause both deficiency and toxicity problems. In most canola-growing areas, B deficiency is the more likely problem, but in some alkaline and sodic soils, such as in the Wimmera and Mallee in Victoria, toxic levels of B occur at 40 cm or deeper in the soil.

Boron toxicity has the two-fold effect of reducing growth and reducing the rooting depth of plants. In soils with high subsoil B, little can be done to ameliorate the problem, but B-tolerant canola types are being investigated.

Adequate B is essential for plant health, and it has an important role during flowering, specifically in the fertilisation process, where it is involved in the growth of the pollen tube. An adequate level of B is particularly important under high temperatures because it improves the level of pollen germination.

Over several seasons, growers and agronomists have observed crops with a reduced number of seeds set within pods. These symptoms are consistent with low levels of B. Unlike seeds killed by frost, where the residue of the dead seed is visible, with B deficiency, the individual seeds fail to develop, resulting in a missing seed, or seeds, in the pod.

Canola requires 6–10 times more B than wheat. In southern New South Wales, canolawheat rotations over 10 or 11 years of continuous cropping have resulted in removal of much B. As well, many soils are low in B, especially the lighter, sandy loam acidic soils that are low in organic matter and common throughout southern New South Wales.

Under this cropping system, a range of crops and pastures, including canola and subterranean clover, frequently have either marginal or deficient levels of B. In some areas of the South West Slopes of New South Wales, yield responses to applied B have been up to 20%.

Boron deficiency causes seedling plants to bunch. The leaves become long and narrow, with a cupped shape, thicker than normal and brittle, causing them to snap easily.



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P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

¹⁶ R Norton (2014) Do we need to revisit potassium? GRDC Update Papers, 25 February 2014, <u>https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Do-we-need-to-revisit-potassium</u>



Deficiency is more likely during periods of low moisture availability or where liming has reduced the availability of B.¹⁷

5.7.2 Fertiliser requirements

Tissue testing is the best way to confirm a deficiency (Figure 9), especially as the symptoms of sulfonylurea herbicide damage are similar. If there is a deficiency, apply 1-2 kg/ha of boron.

High rates of boron are used in herbicides to sterilise soil, so it is critical that only recommended rates are applied where a deficiency has been identified.¹⁸



Figure 9: Boron deficiency was confirmed here by tissue testing, but symptoms can be confused with manganese toxicity and are similar to sulfonylurea herbicide damage. (Photo: P. Parker, NSW DPI)

5.8 Micronutrients

5.8.1 Zinc

Although canola is a non-mycorrhizal crop, it requires zinc (Zn) on alkaline soils. Zinc is best applied to the soil and thoroughly incorporated, but if this is not possible, apply it with starter fertiliser and place 2.5 cm to the side of and below the seed at planting. Zinc competes with the seed for soil moisture and so it should not be added in the seed line.

Foliar spraying of zinc sulfate heptahydrate at 1 kg/ha plus wetting agent is an alternative application method if sprayed twice to deficient crops at 3 and 5 weeks after emergence. There are also zinc oxide formulations and zinc chelate formulations. Zinc sulfate is incompatible with some herbicides and insecticides. Zinc seed treatments



¹⁷ P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/</u> <u>uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

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are not normally applied to canola, because insufficient Zn will be applied with the low seeding rate used. ¹⁹

Deficiency symptoms

Zinc deficiency appears in crops as poor plant vigour, with areas of poorer growth alongside healthy, apparently normal plants, giving the crop a patchy appearance (Figure 10). Although there are few reports of Zn deficiency in canola, growers should be cautious.

Zinc deficiencies can occur in the following situations:

- in strongly alkaline soils, pHCa >7.0
- with high P levels
- after long periods of fallow
- · following land-forming where alkaline subsoil is exposed

Other major and trace elements apart from Zn may also need special consideration in land-formed paddocks. $^{\rm 20}$

Fertiliser strategies

Where responses to Zn are known to occur, incorporate Zn into the soil before sowing canola.

Zinc oxide is the cheapest and most concentrated form of Zn and it is usually broadcast with fertiliser to ensure an even application. However, it is not water-soluble and is not an effective means of adding Zn if a quick response is required. When coated onto fertiliser, zinc oxide can flake off, resulting in problems with distribution. Foliar sprays are a short-term correction only and need to be applied before symptoms are obvious, soon after crop emergence or if Zn deficiency has been identified through tissue analysis.²¹



Figure 10: Zinc deficiency appears as bronzing on the upper leaf surface and may occur in neutral to alkaline soils. (Photo: B. Holloway, SARDI)



Corporation

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¹⁹ L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>

²⁰ P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

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5.8.2 Molybdenum

Role and deficiency symptoms

Molybdenum (Mo) is important in enabling plants to convert nitrates from the soil into a usable form within the plant. Deficiency is more common in acid soil (pHCa <5.5) but is difficult to diagnose other than by a tissue test. Deficiency can be avoided by applying Mo at a rate of 50 g/ha every 5 years. The most common practice is the application of 150 g/ ha of the soluble form sodium molybdate (39% Mo) sprayed onto the soil surface. ²²

Fertiliser requirements

Although fertilisers containing Mo can be used at sowing, the concentration of Mo they contain is less than recommended and they are more expensive than using sodium molybdate.

Molybdenum-treated single superphosphate applied during the pasture phase is costeffective and it should supply enough Mo for the canola crop.²³

5.8.3 Magnesium

In recent years, magnesium (Mg) deficiency has been reported in several seedling crops. As the crop grows and develops a deeper root system, the deficiency symptoms disappear because most soils have adequate Mg deeper in the profile. Low surface levels of Mg are probably due to low levels of sulfonylurea herbicide residues and the harvesting of subterranean clover hay, where large quantities of Mg are exported from the paddock.

Lime–dolomite blends can be used when liming acid soils if there is a history of deficiency symptoms, and other dry and foliar applied fertilisers are available. ²⁴

5.8.4 Calcium

Calcium (Ca) is important in plants because it assists in strengthening cell walls, thereby giving strength to plant tissues. Calcium is not readily transferred from older to younger tissue within a plant, so if a deficiency occurs it is first seen in the youngest stems, which wither and die, giving rise to the term 'withertop' to describe Ca deficiency (Figure 11).

Calcium deficiency is not common but it can occur in acid soils, especially if the level of exchangeable Ca is low. The use of lime (calcium carbonate) on acid soils and gypsum on sodic soils has meant only an intermittent occurrence of 'withertop' in canola.²⁵

P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>



P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

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²⁴ P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for southeastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>





Figure 11: Death of the canola flower head from calcium deficiency. (Photo: D. McCaffery, NSW DPI)

5.9 Toxicity

The most effective treatment for AI and Mn toxicity (Figure 12) is liming to increase the soil pH to >5.0 Calcium chloride. Lime rates used will depend on the pH to depth and the cation exchange capacity of the soil. Microfine lime is usually applied at 2.5–4.0 t/ ha. Shallow incorporation of lime is sufficient to ameliorate surface soil acidity, but deep ripping is required to incorporate the lime, reduce soil strength and improve drainage where there is the more serious problem of subsoil acidity.

Research has shown that deep ripping for lime incorporation is not beneficial and can have negative impact on yield due to moisture loss.

"Provided the surface soil is not acid, canola appears to be relatively tolerant of subsurface acidity, except where exchangeable aluminium exceeds 20%, manganese is toxic, or where the acid 'throttle' is greater than 20 cm deep. Typical subsurface acidity can be managed by liming the surface to pHca5.5." Canola Yield Decline in south-eastern Australia, results from GRDC funded project at <u>http://www.grassrootsag.com.au/CiD%20low%20res.pdf</u>

Agronomist's view

The sensitivity of canola to soil acidity has had beneficial spin-offs, in that it has forced Australian growers to implement liming programs before their soils become too acidic for less sensitive crop and pasture species.

There are breeding programs to improve the AI and Mn tolerance of Australian canola, by using both conventional technology and genetic engineering. The rationale for increasing the tolerance of canola to soil acidity is to broaden management options for growers while they implement liming programs. ²⁶

P Hocking, R Norton, A Good (1999) Crop nutrition. In 10th International Rapeseed Congress. GCIRC, http://www.regional.org.au/au/gcirc/canola/p-05.htm



https://www.csu.edu. au/_data/assets/ pdf_file/0003/922764/ Canola -and- subsoil constraints.pdf



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Figure 12: Symptoms of severe manganese toxicity in young canola on an acid soil.

5.10 Nutrition effects on the following crop

Canola has provided the opportunity for more reliable responses to N in subsequent cereals by reducing cereal root diseases. However, low yields and poor growth have been reported in crops following canola. ²⁷

This is due to the depletion of soil microorganisms called arbuscular mycorrhizal fungi (AMF). They are beneficial soil fungi, assisting the uptake of P and Zn that would otherwise be unavailable to the crop. Canola does not need these fungi to help it take up P and Zn, so under canola, the AMF population declines to a low level. To avoid this problem, follow canola with a short-fallow crop that depends on AMF such as wheat or another cereal crop rather than pulses.²⁸



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R Norton, J Kirkegaard, J Angus, T Potter. Canola in rotations. Australian Oilseed Federation, <u>http://www.australianoilseeds.com/______data/assets/pdf_file/0014/2705/Chapter_5_-_Canola_in_Rotations.pdf</u>

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FAC Weed control

Canola is highly susceptible to weed competition during the early stages of growth, making early weed control essential.

Although the competitive ability of canola improves markedly once the crop canopy has closed, serious yield losses can occur beforehand.

Weeds present at harvest can cause excessive weed-seed contamination, reducing grain quality. As well as yield and quality considerations, uncontrolled weeds (i.e. weeds still growing in the crop after all treatments have been used) will add seeds to the soil seedbank, creating an ongoing weed problem.

Weed control in canola requires use of the range of available herbicide and nonherbicide options, that is, integrated weed management (IWM). ¹

6.1 Key points:

- Choose paddocks relatively free of broadleaf weeds, especially charlock, wild turnip, wild radish and other weeds of the Brassicaceae family, because in-crop herbicide options are limited. Grass weeds can be controlled in canola by using trifluralin and/or post-emergent herbicides; however, Group A resistant grasses are still of concern.
- Herbicide resistant varietal systems such as triazine-tolerant (TT), Clearfield[®] and Roundup Ready[®] (RR) can be of use in managing weeds in canola, particularly broadleaf weeds. However, careful management is needed to avoid the buildup of resistant weed populations.
- When choosing paddocks for canola, take care with those treated with residual herbicides, especially Group B and triazine herbicides (for conventional varieties); their residues can affect canola. Check labels for re-cropping intervals, some of which are up to 36 months.
- Ensure that all spray equipment is thoroughly decontaminated before using to spray canola. Apply chlorine if the spraying equipment has previously been used to spray sulfonylureas, ammonia for hormone herbicides (salt and amine formulations) such as 2,4-D amine and MCPA, and liquid alkali detergent for Broadstrike[™] (flumetsulam) and Eclipse[®] (metosulam) decontamination. Where possible, use separate spraying equipment for residual herbicides such as the sulfonylureas.
- Imidazolinone-tolerant varieties are marketed as Clearfield[®] canola. These varieties allow the use of the Group B herbicide Intervix[®] (imazamox and imazapyr). Clearfield[®] varieties do not suffer from the yield and oil penalty that the TT varieties exhibit. The use of Clearfield[®] varieties and other herbicide tolerant systems allow for the rotation of herbicide groups and broaden the spectrum of weeds controlled.²



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A Storrie, S Sutherland (2009) Weed management. Ch. 8. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>https://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

² L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>





NSW DPI: Weed control in winter crops 2015

GRDC: Integrated weed management manual

GRDC: Soil behaviour of pre-emergent herbicides in Australian farming systems

Monsanto: What is Roundup Ready®_ canola?_

BASF: Clearfield Production System. Best management practice 2015

GRDC: Herbicide tolerant canola in farming systems: a guide for growers



WeedSmart - Options for crop topping canola

1000

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Weed management is strongly influenced by crop rotation sequence. Careful planning of a 5-year rotation will enable targeted weed control through both cultural and chemical methods, as well as the ability to plan herbicide rotations. The widespread occurrence of herbicide resistance in Australian weeds puts further emphasis on the need for careful planning and resistance-management strategies such as monitoring, herbicide mode-of-action (MOA) rotation and cultural management techniques including harvest weed seed control.

The area sown to herbicide-tolerant varieties of canola has increased dramatically in recent years; however, widespread use of these varieties without integrated weed-management techniques is likely to accelerate the development of resistance to the herbicides.

The resistance to several of these herbicides that already occurs in Australian weeds shows that these herbicide-tolerant varieties are not a panacea for herbicide-resistance management, but they will add significantly to the options available to farmers for resistance management.

6.2 Weed density

If weeds are very dense, they represent a greater threat to yield, especially if herbicide control is poor. Table 1 shows the impact of initial weed density and herbicide control percentage on final weed density. The greater the initial weed density, the higher the final number of weeds, especially if herbicide effectiveness is reduced. In addition, if large numbers of weeds are sprayed, the likelihood of herbicide-resistant biotypes being selected increases.

Constant spraying of large numbers of weeds, especially with the same MOA herbicide group, will accelerate the evolution of herbicide-resistance in weed populations. The choice of weed-management strategies will depend on the species present and their resistance status. ³

Weedmaster DST has now been registered for pre-harvest use in canola to manage late season ryegrass and is a very effective IWM tool that has been rapidly adopted by growers.

Final weed density (plants/m		
Initial density (plants/m ²)	95% control	75% control
10,000	500	2500

Table 1: Impact of initial weed density on final weed numbers

6.3 Weed spectrum and herbicide resistance

50

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250

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Many weed species affect canola production; those that feature consistently in Australia are listed in Table 2. Prior to the introduction of herbicide-resistant canola varieties, control of key broadleaf weeds was the most important constraint to production of canola throughout Australia.

The degree to which such weeds have restricted the canola area is reflected in the rapid adoption of the TT varieties across Australia.⁴

⁴ S Sutherland. Canola weed management. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/______data/assets/pdf______file/0012/2712/Chapter__12_-__Canola_Weed_Management.pdf</u>



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A Storrie, S Sutherland (2009) Weed management. Ch. 8. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>https://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>



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 Table 2:
 Common weeds of Australian canola crops

*Weeds species that have been particularly important in restricting canola production prior to the introduction of triazine-tolerant varieties

Weed (common name)	Scientific name
Wild radish* (Figure 1)	Raphanus raphanistrum
Indian hedge mustard*	Sisymbrium orientale
Annual ryegrass	Lolium rigidum
Shepherds purse*	Capsella bursa-pastoris
Wild turnip*	Brassica tournefortii
Charlock*	Sinapsis arvensis
Paterson's curse*	Echium plantagineum
Vulpia*	Vulpia spp.
Wireweed	Polygonum aviculare
Toad rush	Juncus bufonius
Wild oats	Avena spp.
Spiny emex	Emex australis
Turnip weed*	Rapistrum rugosum
Fumitory	Fumaria spp.
Buchan weed	Hirschfeldia incana
Cape weed	Arctotheca calendula
Volunteer cereals	



Figure 1: Wild radish is a common weed in canola crops.

6.3.1 Herbicide resistance in Australian weeds

Australian farmers have moved away from aggressive tillage practices because of the extreme risk of soil erosion. Few farmers use inversion tillage as is practiced in Europe; the majority use reduced-tillage methods. Significant proportions of the crops are seeded using no-till. Therefore, crop sequences and seeding techniques are dependent on herbicides.



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Repeated use of herbicides has selected for herbicide-resistant weed biotypes. Herbicide resistance now affects many species of weeds in Australia, foremost among them annual ryegrass. Where canola production was restricted by weeds such as wild radish prior to the introduction of TT varieties, it is likely that herbicide-resistant weeds will re-impose restrictions if not carefully managed. This could be the case with multiple resistance and/or cross-resistance in single species, as well as mixed populations of resistant weed species.

Canola growers in Australia use a range of herbicides from many herbicide groups on canola crops, and the number of groups will increase with the commercial production of additional herbicide-resistant varieties in the next few years (Table 3).

Table 3: Common herbicides in use in canola crops in Australia

Herbicide Groups	Herbicides
A	Fluazifop, haloxyfop, sethoxydim, quizalofop, clethodim, butroxydim
В	Intervix (Clearfield® varieties)
С	Simazine, Atrazine, Terbuthylazine (TT varieties),
D	Trifluralin, Pendimethalin, Oryzalin, Propyzamide
L	Clopyralid
К	Metolachlor,
Μ	Glyphosate (RR varieties)

There are confirmed cases where annual ryegrass biotypes are resistant to all selective herbicides currently available. For each paddock, monitoring and resistance testing are imperative to understand the control options open to the grower.

The major herbicide resistance problems in weeds in Australia are with Groups A and B herbicides; however, resistance to Groups C, D, F, L and M herbicides has also been discovered. $^{\rm 5}$

Wild radish has now developed resistance to Group B, Group C and Group F herbicides. Combined with the resistance in ryegrass, this has serious implications for farmers in general but particularly to those wishing to use the IT and TT varieties.

While the majority of farmers are fully aware of the resistance problem, most still react to the development of resistance to a particular herbicide by changing to another herbicide. This is exemplified by the widespread change to trifluralin by southern Australian farmers in response to the failure of the Group A and Group B herbicides over the last two to three seasons. This will have the inevitable consequence that trifluralin resistance will increase.

The introduction of herbicide resistant crops will immediately increase the frequency of use of the specific herbicides on weeds. It is probable that this increased exposure to the herbicides will lead to more resistance problems, particularly in the case of the TT and IT varieties.

Farmers across Australia are being encouraged to adopt IWM in order to address the resistance problem. There are two essential components to IWM, namely the rotation of herbicide groups to avoid repetitious use of the same or similar herbicides, and the avoidance of treating large numbers of weeds with a single herbicide. To achieve the second component, farmers must move away from a high dependence on herbicides for weed control.⁶

For more information on integrated weed management, see the GRDC Integrated Weed Manual at <u>http://www.grdc.com.au/IWMM</u>.



Australian Pesticides and Veterinary Medicines Authority



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S Sutherland. Canola weed management. Australian Oilseeds Federation, <u>http://www.australianoilseeds.</u> com/______data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf

⁶ <u>http://www.australianoilseeds.com/__data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf</u>



6.4 Weed management in differing scenarios

6.4.1 Canola following pasture

The pasture ley system of farming was developed in Australia to allow crops to make use of nitrogen provided by legume pastures. A cropping phase of a single year to several years follows a period of pasture production. Growing canola in the first year after pasture has been the preferred practice. The system provides fertile, low-weeddensity conditions for the crop. A significant bonus is that cereal root diseases are controlled for the following wheat crop, provided grasses are controlled in the pasture. The ley-pasture phase provides farmers with one or more growing seasons in which weed numbers can be reduced by using non-selective techniques such as grazing, winter cleaning (pasture manipulation), topping, hay-making and silage production. In the spring prior to sowing, the pasture and weeds are killed with glyphosate. In a well-managed ley system, weed numbers are significantly reduced prior to planting the canola.

A common practice is to keep the canola crop as clean as possible of weeds, using the techniques outlined. This often allows the following wheat crop to be produced without selective herbicides.

The ley-pasture cropping system has a great deal of merit in terms of IWM. The system is excellent for reducing pressure on herbicides, as well as managing weeds that are already resistant to herbicides. Crop and pasture phases are usually of similar length (1–5 years). Management of herbicide resistance is straightforward in these systems.⁷

6.4.2 Canola in a continuous cropping sequence

Weed control in preceding crops consists of manipulating sowing time, exploiting crop competitive effects and relying heavily on selective herbicides.

Selection pressure for herbicide resistance is often high, especially to the Group A and Group B herbicides, because of the need to use these herbicides in the preceding crops.

This increases the risk of resistant biotypes being present in the crops when the herbicides are applied. Because of herbicide resistance, continuous crop programs may include a forage–fodder or green manure crop so that non-selective weed control can be achieved. Growers are now using non-selective options such as crop topping, crop competition and harvest weed seed control.

In both the ley system and the continuous cropping system, a significant component of weed management may be achieved through crop competition, although the effectiveness will vary between environments. ⁸ Weed management is also being achieved through crop-topping and harvest weed seed control including narrow windrow burning, chaff decks and chaff carts.

6.4.3 Triazine-tolerant canola

In 1999, TT canola accounted for almost 50% of the Australian crop. In most cases, TT canola is chosen because the weeds present cannot be controlled in the conventional varieties. In some situations, TT canola may be chosen as part of a strategy to control annual ryegrass resistant to Group A and Group B herbicides, in order to avoid repeated use of trifluralin. In addition, the TT varieties were initially grown without an associated best management package, although this has now been rectified. All future herbicide-resistant crops will be introduced with a best management guide.⁹



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⁷ S Sutherland. Canola weed management. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0012/2712/Chapter_12_-Canola_Weed_Management.pdf</u>

⁸ S Sutherland. Canola weed management. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0012/2712/Chapter_12_-Canola_Weed_Management.pdf</u>

⁹ S Sutherland. Canola weed management. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/______data/assets/pdf______file/0012/2712/Chapter__12_-__Canola_Weed_Management.pdf</u>



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6.4.4 Imidazolinone-tolerant canola

The IT (Clearfield)[®] canola varieties offer some significant benefits, but there are important limitations. These varieties are marketed along with an imidazolinone herbicide mix, originally On Duty[®], but this has been replaced with Intervix[®]. This has a wide spectrum of activity and does not suffer from extended plant-back periods on acid soils. The introduction of IT varieties has reduced the area of TT canola, which will have herbicide-resistance management and environmental benefits. ¹⁰

6.4.5 Roundup Ready[®] canola

Roundup Ready[®] canola (Figure 2) is now available to Australian producers. Roundup[®] has a wide spectrum of activity on weeds, has no soil residual problems (in the great majority of situations), and belongs to a low-risk group in terms of herbicide resistance.

A problem that the industry has to deal with is the increasing number of documented cases of glyphosate resistance in annual ryegrass. If glyphosate is the only herbicide used in RR canola, these biotypes will survive unless some other intervention is used, such as alternative knockdown herbicides prior to sowing, cultivation at or prior to planting, and/or in-crop herbicides. Best management packages include recommendations for minimising the risk of increased selection for the glyphosate-resistant biotypes.¹¹



Figure 2: Herbicide-tolerant canola, including Roundup Ready® varieties. (Source: GRDC)

6.5 Clethodim damage

The application of clethodim at the maximum rate of product as defined for some states (i.e. 500 mL/ha of Select[®], which contains 240 g clethodim/L; 330 mL/ha of Select Xtra[®], which contains 360 g clethodim/L) has been reported to cause the following symptoms on canola:

- delayed flowering
- distorted flower buds
- possible yield suppression
- S Sutherland. Canola weed management. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0012/2712/Chapter_12_Canola_Weed_Management.pdf</u>
- ¹¹ S Sutherland. Canola weed management. Australian Oilseeds Federation, <u>http://www.australianoilseeds.</u> com/___data/assets/pdf__file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf



Roundup Ready[®] canola Crop Management Plan (CMP)

Pacific Seeds Hyola RT Technology

PIONEER[®] Brand OPTIMUM[®] GLY Canola



Canola Damage from Clethodim

Hart: <u>Control of</u> <u>clethodim resistant</u> <u>annual ryegrass in break</u> <u>crops</u>

Hart Trial Results Book





There may be varietal differences in crop damage, although little is known in this regard. However, farmers can control the timing and rate of herbicide application. Spraying earlier may avoid moisture stress, particularly in seasons when rainfall is light. Spraying early means that late-emerging grass weeds will not be controlled with in-crop sprays but these plants are likely to be suppressed by a rapidly closing canola canopy. Seed production from these weeds could still be managed with non-chemical options such a windrow burning.¹²

We have seen significant crop damage in canola with later applied clethodim. The Sumitomo Tech Sheet for Status and label state that it should not be applied after the rosette stage for rates over 250mL/ha.

Agronomist's view

Clethodim resistance in annual ryegrass is increasing. In the past, this was managed by increasing the rate of clethodim. However, populations of annual ryegrass now exist that are resistant to clethodim at 500 mL/ha, and some will survive when treated with 2 L/ha.

No new post-emergent grass herbicides for canola are in the pipeline, so pre-emergent herbicides will have a greater role in managing annual ryegrass post-emergence. The ability of some currently registered and potential products for controlling annual ryegrass in canola was assessed in 2012 at Roseworthy, South Australia (Table 4). None of the pre-emergent herbicides was particularly efficacious against clethodim-resistant annual ryegrass and none was better than using clethodim.¹³

Table 4: Control of clethodim-resistant annual ryegrass in canola at Roseworthy in 2012.IBS, Incorporated by sowing; POST, herbicides were applied 8 weeks after sowing; CT, crop-topped. Within a column, means followed by the same letter are not significantly different at P = 0.05

Herbicide program	Annual ryegrass plants 8 weeks after sowing (no. per m²)	Annual ryegrass spikes at harvest (no. per m²)	Crop yield (t/ha)
1.5 kg/ha of atrazine IBS + 500 mL/ha of Select [®] POST	387ab	149cd	1.34a
1.5 kg/ha of atrazine IBS + 250 mL/ha of Select [®] POST	262b	306c	1.13a
1.5 kg/ha of atrazine IBS + 500 mL/ha of Select [®] + 80 g/ha of Factor [®] POST	333b	92d	1.37a
Group K IBS	498a	1105a	0.46d
Group K + 2.0 L/ha of Avadex® Xtra IBS	298b	775b	0.76c
Group K + 2.0 L/ha of Avadex® Xtra IBS	235b	260cd	0.88bc
Group K + 250 mL/ha of Dual Gold [®] IBS	350ab	802b	0.50cd
Group D IBS	108c	149cd	1.11ab

For more information on weed management in winter crops, see the *GrowNotes* Wheat. Section 6. Weed control.



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More information

<u>GRDC Update Papers:</u> <u>Maintaining the best</u> <u>options with herbicides</u>

GRDC Update Papers: Options for using more residual herbicides in northern no-till systems

GRDC Update Papers: Herbicides and weeds regional issues trials and developments

GRDC Ground Cover: Revisiting canola management can lift returns

¹² T Cook, G Brooke, M Widderick, M Street (2014) Herbicides and weeds regional issues trials and developments. GRDC Update Papers, 6 March 2014, <u>https://grdc.com.au/Research-and-Development/</u> <u>GRDC-Update-Papers/2014/03/Herbicides-and-weeds-regional-issues-trials-and-developments</u>

¹³ C Preston, P Boutsalis, S Kleeman, RK Saini, G Gill (2013) Maintaining the best options with herbicides. GRDC Update Papers, 28 August 2013, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/08/Maintaining-the-best-options-with-herbicides</u>



SECTION 7

Insect control

Stay informed

Stay informed about invertebrate pest threats throughout the winter growing season by subscribing to SARDI's <u>PestFacts</u> <u>South Australia</u> and **cesar**'s <u>PestFacts</u> <u>south eastern</u>.

Subscribers to PestFacts also benefit from special access to **cesar**'s extensive <u>Insect</u> <u>Gallery</u>, which can be used to improve identification skills of pest and beneficial insects.



SARDI: PestFacts South Australia

cesar: PestNotes

cesar: PestFacts south eastern

<u>GRDC Update Papers:</u> <u>Viral diseases in canola</u> <u>and winter pulses</u>

<u>GRDC Update Papers:</u> <u>Emerging insect pests</u>

GRDC: 'Serial pests' wrap up—lessons from 2014 and 2015 and some research updates

CropPro: Canola



Grains Research & Development Corporation Insects that can pose a problem in canola include blue oat mites (*Penthaleus* spp.), redlegged earth mites (*Halotydeus destructor*), *Bryobia* mites (*Bryobia* spp.), *Balaustium* mites (*Balaustium medicagoense*), cutworms, diamondback moth (DBM, *Plutella xylostella*), aphids, slugs, snails, earwigs, millipedes, slaters, lucerne flea (*Sminthurus viridis*) and Rutherglen bugs (RGB, *Nysius vinitor*).

Viruses can also occur in canola, carried by aphids that suck sap from leaves, transferring the virus and causing yield loss and sometimes plant death. Protection against early aphid infestation in seedling canola may reduce the incidence of viruses in the crop.

Gaucho[®] (imidacloprid) is the only seed dressing registered for control of aphids in canola. Sowing canola into standing cereal stubble may help to reduce aphid numbers and hence virus infection (Figure 1). ¹



Figure 1: Sowing canola into standing cereal stubble may help to reduce aphid numbers and hence virus infection. (Photo: Penny Heuston)

L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>

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IPM Workshops: Decision making for insect management in grain crops

IPM Workshops: 'Best Bet' IPM strategy

NIPI: I SPY, Insects of southern Australian broadacre farming systems identification manual

DEDJTR: Pest insects and mites

Research paper: Insect pests

cesar: PestFacts southeastern

7.1 Integrated pest management

Pests are best managed by using an integrated pest management (IPM) approach. Careful planning prior to sowing, followed by regular monitoring of crops after sowing, will ensure that potential problems are identified and, if necessary, treated early.

The IPM approach uses a range of management tactics to keep pest numbers below the level where they cause economic damage. It focuses on natural regulation of pests, particularly by encouraging natural enemies, and on using broad-spectrum chemicals only as a last resort. IPM relies on monitoring the crop regularly, having pests and beneficial insects correctly identified and making strategic control decisions according to established damage thresholds.²

7.1.1 Key IPM considerations for canola

Integrated pest management is a year-round approach to pest management and includes 'off-season' operations and planning as well as crop management:

- Monitor regularly and record numbers of pests and beneficials. Review checking data for population trends.
- Tolerate early damage. Canola can compensate for early damage by setting new buds and pods to replace those damaged by pests. Excessive early damage may reduce yield.
- Use aphid-selective products (e.g. pirimicarb) to preserve the beneficial insects, potentially reducing the need for follow-up applications.
- Biopesticides used in vegetative canola prior to flowering will preserve beneficials.
- Nuclear polyhedrosis virus (NPV) is effective against *Helicoverpa* larvae <7 mm long.
- Bacillus thuringiensis (Bt) is effective against DBM and Helicoverpa (<7 mm long).
- Consider the use of spray oils where aphid populations are low to moderate (repeat applications required).
- Where pests invade from adjacent fields, consider spraying only borders and not the whole field.
- Control some pests (e.g. lucerne flea or mites) in preceding pasture or broadleaf crops.
- Seed dressings may be the most effective control for some soil insects, as well as the least disruptive to natural enemies.
- Consider cultural control or biological control methods (Table 1).³



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K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0005/284576/</u> Insect-and-mite-control-in-field-crops-2013.pdf

IPM guidelines—Canola. National Invertebrate Pest Initiative, http://ipmguidelinesforgrains.com.au/crops/canola/



Table 1: Summary of 'Best Bet' IPM strategies ⁴

phids, particularly green peach ap Assess virus risk.	hid (GPA) Monitor crops for aphid	Spring
ssess virus risk.		March and the second fit and the second fit is a fit of the second state of the second
 ligh risk where: summer rainfall creates a <i>Brassica</i> green bridge warm conditions favour early aphid buildup and timing of flights i high risk: use an insecticide seed treatment to manage virus spread (e.g. <i>Beet western yellows virus</i>) by GPA manage <i>Brassica</i> weeds and volunteers (ideally area wide) 3–4 weeks before sowing sow early to promote early flowering in spring before aphids peak 	 colonisation from late winter when daily temperatures start to rise. High risk where: mild winter GPA present on vegetative plants forecast is for warm and dry conditions that favour aphid development no beneficial activity (predation or parasitism) 	 Monitor trends in aphid and beneficial populations over time. High risk where: aphid populations rapidly increasing during early flowering-bud formation forecast is for warm and dry conditions to continue low or no beneficial activity broad-spectrum insecticides (e.g. synthetic pyrethroids (SPs)/organophosphates (OPs) have been used to control DBM or native budworm) Use thresholds to guide spray decisions, considering crop stage (% flowering) and moisture stress. NSW, SA, WA thresholds: 10–50% of plants infested. If spraying: use soft products (pirimicarb) to retain beneficials consider border sprays to prevent/delay buildup rotate insecticide groups to reduce selection for resistance in GPA
Rutherglen bug (RGB)		
 Remove summer–autumn weeds Respecially fleabane, wireweed, and ape weed) in and around fields -4 weeks before sowing. Monitor rrops for RGB and other pests luring establishment. ligh risk if: warm conditions in late summer–autumn nearby weeds (in or near crop) drying off spraying: border-spray infested areas of crop and nearby host weeds monitor for reinvasion and the need for repeat application 	overwinter allowing build- up of local populations	 Monitor crops from flowering to windrowing-harvest. High risk where: hot, dry conditions in spring and early summer force RGB to move from weed hosts moisture stressed plants (limited compensation potential) long-distance migration into cropping areas Use economic thresholds to guide spray decisions, considering moisture stress. If spraying, monitor for reinvasion and the need for repeat sprays. Large numbers of RGB at harvest may pose a live-insect contamination risk. NSW threshold: 10 adults or 20 nymphs per plant (podfill-harvest)
Diamondback moth (DBM)		
 Manage Brassica weeds and olunteers (ideally area wide) 3–4 veeks before sowing. High risk where: high summer rainfall creates a green bridge of Brassica hosts (e.g. wild radish, volunteer canola) warm summer–autumn conditions favour early DBM buildup 	 Monitor crops for moths and larvae from midwinter. High risk where: DBM population present in mid–late winter warm temperatures in mid–late winter seasonal forecast is for a warm/dry spring If high risk: consider a <i>Bt</i> spray to delay population buildup. Best results where most larvae are small and beneficial activity and/or DBM parasitism (e.g. <i>Diadegma</i> sp.) is detected. 	 Monitor crop with a sweep-net for larvae until maturity. High risk where: warm and dry conditions favour rapid population development low beneficial activity and/or DBM parasitism (note: this can also happen if SPs/OPs are used) moisture-stressed plants Use thresholds to guide spray decisions, considering crop stage and moisture stress. If spraying: avoid SPs/OPs, which destroy beneficial insects (may flare pests) and increase resistance selection in DBM consider <i>Bt</i> to control small larvae consider emamectin or spinetoram to control larger larvae rotate insecticide groups across seasons ensure good spray penetration into the canopy monitor after spraying to determine need for repeat
		application SA threshold: Mid-late flowering: 20 larvae per 10 sweeps

⁴ 'Best Bet' IPM strategy. IPM Workshops, <u>http://ipmworkshops.com.au/wp-content/uploads/BestBet_Canola2014.pdf</u>





Summer-autumn	Winter	Spring
Helicoverpa punctigera (native budy	vorm)	
	Monitor for moth flight activity from mid–late winter, using pheromone traps or monitoring outside lights at night. High risk when: • wet winter in inland breeding areas • moth flights detected If high risk: • monitor crops for eggs and larvae consider biological insecticides (Bt or NPV) to control small larvae	 Monitor crops with a sweep net 1 or 2 times per fortnight from flowering–podding until maturity. If spraying is warranted: consider biological insecticides (Bt or NPV) to control small larvae <7–8 mm avoid SPs where aphids and/or DBM are present (flare pests and increase resistance selection in DBM) Thresholds: NSW: ≥5 larvae (>10 mm)/m² + evidence of pod damage WA: 4 larvae per 10 sweeps at pod maturity

7.2 Incidence of insect pests in canola

Various factors contribute to whether a canola crop is at risk from insect pests (Table 2). Economic damage from insect pests is most likely to occur during establishment and from flowering until maturity (Table 3).

Rutherglen bug is best known as a seed-feeding pest, attacking grain as it develops and fills. However, in some seasons, large numbers of nymphs and adults can cause damage to establishing winter or summer crops. RGB populations can build up in summer weeds and move from these into establishing winter crop, feeding on and killing small seedlings. Large numbers of RGB moving out of canola stubble pose a threat to nearby establishing summer crop.

Table 2: Insect pest risk in canola

High risk	Reduced risk	Low risk
Earth mites		
 Canola sown into paddocks coming out of pastures 	 Intensive grazing reduces survival of mites in pasture 	 Rotation with non- host crop (e.g. lentils, chickpeas, wheat, barley, lupins and linseed) will reduce the size of mite populations in a paddock (non-host crop must be weed-free)
Lucerne flea		
 History of lucerne flea. Loamy, clay soils Weedy fallow or pasture with no lucerne flea control 	 Intensive grazing reduces carry-over Cultivation can reduce oversummering eggs 	
Cutworm		
 Weedy fallow hosting cutworm Weeds in proximity to seedling crops Spraying-out weeds with large cutworm larvae that then move onto establishing crop 	Controlling weed hosts at least 2 weeks prior to crop emergence	



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High risk	Reduced risk	Low risk
Diamondback moth (DBM)		
 High summer rainfall creating <i>Brassica</i> green bridge Warm and dry conditions July through spring No significant rainfall events (>10 mm) 	 Significant heavy rainfall (>10 mm) (will dislodge and drown larvae) High beneficial activity and/or DBM parasitism 	 Cool moist conditions late winter through spring Epizootics of fungal disease (e.g. <i>Zoopthera</i> <i>radicans</i>)
Aphids		
 Weedy crop edges and neighbouring fields with <i>Brassica</i> weeds (wild radish, wild turnip, cape weed) Above-average rainfall in autumn promotes weed growth Use of broad-spectrum insecticides will kill natural enemies that may suppress populations 	• Drought stress increases impact of aphids by increasing the rate of aphid population growth and reducing the crop's ability to compensate for flower and pod abortion	 Early sowing so crop flowers in early spring, before aphid populations peak Cold, wet conditions in winter suppress populations High in-season rainfall can suppress populations and promote the outbreak of diseases Soft chemicals (pirimicarb, petroleum spray oils) that preserve beneficials that may control survivors
Native budworm		
 Wet winters in breeding areas of Central Australia + suitable weather conditions facilitate spring migrations Repeated influxes of moths over long periods mean reinfestation can occur post-treatment 	 Hot spring weather can cause small larvae to burrow into pods Broadleaf weeds can host large numbers which can move into crops as medium-large larvae and rapidly damage pods Treating aphids and DBM with broad-spectrum insecticides can disrupt beneficials that may suppress outbreaks 	 Dry winters in breeding areas contribute to a low population source and the absence of migration opportunities
Slugs and snails		
 Annual rainfall >500 mm Above average spring- autumn rainfall No-till stubble retained Previous paddock history of slugs and snails Summer volunteers and weeds No sheep in enterprise 	 450–500 mm annual rainfall Tillage or burnt only Sheep on stubble 	 <450 mm annual rainfall Drought Tillage and burnt stubbles No volunteers and weeds
Other pests		
Late sowing into cold soil reduces plant growth and increases vulnerability to insects and slugs		Cultivation in autumn destroys the potential habitat and food source of many pests Early-sown crops



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Use Table 3 and <u>ISPY</u> to identify insect pests by key behavioural and morphological characteristics, and by the damage caused.

Table 3: I SPY ready reckoner for key insects in canola ⁵

Crop damage or symptom in canola	Possible pest
ransparent windows and holes chewed in leaves. Dumpy, vingless, greenish-yellow insect-like creatures that spring off plants when disturbed	Lucerne flea
Plants stunted or dying, roots eaten. Slow-moving, soft-bodied nsects usually in a 'C' shape, cream-coloured apart from yellow or prown head; found near roots	
Surface tissue of leaves rasped or mottled by small mites with black or brown bodies and 8 orange-red legs (tiny nymphs have 6 egs), giving leaves a silvered appearance	Redlegged earth mite, blue oat mite, <i>Bryobia</i> mite, <i>Balaustium</i> mite
Pear-shaped insects sucking leaves, usually come from summer veeds	Rutherglen bug
e-mm-long cigar-shaped with and without wings; rarely cause lamage	Thrips
Presence of smooth, fat caterpillars without distinctive markings, up to 40 mm long; just under soil clods during the day	Cutworms (could be confused with armyworms)
arge sections of leaves chewed; in severe cases plants eaten down to ground level; roots not damaged. Presence of dull grey- prown weevils (adults) 10 mm long or yellow-green larvae up to 15 nm long with flattened, slug-like bodies; larvae usually found in vinter	Vegetable weevil, adult and larvae
arge sections of leaves chewed; in severe cases plants eaten lown to ground level. Adult weevils chew cotyledons, leaves and tems and may eat plants down to ground level	Spotted vegetable (<i>Desiantha</i>) weevil, Fullers rose weevil
eed on leaves of young seedlings; in severe cases seedlings are ing-barked at ground level causing them to drop. Adults are 3–5 nm long, round and dull brown, resembling small clods of dirt	Mandalotus weevil (south- eastern Aust. only)
areas of leaves chewed; presence of black and yellow striped are presence of black and yellow striped are presented by the striped by the stripe	Brown pasture looper
Plants eaten at ground level. Shiny, dark brown larvae (up 20 mm) vith spines or pincers at the tail end; mainly present when canola s sown in heavy stubble. (This could also describe grey or small alse wireworm.) Earwigs attack all parts of emerging seedlings, and are known to shred leaves. Their damage can be very different o bronzed field beetle	Bronzed field beetle, European earwigs
Seedlings can be defoliated and die. Caterpillars feed on leaves Inder a fine web, skeletonising leaves; mostly present in seasons vith early autumn rainfall and warm weather	Weed web moth
Ainor leaf chewing; presence of dark brown to black caterpillars up to 60 mm long with two yellow spots near posterior end. Minor best, usually after pasture	Pasture day moth
eaves shredded or chewed, slimy trails	Slugs and snails
Germinating seed or emerging seedlings are ring-barked and hypocotyl severed just below the surface; large bare patches can be seen a few weeks after sowing. Larvae up to 9 mm long, shiny brown-grey on top with paler undersides and two distinct upturned spines on last body segment	Grey false wireworm (south- eastern Aust. only)
Seedlings chewed at or above ground level, ring-barking or completely cutting stems. Adults of common species are 6–8 mm ong, dark grey-black and often have a covering of soil	False wireworms or vegetable beetle adult
Flower stems covered with masses of small, soft-bodied insects and black sticky mould; small soft-bodied insects on undersurface of leaves	Aphids
loles chewed in leaves, surface of pods attacked by small, thin, green caterpillars, up to 10 mm long that wriggle rapidly when	Diamondback moth

J Bellati, P Mangano, P Umina, K Henry (2012) I SPY. Insects of southern Australian broadacre farming systems identification manual and education resource. PIRSA/DAFWA, <u>http://www.grdc.com.au/Resources/</u>Bookshop/2012/11/I-SPY



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Feedback

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	Crop damage or symptom in canola	Possible pest
	Round holes in pods; seeds eaten by large (up to 40 mm long), sparsely haired and often brightly coloured caterpillars	Native budworm
More	Leaves and flowers attacked, especially the basal leaves; leaves can be combined together with webbing. Small, creamish caterpillars with dark heads; may tunnel into growing points	Cabbage centre grub
V information NIPI: I SPY, Insects of southern Australian broadacre farming systems identification manual	Large, irregular holes chewed in leaves. Velvety green caterpillars (up to 30 mm)	Cabbage white butterfly
	Pieces of leaves and stems chewed; complete defoliation can occur in severe cases. Grasshoppers and locusts present	Grasshoppers and locusts
	Plant growth stunted, and in severe cases, heads can be distorted. Large numbers of narrow-bodied, greyish-brown flying insects, 3–4 mm long, contaminating harvested grain	Rutherglen bug

Earth mites 7.3

Earth mites are the major pests of seedling canola. Redlegged earth mite and blue oat mite (Penthaleus major) are two soil-dwelling mites that damage crops in autumn, winter and spring. They are primarily pests of seedlings but can also seriously injure older plants. Winter crops at establishment may be severely damaged, particularly if growth during and following emergence is slow. Damaged plants die or remain stunted and weak. Sometimes seedlings are killed before they emerge. Both mites prefer light, sandy or loamy, well-drained soils and often occur together in crops. 6

Bryobia and/or Balaustium mites are an increasing problem in some areas. A good mitecontrol program starts with a population-reduction treatment the previous spring. Learn to identify these four species of mites to ensure that the correct insecticide and rate is applied to the correct species.

See www.apvma.gov.au for up-to-date on-label information.

Table 4: Recommended control strategies for earth mites 7

Pre-season (previous spring-summer)

Assess risk

High-risk situations: History of high mite pressure Pasture going into crop Susceptible crop being planted (e.g. canola, pasture, lucerne) Seasonal forecast is for dry or cool, wet conditions that slow crop growth

Actions if risk is high:

Ensure accurate identification of species Use Timerite® (redlegged earth mites only) Heavily graze pastures in early-mid spring

Pre-sowing

Actions if risk is high:

Use an insecticide seed dressing on susceptible crops Plan to monitor more frequently until crop established Use higher sowing rate to compensate for seedling loss Consider scheduling a post-emergent insecticide treatment

Actions if risk is low:

Avoid insecticide seed dressings (esp. cereal and pulse crops) Plan to monitor until crop establishment

- K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/ data/assets/pdf_file/0005/284576/ Insect-and-mite-control-in-field-crops-2013.pdf
- P Umina (2014) Persistent pests; aphids, mites, millipedes and earwigs. GRDC Update Papers, 5 February 2014, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Persistent-pestsaphids-mites-millipedes-and-earwigs



GRDC Ground Cover: Nutrient management may double as pest <u>control</u>



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Emergence

Monitor susceptible crops through to establishment using direct visual searches

Be aware of edge effects; mites move in from weeds around paddock edges

Actions if spraying:

Ensure accurate identification of species before deciding on chemical

Consider border sprays

Spray prior to the production of winter eggs to suppress populations and reduce risk in the following season

Follow threshold guidelines

Crop establishment

As the crop grows, it becomes less susceptible unless growth is slowed by dry or cool, wet conditions

7.3.1 Redlegged earth mite

The redlegged earth mite is native to southern Africa, and cape weed (*Arctotheca calendula*) is its preferred host plant. Other hosts include prickly paddy melon, wild turnip, common sowthistle, Paterson's curse and chickweed (weeds); and pastures, canola, lupins, field peas and linseed (field crops). Sometimes, mites may move into young winter cereals from a fenceline or adjoining pasture and cause damage along one or more of the crop edges.

Description

Adult mites are eight-legged and ~1 mm long with oval, flattened, black bodies and pinkish-orange legs and mouthparts (Figure 2).



Figure 2: Redlegged earth mites (Halotydeus destructor). (Source: cesar)

Seasonal development

Three overlapping generations usually occur between mid-autumn and spring, and adult populations are normally highest in May–June and September–October. Redlegged earth mites oversummer as unlaid, aestivating eggs in the dead bodies of spring-generation adult mites lying on or near the soil surface. The aestivating eggs are highly resistant to desiccation and usually do not begin to develop until late summer–early autumn. They hatch when favourable conditions of soil temperature and moisture occur in the following mid-autumn to early winter.

TIMERITE[®] for management of redlegged earth mite

TIMERITE[®] is an information package that provides individual farmers with the optimum spray date on their farm to control redlegged earth mites during spring. Developed by CSIRO and Australian Wool Innovation, TIMERITE[®] predicts the optimum date in spring to control redlegged earth mites, just after they have ceased laying normal winter eggs on pasture and just before diapause. (Diapause is when adult redlegged earth mites produce eggs that are retained in the body of the adult female and are therefore protected from the effects of insecticide applications.) The single, strategic spray has a two-fold effect, controlling redlegged earth mites in spring and decreasing the summer



GRDC Update Papers: Persistent pests; aphids, mites, millipedes and earwigs



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population that emerges in the following autumn. The package may form part of an integrated management strategy to control redlegged earth mites.

Close attention should be paid to individual pesticide labels when controlling earth mites. Application rates vary with situations, such as bare earth or post-emergence of crops or pasture. Correct identification of earth mite species is essential. Registrations sometimes include redlegged earth mites only, not blue oat mites or *Bryobia* mites. Application rates may vary with earth mite species. See <u>www.apvma.gov.au</u>.

This strategic approach has little effect on non-target invertebrates, both pest and beneficial, during the following autumn. Farmers need to identify geographically the location to be sprayed. This can be done by a local feature, such as town or mountain, or the longitude and latitude of the area. This information is used to find the optimum date from the package. The spray date for each farm is the same date each year. For information, phone Australian Wool Innovation toll free on 1800070099 or visit the website www.timerite.com.au. ⁸

7.3.2 Blue oat mite

Blue oat mites are often confused with redlegged earth mites. There are three recognised pest species of blue oat mites in Australia: *Penthaleus major, P. falcatus,* and *P. tectus*. Accurate identification of the species requires examination by an entomologist. The species vary with respect to their geographical distribution in Australia.

Description

Adult mites have eight legs and are \sim 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 (Figure 3). ⁹



Figure 3: Blue oat mite (Penthaleus sp.). (Photo: A Weeks, cesar)

Seasonal development

Overlapping generations of the blue oat mites 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 temperature and moisture conditions occur in the following mid-autumn to early winter.¹⁰



CSIRO: TIMERITE information package



K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0005/284576/</u> <u>Insect-and-mite-control-in-field-crops-2013.pdf</u>

K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0005/284576/</u> <u>Insect-and-mite-control-in-field-crops-2013.pdf</u>

K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/284576/</u> <u>Insect-and-mite-control-in-field-crops-2013.pdf</u>



Impact

Damage to crops and pastures is incurred in the establishment phase. ¹¹ Feeding causes a silver or white discoloration of leaves (Figure 4) and distortion or shrivelling if severe. Mites are most damaging to newly establishing pastures and emerging crops, greatly reducing seedling survival and development. ¹²

Host-plant preferences vary with the species, as do their life cycles and tolerances to various pesticides. Host plants include pastures and various weeds, such as black thistle, chickweed, curled dock, dandelion, deadnettle, prickly lettuce, shepherds purse, variegated thistle and wild oat. Cultivated field-crop hosts include canola, wheat, barley, oats, rye, field peas, lupins and linseed. ¹³



Figure 4: Feeding damage from blue oat mite.

7.3.3 Balaustium mites

Description

Balaustium mites grow to 2 mm in length and have a rounded red-brown body with eight red-orange legs (Figure 5). Adults are covered with short, stout hairs. They are slow moving and have distinctive, pad-like structures on their forelegs. The *Balaustium* mite is commonly confused with *Bryobia* mite, and sometimes with blue oat mite and redlegged earth mite. However, *Balaustium* mites are generally twice as large as other mites when adults. Newly hatched mites are bright orange with six legs and are only 0.2 mm in length.



Figure 5: Balaustium mites (Balaustium medicagoense). (Photos: A Weeks, cesar)

Seasonal development

Little is known about the biology of *Balaustim* mites. *Balaustium* mites usually have two generations per season and are unlikely to require cold temperatures to stimulate egg hatching like other species.

- ¹² GRDC. Blue oat mite (south). Ute Guide Crop Insects. GRDC, <u>https://www.grdc.com.au/Resources/Ute-Guides/Insects/Mites/South/Blue-Oat-Mite</u>
- ¹³ K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0005/284576/</u> <u>Insect-and-mite-control-in-field-crops-2013.pdf</u>



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Impact

Balaustium mites are unusual in that they not only feed on plants but also prey upon other small invertebrates. They have been reported to feed on several different groups, including various Collembola species and other mites. *Balaustium* mites were originally thought to be a beneficial predator with some reports suggesting that they provided localised control of redlegged earth mites. Only recently have *Balaustium* mites been confirmed to feed on plant material.

Canola, lupins and cereals are the most susceptible crops, particularly at the seedling stage. Some broadleaf weeds are alternative hosts. Typical damage to cereals, grasses and pulses is 'silvering' or 'whitening' of the attacked foliage, similar in appearance to damage caused by redlegged earth mites and blue oat mites. However, *Balaustium* mite damage differs in that they tend to attack the leaf edges and tips of plants. Adult mites are likely to be responsible for the majority of feeding damage to plants.

In canola, feeding damage is characterised by distorted and cupped cotyledons, which may have a leathery appearance (Figure 6).

Balaustium mites feed on plants by using their adapted mouthparts to probe leaf tissue and suck up sap. In most situations, they cause little damage; however, when numbers are high and plants are already stressed from other environmental conditions, significant damage to crops can occur.



Figure 6: Typical Balaustium mite damage on canola. (Photo: A Weeks, cesar)

Management

There are very few effective biological control options. Early control of summer and autumn weeds within and around paddocks, especially cape weed and grasses, will help to control populations. *Balaustium* mites have a high natural tolerance to chemicals and they will typically survive pesticide applications aimed at other mite pests. ¹⁴

Distribution

Balaustium mites are widespread throughout most agricultural regions in southern Australia with a Mediterranean-type climate (Figure 7). They are found in Victoria, New South Wales and South Australia. They are generally restricted to coastal areas and do not occur far inland or in the drier Mallee areas of Victoria and South Australia. *Balaustium* mites have been found in Tasmania; however, no systematic sampling has been conducted and the distribution across the state remains unknown.

Similar to other pest mites, long-range dispersal is thought to occur via the movement of eggs in soil adhering to livestock and farm machinery or through transportation of plant material. Movement may also occur if oversummering eggs are moved by summer winds.

GRDC. Crop mites. Back Pocket Guide. GRDC, <u>http://www.grdc.com.au/Resources/Publications/2012/06/</u> <u>GRDC-Crop-Mites-Back-Pocket-Guide</u>







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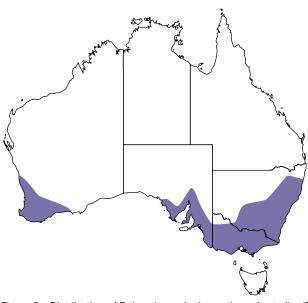


Figure 7: Distribution of Balaustium mite in southern Australia. (Source: Agriculture Victoria)

Monitoring

The impact of mite damage is increased when plants are under stress from adverse conditions such as prolonged dry weather or waterlogged soils. Ideal conditions for seedling growth enable plants to tolerate higher numbers of *Balaustium* mites. Carefully inspect susceptible pastures and crops from autumn to spring for the presence of mites and evidence of damage. It is especially important to inspect crops regularly in the first 3–5 weeks after sowing.

Crops sown into paddocks that were in pasture the previous year should be regularly inspected. Weeds present in paddocks prior to cropping should also be checked for the presence and abundance of *Balaustium* mites. Mites are best detected feeding on the leaves, especially on or near the tips, during the warmest part of the day. They are difficult to find when conditions are cold and/or wet.

One of the most effective methods to sample mites is by using a D-vac, which is based on the vacuum principle, much like a domestic vacuum cleaner. Typically, a standard, petrol-powered garden blower/vacuum machine is used. A sieve is placed over the end of the suction pipe to trap mites vacuumed from plants and the soil surface. ¹⁵

7.3.4 Bryobia mites

Description

Bryobia mites (also referred to as clover mites) are smaller than other commonly occurring pest mites, reaching ~0.75 mm in length as adults. They have an oval, flattened dorsal body that is dark grey, pale orange or olive and have eight pale-orange legs (Figure 8). The front pair of legs is much larger, about 1.5 times their body length. Nymphs are small with bright-red bodies with pale-coloured legs. ¹⁶

The egg of the *Bryobia* mite is minute, globular and red. It can be distinguished from European red mite eggs by its smooth appearance and lack of a spike. The nymph looks like the adult but is smaller. ¹⁷



http://agriculture.vic. gov.au/agriculture/ pests-diseases-andweeds/pest-insectsand-mites/balaustiummite

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Agriculture Victoria (2010) Balaustium mite. AG1413. DEDJTR Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/balaustium-mite</u>

⁶ GRDC. Crop mites. Back Pocket Guide. GRDC, <u>http://www.grdc.com.au/Resources/Publications/2012/06/</u> <u>GRDC-Crop-Mites-Back-Pocket-Guide</u>

¹⁷ Agriculture Victoria (2000) The *Bryobia* mite and the pear-leaf blister mite. DEDJTR Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/the-bryobia-mite-and-the-pear-leaf-blister-mite</u>



Many species of *Bryobia* mites are found in grain crops in Australia. They are found in high numbers in the warmer months from spring through to autumn. *Bryobia* mites prefer broadleaf plants such as canola, lupins, vetch, lucerne and clover, but they will also attack cereals.¹⁸





Figure 8: Bryobia mites. (Photos: A Weeks, cesar)

Management

There are no known biological control options. Crops that follow clover-dominant pastures are most at risk, and should be monitored carefully. Early control of summer and autumn weeds, within and around paddocks, especially broadleaf weeds such as cape weed and clovers, will help to control populations.

Several pesticides are registered for use on *Bryobia* mites; higher rates are usually required than for redlegged earth mites and blue oat mites. *Bryobia* mites have a natural tolerance to several chemicals. ¹⁹

7.4 Lucerne flea

Lucerne flea is an important pest of establishing canola crops. The pest is identified by its action of jumping between plants rather than flying. Early-sown crops are more at risk of attack. Frequent crop inspection from the time of emergence, and early control measures, are important because of the impact of seedling vigour on crop performance. Ensure that monitoring is sufficient to detect localised patches or 'hot spots'. Seek advice on management and spray strategies.²⁰



Figure 9: Adult lucerne flea (Sminthurus viridis). (Photo: cesar)

7.4.1 Description

Adult lucerne fleas are globular, wingless insects, 2–3 mm long with green, brown and yellow markings (Figure 9). They appear yellow-green to the naked eye, although their



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GRDC Back Pocket Guides: Crop mites

DAFWA: Diagnosing Bryobia mite

¹⁸ GRDC. Crop mites. Back Pocket Guide. GRDC, <u>http://www.grdc.com.au/Resources/Publications/2012/06/</u> <u>GRDC-Crop-Mites-Back-Pocket-Guide</u>

¹⁹ GRDC. Crop mites. Back Pocket Guide. GRDC, <u>http://www.grdc.com.au/Resources/Publications/2012/06/</u> <u>GRDC-Crop-Mites-Back-Pocket-Guide</u>

P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/_pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>



globular abdomens are often a mottled pattern of darker pigments. They make jumping movements when disturbed. Nymphs resemble the adults except in size. ²¹

7.4.2 Seasonal development and symptoms

Lucerne fleas hatch following periods of good, soaking autumn–winter rainfall and can cause significant damage to emerging crops and pastures at this time of year. They can also cause considerable damage to older crops if numbers build up under favourable conditions throughout the season. With the recent lack of rainfall experienced across much of south-eastern Australia, lucerne flea hatchings may be delayed and somewhat staggered in many regions.

Lucerne fleas have a wide host range. They will attack most broadacre crops, including canola, lucerne, pastures, cereals and some pulses. Feeding results in the appearance of distinctive transparent 'windows'. They are generally a problem in regions with loam or clay soils.

Crops should be inspected frequently at, and immediately following, emergence, when they are most susceptible to damage. Paddocks are most likely to have problems where they follow a weed-infested crop or a pasture in which the lucerne flea has not been controlled.

7.4.3 Impact

The cells of the upper surface of leaves and cotyledons are eaten, resulting in small 'windows' in the leaves. Severe infestations cause skeletonised leaves, with just the more fibrous veins remaining. This damage is quite distinctive and can be used to help identify lucerne flea as the key pest.

Canola is most susceptible during crop establishment. Damage is often minor, but severe damage can stunt or kill seedlings. Cumulative damage may be severe where crop growth is slowed by cold, wet or dry conditions ²²

7.4.4 Management

Only when infestations are severe should lucerne flea be sprayed. In some instances, spot spraying with registered chemicals may be adequate. Several natural enemies such as mites, beetles and spiders prey upon lucerne fleas. Blanket spraying is harmful to these natural control agents. Seed dressing can also be a useful technique to prevent damage by lucerne flea.²³

<u>Snout mites</u> (which have orange bodies and legs) are effective predators of lucerne fleas, particularly in pastures, where they can prevent pest outbreaks. The complex of beneficial species (including snout mites) should be assessed before deciding on control options. ²⁴

Several options are available to growers for controlling the lucerne flea. Foliar insecticides can be applied approximately 3 weeks after lucerne fleas have been observed in a newly emerged crop. This will allow for further hatching of oversummering eggs but will be before lucerne fleas reach the adult stage and begin to lay winter eggs. If spraying is required, do not use synthetic pyrethroids.

In paddocks where damage is likely, a border spray may be sufficient to prevent movement of lucerne fleas into the crop from neighbouring paddocks. Lucerne fleas are often distributed patchily within crops; therefore, spot spraying is generally all that is required. Do not blanket spray unless the infestation warrants it.

- ²¹ CropPro. Lucerne flea. Pests in canola. CropPro, <u>http://www.croppro.com.au/cb_pages/pests_in_canola_-</u> in_crop.php?category_id=2374
- ²² CropPro. Lucerne flea. Pests in canola. CropPro, <u>http://www.croppro.com.au/cb_pages/pests_in_canola_-in_crop.php?category_id=2374</u>
- ²³ CropPro. Lucerne flea. Pests in canola. CropPro, <u>http://www.croppro.com.au/cb_pages/pests_in_canola_-</u> in_crop.php?category_id=2374
- ²⁴ cesar (2010) Lucerne flea. PestFacts south-eastern, Issue 3, 21 May 2010. cesar, <u>http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2010/pestfacts-issue-no-3-21st-may-2010/lucerne-flea/</u>



AOF: Insect pests of canola. Lucerne flea (p. 3)

GRDC Grain Research Advice: Knowledge, timing, key to lucerne flea control

NIPI IPM Guidelines: Lucerne flea in winter seedling crops

Agriculture Victoria: Lucerne flea

<u>GRDC: Canola best</u> practice management guide. Lucerne flea (p. 51)

<u>NIPI: I Spy Manual.</u> <u>Lucerne flea (section 4, pp. 63–64)</u>





7.5 Slugs

The main slug pests of canola crops in southern Australia are the grey-coloured reticulated slug (or grey field slug) and the black-keeled slug. Several other pest slug species are also found in canola.²⁵

Canola sown into dense stubble or adjacent to grassy fence lines, creek banks or damp areas is at greatest risk of slug damage because these areas provide an ideal habitat for slugs to survive over summer. Heavy, cracking soils provide additional hiding places for slugs. Closely monitor crops at risk for 6–8 weeks after sowing, so that any infestation can be treated with Molluscicidal baits if required.²⁶

7.5.1 Description

Typically, the grey field slug is 35–50 mm long and light grey to fawn, with dark brown mottling (Figure 10). When disturbed, it will exude a sticky, milky secretion over its body. The black-keeled slug is 40–60 mm long and uniform black or brown with a ridge (keel) down its back (Figure 11). It can burrow to 20 cm underground. ²⁷



Figure 10: Grey field or reticulated slug (Deroceras reticulatum). (Photo: M Nash)



Figure 11: Black-keeled slug (Milax gagates). (Photo: M Nash)

7.5.2 Seasonal development and symptoms

Slugs are hermaphrodites, therefore, both individuals of a mating pair lay eggs. They will breed whenever moisture and temperature conditions are suitable—generally from midautumn to late spring. Eggs are laid in batches in moist soils and they will hatch within 3–6 weeks, depending on temperature. Juveniles look like smaller versions of the adult.



²⁵ G Baker (2009) Pests of canola and their management. Ch. 9. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>https://www.grdc. com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>

²⁷ GRDC (2013) Slug identification and management. GRDC Slug control Fact Sheet, March 2013, <u>http://www.grdc.com.au/~/media/412EEE56898A4AFB8B50409EC87FEBFE.pdf</u>



Slugs feed aboveground on stems and leaves, and belowground on seeds, shoots and roots. Damage is greatest when seedling growth is slow because of cool, wet or dry conditions. Grey field slugs are mainly surface-active, whereas black-keeled slugs burrow and can feed directly on germinating seeds. Slugs can be underestimated as pests because they are nocturnal and shelter during dry conditions, and therefore are not generally visible during daylight hours.²⁸



<u>GRDC: Canola best</u> practice management guide. Slugs (p. 51)

GRDC Fact Sheets: Slug control

NIPI: Slugs in seedling crops

NIPI: I Spy Manual. Slugs (section 4, pp.70–71)

7.5.3 Impact

Slugs damage newly sown crops and pasture, and damage is often difficult to detect or is incorrectly attributed to agronomic factors. Populations as low as 1 grey field slug/ m² can inflict severe damage on canola at establishment. If the population is large, damage to seedlings can be extensive. The black-keeled slug is more problematic in drier environments such as South Australia, although it is widespread throughout south-eastern Australia. ²⁹,³⁰

7.5.4 Management

Cultivation prior to sowing, delaying sowing after summer cover has been sprayed out, stubble and weed removal, and baiting are all effective methods for reducing slug populations. When slug pressure is high, baiting alone may not provide total crop protection. ³¹

7.6 Diamondback moth

Diamondback moth has been observed in canola crops for many years. Caterpillars of DBM do most damage when large numbers are present in seedling crops or when they move from leaves to graze developing pods during crop ripening. DBM has developed resistance to a range of insecticides. Future management will involve regular monitoring and careful selection of control methods.³²

7.6.1 Appearance

Diamondback moths are 10 mm long and grey-brown. They have a white diamondpatterned stripe down the centre of the back when the wings are folded over the body (Figure 12). Eggs are pale yellow, oval and about 0.5 mm in length. DBM larvae grow to 12 mm long, are pale yellowish-green and are tapered at both ends (Figure 13). They wriggle when disturbed and often drop from the plant on a silken thread. Mature larvae pupate after spinning gauze-like cocoons, usually on the underside of leaves. The pupa changes colour from green to brown before emerging as an adult moth.³³



²⁸ GRDC (2013) Slug identification and management. GRDC Slug control Fact Sheet, March 2013, <u>http://www.grdc.com.au/~/media/412EEE56898A4AFB8B50409EC87FEBFE.pdf</u>

²⁹ G Baker (2009) Pests of canola and their management. Ch. 9. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>https://www.grdc. com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

³⁰ GRDC (2013) Slug identification and management. GRDC Slug control Fact Sheet, March 2013, <u>http://www.grdc.com.au/~/media/412EEE56898A4AFB8B50409EC87FEBFE.pdf</u>

³¹ CropPro. Slugs. Pests in canola. CropPro, <u>http://www.croppro.com.au/cb_pages/pests_in_canola_-_in_crop.php?category_id=2381</u>

³² P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/_pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>

³³ GRDC (2013) Diamondback moth is a sporadic but serious canola challenge. GRDC Diamondback moth Fact Sheet, July 2013, <u>http://www.grdc.com.au/GRDC-FS-DBM</u>

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Figure 12: Diamondback moth (Plutella xylostella).



Figure 13: When larvae of the diamondback moth are disturbed, they will wriggle, and may drop from the plant by a silken thread. (Photo: DAFWA)

7.6.2 Seasonal development and symptoms

Diamondback moths are active at dusk and throughout the night, but usually do not fly far within a crop. However, they can migrate long distances on prevailing winds, especially when their host plant has died. DBM survive between growing seasons on summer *Brassica* weeds such as wild radish and Lincoln weed. Summer rainfall increases the 'green bridge' and DBM populations.

In autumn–early winter, DBM fly into canola crops. Female moths lay eggs singly or in small clusters along the leaf vein on both sides of plant leaves. Eggs hatch after 4–6 days. Development from eggs to moths is faster in warm weather and slower in cool weather; at 28°C, the life cycle takes 14 days, whereas at 12°C it takes >100 days. In warm weather, there is often overlap in generations and all life stages may be present in a crop at one time.

DBM populations can suddenly crash and the reason for this is only partially understood. One factor may be the outbreak of insect fungal diseases during wet, warm weather.

The damage caused by newly hatched larvae appears as characteristic pale-white traces. Older larvae often cause holes on the underside of the leaves with the upper surface intact, which creates a see-through window effect. Larvae can be found at any stage of a canola crop's development, with their numbers often increasing before flowering. Canola can tolerate considerable leaf damage before crop yield is affected. ³⁴.



⁴ GRDC (2013) Diamondback moth is a sporadic but serious canola challenge. GRDC Diamondback moth Fact Sheet, July 2013, <u>http://www.grdc.com.au/GRDC-FS-DBM</u>



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7.6.3 Impact

Larvae of DBM can cause extensive damage to canola, but this does not happen in all years. Severe infestations of DBM larvae can cause complete defoliation and substantial yield losses. As flowering progresses, increasing numbers of larvae move to the floral buds, flowers and pods. Large larvae may feed on small young pods. Damage to mature plants during the late spring by increasing populations of DBM often causes visible scarring of the outer pod walls, although this rarely results in economic loss. ³⁵

7.6.4 Management

Monitoring and thresholds

Canola crops should be monitored by using an insect sweep-net at the first sign of damage and at intervals throughout the growing season from mid-July to late spring–early summer. Numbers of DBM are likely to increase quickly with early-season infestation and with prolonged warm weather allowing the pest to complete three or four generations.

Two sets of 10-sweep samples (i.e. 10 consecutive sweeps with a sweep-net) should be taken at each of a minimum of four locations within each canola crop. Empty the contents of each set of 10 sweeps onto a white or light-coloured surface, and count the larvae. Note the sizes of the DBM larvae and the presence of other insects. If no DBM or low numbers are detected, monitor again in 2 weeks. When DBM numbers increase, at least three estimates of larval density over 12 days are needed to determine how the population is changing. On each occasion, eight or more 10-sweep samples should be taken throughout the crop. Cool, wet, windy weather can reduce DBM numbers. Numbers of larvae can also be reduced by beneficial insects and insect diseases.

Economic thresholds vary from 30 to 200 larvae per 10 sweeps. Crop growth stage, grain price and cost of spraying need to be considered when deciding whether spraying will provide an economic return. Variation in regional and seasonal conditions also influences spray threshold levels. As canola develops, it can tolerate increasing numbers of DBM without significant yield loss.

The presence of many small larvae (<3 mm long) indicates that numbers are likely to increase further. Moisture-stressed crops are more susceptible to insect damage and a lower threshold may be used if extended dry periods are anticipated. In pre-flowering crops, spraying should be considered if the average number of larvae exceeds 30 in 10 sweeps.

Pesticides

Diamondback moth has developed widespread resistance to many insecticides, including synthetic pyrethroids and organophosphates. In 2012, two new insecticides were registered for DBM control in canola: Affirm[®] (Group 6) and SuccessTM Neo (Group 5). Together with the biological insecticide Bt, growers can now choose from three effective insecticide groups.

To reduce the risk of resistance developing to these newer insecticides, spray for DBM only when thresholds are exceeded, and alternate between insecticide groups from one season to the next. If sweep-netting indicates that DBM larval densities are at the spray threshold, a quick response with two spray applications (5–7 days apart) can give adequate control of larvae and reduce yield losses. Under typical temperature conditions, this strategy will ensure that DBM in life stages that survive the first application are controlled.

The period between applications may vary with choice of chemical. Growers should note that withholding periods before harvest and at windrowing are the same, and that they must abide by registration details on the product label.



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⁵ GRDC (2013) Diamondback moth is a sporadic but serious canola challenge. GRDC Diamondback moth Fact Sheet, July 2013, <u>http://www.grdc.com.au/GRDC-FS-DBM</u>



Good chemical penetration into a canopy crop is important, with ~20% of DBM larvae on the lower plant canopy. Under good spraying conditions, aerial (CP90 nozzles with 30 L/ha of water) and ground-based (flat-fan 11015 nozzles with 50 L/ha of water) applications can be equally effective in achieving good leaf coverage and spray penetration to lower leaves.

Where 'soft' chemicals (such as *Bt*) that are less disruptive to beneficial insects are used, the majority of larvae should be less than 5 mm in length at spraying. *Bt* is broken down by ultraviolet light, so the best results are achieved by dusk application.

1 More information

<u>GRDC Fact Sheets:</u> <u>Diamondback moth in</u> <u>canola</u>



GRDC Fact Sheets: FAQ Reducing aphid and virus risk

GRDC Fact Sheets: Resistance management strategy for the green peach aphid in Australian grains

GRDC Ground Cover: Unified attack on pests and diseases

<u>GRDC Ground</u> <u>Cover: Insect pests –</u> <u>resistance, virus vectors</u> <u>and lessons from 2014</u>

GRDC Back Pocket Guides: Crop aphids

Natural enemies

Several beneficial insects attack DBM, including parasitic wasp species. These wasps lay their eggs inside DBM larvae and/or pupae (depending on the wasp species). The parasitised DBM larvae or pupae fail to develop. Predators such as brown and green lacewings, several predacious bugs and a range of spiders will feed on DBM eggs, larvae and pupae. ³⁶

7.7 Aphids

Aphid flights can occur in autumn and winter and can infest young canola crops. Crops may need to be treated with insecticide to prevent transmission of virus diseases, and to reduce seedling damage and the risk of spring infestations. The green peach aphid is the major vector of *Beet western yellows virus* (BWYV), which caused significant crop damage in south eastern NSW in 2014. Seed treated with imidacloprid (e.g. Gaucho[®]), Poncho[®] Plus and Cruiser[®] Opti will protect seedling canola for up to 5 weeks. This is especially important in seasons and at sites where early infestation with aphids occurs. ³⁷ Aphids flights are also commonly observed in spring and early summer.

7.7.1 How to identify key aphids

Life cycle diagrams are available from the National Invertebrate Pest Initiative for the following aphid groups (links to pdfs): <u>cabbage aphid</u>, <u>cereal aphid</u>, <u>green peach aphid</u>, <u>turnip aphid</u>, <u>winter cereal aphid</u>.

Turnip aphid

The turnip aphid (Figure 14) infests canola. It is generally restricted to crops and weeds within the cruciferous plant family. Alternative hosts are wild radish and wild turnip. It causes reduced podset, podfill and seed quality.



Figure 14: Turnip aphid (Lipaphis erysimi).

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- GRDC (2013) Diamondback moth is a sporadic but serious canola challenge. GRDC Diamondback moth Fact Sheet, July 2013, <u>http://www.grdc.com.au/GRDC-FS-DBM</u>
- ³⁷ P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/_pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>



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Cabbage aphid

The cabbage aphid (Figure 15) infests canola. It is generally restricted to crops and weeds within the cruciferous plant family. Alternative hosts are wild radish and wild turnip. It causes reduced podset, podfill and seed quality.



Figure 15: Cabbage aphid (Brevicoryne brassicae).

Green peach aphid

The green peach aphid (Figure 16) infests canola. Alternative hosts are wild radish and wild turnip, lupins, cape weed and others. It transmits BWYV and many other important plant viruses. It is an early-season pest with potential to affect yield through transmission of BWYV. It rarely persists to cause direct yield loss.



Figure 16: Green peach aphid (Myzus persicae).

7.7.2 Aphids in canola

The main aphid pests in canola are the turnip aphid, the cabbage aphid, and the green peach aphid.

Impact

Aphids will often colonize canola crops in autumn. Green peach aphids are most common at this time, but will only occasionally cause economic damage to canola through direct feeding. Severe infestations by aphids may cause death of young plants. Early infestations may continue to develop hotspots. Heavily infested plants will show signs of wilting. Wilting may be more severe if the crop is water-stressed. Aphids often infest plants on crop edges. Winged aphids can colonise plants throughout the field.

Early colonisation by virus-infected aphids can result in significant canola yield losses, as seen in 2014 with beet western yellows virus.





Aphids also infest crops in the spring, especially in years of moisture stress. Bud formation and flowering is the stage most sensitive to damage. Infestations reduce flowering and reduce or prevent podset and podfill on the infested racemes. Look for infestations amongst buds and flowers, and aphids on stems, lower leaves, buds and flowering heads. Warm dry spring promotes rapid population growth; moisture stress limits crop compensation, podset and podfill. Canola can compensate to some extent through larger seed in pods that are set and more flowering branches.

Large populations of aphids are more evident and potentially damaging in dry seasons. Monitoring for beneficial insects is important, because control may not be justified in some cases. If control is warranted, careful selection of an insecticide is essential to ensure that damage is not caused to nearby beehives or to beneficial insects within the crop. Be sure to adhere to the harvest withholding period (WHP) of the insecticide.

Monitoring and thresholds

Monitor from early bolting onwards. Monitor earlier in high-risk season, such as a wet autumn that promotes weed growth. Visually check stems, amongst buds, and flowering heads.

Check regularly at least 5 points in the field and visually inspect 20 plants at each point. Populations are often patchy (radiating from hotspots) and densities at crop margins may not be representative of the whole field.

Regular monitoring, on a weekly basis during flowering and podset, is required to detect rapid increases in aphid populations.

Aphid infestation can be reduced by heavy rain events. If heavy rain occurs after a decision to spray has been made but before the spray has been applied, check the crop again to determine whether the treatment is still required.

Monitoring for canola aphids is often done at the same time in spring (early flowering to harvest) as sweep netting for DBM caterpillars.

At each sampling visit, record:

- the aphid species present in the crop and relative abundance of the species (presence of green peach aphid may require a different approach to control—it is known to be resistant to some insecticides)
- number of heads counted, number of heads infested; calculate % infestation = (heads infested ÷ heads counted) x 100
- the size of the infestation on each head, in cm of stem infested—indicates how established the infestation is and can be used at repeat visits to determine how rapidly the population is increasing
- · impact of the infestation on the crop
- presence of beneficials—number and species (including aphid mummies as an indication of parasitoid wasp activity)

The number of heads per plant infested within a crop is more important than the size of infestations when considering control. Small populations will prevent the head from flowering and setting pods normally.

Threshold recommendations to control:

- if >20% of plants infested with colonies, consider control (from Western Australia)
- if >50% of plants with clusters 25 mm long on stems or 4–5 stems/m² with clusters 50 mm long on stems (from NSW)

Compensation likely plays an important part in moderating yield loss in crops. Droughtstressed crops are more likely to suffer yield loss. However, the reduction in yield potential of stressed crops can make it uneconomic to control pests, even if they are causing visible damage to the crop.





Management

Beneficials

These include parasitoids (wasps, aphid mummies) and predators (ladybirds, hover flies and lacewings).

The earlier a decision to control aphids is made, the more important it is to preserve beneficials. The longer the period between aphid control and harvest, the greater the risk of aphid populations building up again. In this situation, the impact of beneficials on small, surviving aphid colonies can be significant.

Beneficials will suppress low to moderate aphid populations but will not control heavy infestations quickly enough to prevent impact on the crop. The number of beneficials required to control a population of aphids has not been studied in canola.

Beneficials may not arrive in crop early enough to prevent the buildup of aphid numbers to above threshold levels. However, they can be important in suppressing population buildup following control. For this reason, it is important to determine the potential impact of an insecticide used for aphid control on natural enemy populations. Preserve beneficial insects wherever possible by avoiding the use of broad-spectrum insecticides.

Cultural control

Control aphid hosts of wild turnip, wild radish and cape weed early in the season to prevent buildup of aphids. Because winged aphids may move large distances, weed control to minimise aphid outbreaks needs to be done on an area-wide basis.

In a season with warm, wet autumn and spring, the abundance of hosts and aphids will make the management of alternative hosts difficult. Sow crops early, where possible, to enable plants to flower and set pods before aphid numbers increase. Sow canola into standing stubble wherever possible, as this will deter aphid landings in autumn.

Chemical control

If chemical control is required, consider early application of aphid-specific products to preserve beneficials, particularly where the potential for reinfestation is high.

Seed treatments and border spraying (autumn–early winter) when aphids begin to colonise crop edges may provide sufficient control. Early control of aphid populations can delay buildup significantly, but it may be of little benefit in seasons when pest pressure is high and movement of aphids into the crop occurs over a long period.

Sow canola into standing stubble wherever possible, as this will deter aphid landings in autumn.

Green peach aphid has resistance to several insecticides, and this resistance is widespread across southern Australia.

Rotate chemical groups to minimise the development of resistance, particularly where a pest is treated more than once in the same crop.

Multi-pest considerations

The use of broad-spectrum insecticides (e.g. pyrethroids, methomyl) can flare aphid and DBM numbers because of the reduction in beneficial populations by these applications.

Communication

An area-wide management approach to the control of weed and volunteer hosts may be useful. Agronomist and growers can discuss:

- controlling aphid hosts in fallows and around the farm (e.g. weeds, volunteers)
- · monitoring methods and frequency of checking
- control options for aphids and a likely sequence of insecticides to control other pests from establishment through to harvest, in particular the potential off-target effects of any broad-spectrum options and resistance-management strategies



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Agriculture WA: Aphid management in canola crops

Research Paper: Managing aphids in flowering canola in central west NSW

cesar: PestFacts southeastern. Canola aphid



GRDC Fact Sheets: Resistance management strategy for the green peach aphid in Australia grains

GRDC Update Papers: Insect management in faba beans and canola recent research keeping and reviewing crop records of aphid infestations over time to determine whether populations are increasing or decreasing

Industry publications provide up-to-date regional information about pest activity in crops. These include PestFax (WA) and PestFacts (Vic./NSW, SA) newsletters, and Beatsheet blog (Qld, NSW).

7.7.3 Resistance management strategies for green peach aphid

Green peach aphids are a widespread and damaging pest of canola and a range of pulse crops, causing damage by feeding and transmitting viruses.

Five chemical subgroups are registered to control green peach aphids in grain crops: carbamates (Group 1A), synthetic pyrethroids (Group 3A), organophosphates (Group 1B), neonicotinoids (Group 4A), and sulfoxaflor (Group 4C). Paraffinic spray oils are also registered for suppression of green peach aphids.

High levels of resistance to carbamates and pyrethroids are now seen across Australia. Moderate levels of resistance to organophosphates have been observed in many populations, and there is evidence that resistance to neonicotinoids is evolving. Transform[™] (sulfoxaflor) is a new selective insecticide for control of early-season infestations of green peach aphid in canola. ³⁸

A strategy to manage insecticide resistance in green peach aphid populations is available for use by grain growers and their advisers. The strategy may vary across regions and industries to be effective.

7.8 Rutherglen bugs

7.8.1 Description

Rutherglen bug adults (Figure 17) are 4 mm long, have clear wings folded flat on the back, are grey-brown-black in colour and are very mobile. Nymphs are smaller and have a pear-shaped, red-brown body (Figure 18). The coon bug, *Oxycarenus arctatus*, is similar to this pest except that its nymphs are red and it is not as abundant or as damaging; the green mirid (*Creontiades dilutus*) is also similar. ³⁹



Figure 17: Adult Rutherglen bug (Nysius vinitor).

P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/</u> pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf

³⁹ GRDC Ute Guide Rutherglen bug. GRDC, <u>https://www.grdc.com.au/Resources/Ute-Guides/Insects/Bugs/West/Rutherglen-Bug</u>



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Figure 18: Growth stages of Rutherglen bug: winged adult (top left), nymphs (right).

Rutherglen bug is best known as a seed-feeding pest, attacking grain as it develops and fills. However, in some seasons, large numbers of nymphs and adults can cause damage to establishing winter or summer crops. RGB populations can build up in summer weeds, and move from these into the establishing winter crop, feeding on and killing small seedlings. Large numbers of RGB moving out of canola stubble pose a threat to nearby establishing summer crop.

7.8.2 Impact

Infestation of canola during flowering and grainfill decreases yield, oil content and oil quality. Adults may also be a grain contaminant. Young crops may be retarded when large numbers are present on weeds after summer rains.

Seedlings can be damaged by RGB nymphs in seasons where large numbers of nymphs survive in weeds over summer, that is, mild summer with rainfall to promote weed hosts such as wireweed and marshmallow. Seedlings can be killed by sheer feeding pressure caused by nymphs moving from weeds on field edges. Young crops may be retarded when large numbers are present on weeds after summer rains. Seed treatments will not protect seedlings against this extreme pressure. Damage is often confined to field margins.

Adults migrate into fields from local weed hosts, or from sources more distant in spring. Infestations can be large and the period of invasion prolonged.

Adults and nymphs feed on growing tips, buds, flowers, pods and seed, causing flower abortion and reduced podset and seed development. Feeding directly on developing seed affects oil quantity and quality and seed viability.

RGB can persist into windrows, and at harvest cause problems with seed flow through harvesters and by raising the moisture content of the grain above acceptable standard.

7.8.3 Monitoring and thresholds

Canola should be checked during podding. Weeds that germinate with summer rains and persist into autumn can host large populations of bugs. All young crops should be checked, especially those sown into paddocks that had summer weeds.

Check the crop from flowering to harvest at weekly intervals. Inspect flower heads visually or shake heads into a bucket. Examine 20 heads at 5–10 locations within the crop.



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Distribution is typically patchy across the field, which means that the greater the number of samples taken, the greater the level of confidence in estimating the size of the infestation. In seasons with wet, mild summer and abundant weed growth, check weeds around the paddock that may be hosting RGB. In particular, wireweed is known to be a summer host. Capeweed is a common autumn–summer host for RGB.

Record the number of RGB adults and nymphs in each sample. Average the counts from across the paddock to get a field estimate of density. Note the presence of other pests and beneficials, crop stage, and proximity to maturity.

Thresholds for RGB are provisional: 10 adults or 20 nymphs per raceme at flowering– early podding. Higher numbers can be tolerated if moisture is not limiting.

7.8.4 Management

Cultural control

Control summer–autumn weeds around field edges and in fallows that may host RGB (e.g. wireweed). Invasion of RGB nymphs from weeds in autumn can be slowed by ploughing a deep furrow between the weeds and the crop, but the effectiveness of this approach remains uncertain.

At harvest, allow RGB to escape from open bins to reduce numbers in deliveries.

Pesticides

Repeated influxes of migrating adults can make repeat applications necessary. If spraying windrowed canola to control RGB, consider the WHP or chemical restrictions on spraying this late in the season.

The application of broad-spectrum insecticides in a strategic and targeted manner (e.g. spot or border spraying rather than whole-paddock applications) will help to avoid detrimental effects on natural enemies and maintain their contribution to the management of other pest species (e.g. aphids, DBM, *Helicoverpa*).

Natural enemies

The most commonly recorded beneficials attacking RGB are egg parasitoids wasps. Their major impact on RGB lies in reducing population size. They may have some impact on populations over summer or during winter, but have little capacity to control infestations in crops, particularly where infestations are driven by large influxes of adults. Little is known about the impact of predators, but spiders may be a predator of RGB.

Communication

Communication with agronomists and among growers should involve:

- management of weeds in proximity to canola crops (or paddocks where it will be sown) over summer and into autumn
- checking weeds in autumn to assess risk of RGB populations moving from weeds into seedling crops
- monitoring methods and frequency of checking, checking data over several weeks and what it means for management
- maintaining communication regarding influxes of RGB
- industry publications providing up-to-date regional information about pest activity in crops



Grains Research & Development Corporation



<u>cesar: PestNotes</u> <u>southern-Rutherglen</u> <u>bug</u>

IPM Guidelines: Rutherglen bug in canola

AOF: Insect pests of canola. Rutherglen bug (p. 5)

GRDC: Canola best practice management guide. Rutherglen bug (p. 58)

NIPI: Rutherglen bug in canola



7.9 *Helicoverpa punctigera* (native budworm)

7.9.1 Background

Native budworm is widely distributed throughout mainland Australia, and during winter, it breeds in semi-arid parts of South Australia and south-western Queensland. These vast inland areas are the sources of the moths that produce the spring generation of caterpillars. The moths are strong fliers and may be carried long distances by wind, to initiate infestations in localities far from where they developed as caterpillars.

The amount of damage caused by the native budworm and corn earworm varies considerably from year to year. Moth activity alone cannot be taken as a guide for spraying. In some years when moths are common, egg and caterpillar numbers are limited by adverse cool or cold, wet weather, parasitoids, predators and diseases, and damage may be restricted or insignificant. In other years, a relatively small moth population may produce many caterpillars and cause significant damage.

7.9.2 Description

Eggs

Budworm eggs can be found singly on the growing tips and buds of plants. Newly laid eggs are white or yellowish white, dome-shaped, flattened at the base, ribbed and 0.5 mm in diameter. They are visible to the naked eye on close inspection of the plant. Caterpillars hatch in 3–5 days in warm weather and 6–16 days in cooler weather.

Larvae and pupae

Newly hatched caterpillars (larvae) are 1–1.5 mm long with dark heads and dark-spotted white bodies. The newly hatched caterpillars are very small and are often easily missed when inspecting a crop. They will pass through six or seven growth stages or instars, until they are 35–40 mm long (Figure 19).

Young caterpillars up to about 15 mm long have dark heads and pale yellow, greenish or brownish bodies with conspicuous upper body hairs in dark bases and, often, narrow dark stripes down the back and along each side. Older caterpillars up to 50 mm long vary greatly in colour from yellow to almost black, often have a broad pale stripe along each side, and their upper body hairs are usually on raised processes, which makes the skin rough to touch (Figure 20).

Pupae are cigar-shaped, 12–22 mm long, and during development change in colour from a yellow-orange to a shiny dark brown.

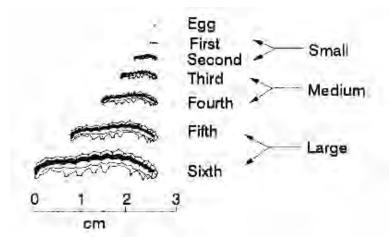


Figure 19: Approximate instar sizes of the native budworm (Helicoverpa punctigera).



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More

Agriculture Victoria:

Native budworm

information



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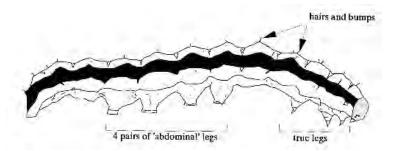


Figure 20: Distinguishable features of native budworm larva.

Adults

Adult moths are medium-sized (wingspan 30–40 mm) and stout-bodied. The forewings are buff-olive to red-brown with numerous dark spots and blotches. The hind wings are pale gray with dark veins and a dark band along the lower edge. Moths are usually active during the evening and night.

7.9.3 Importance

The native budworm is native to Australia and is distributed, particularly during spring, throughout much of the central and southern regions of the country. It is the major pest of all grain legumes (although pea weevil is equally important in field peas). It also attacks most oilseed crops, some vegetables, particularly tomato and sweet corn, and various pasture species such as clover and lucerne.

Before deciding control, it is important to be sure that the caterpillars are native budworm. For example:

- Corn earworm (or cotton bollworm) has a very similar appearance to native budworm, but rarely occurs in significant numbers in Victoria, SA and Southern NSW grain legume or oilseed crops. It is nonetheless an important pest when it does occur in large numbers, because it may be resistant to many of the commonly used insecticides. The most obvious distinguishing features are two small dark patches on the segments above the true legs.
- Diamondback moths are frequently misidentified as native budworm. They are most easily distinguished from budworm by the absence of stripes, and by their vigorous wiggling movement when touched.

7.9.4 Seasonal development and symptoms

Adult migration and feeding

A notable feature of this pest is its capacity to migrate at high altitudes over large distances (100–1000 km) each night. The moths fly from areas where conditions do not favour another generation to site of abundant food plants for further breeding. Recent research has shown that the species will breed rapidly on flowering plants in the arid inland (desert) regions of Queensland, South Australia, Western Australia and New South Wales during winter, provided there has been adequate winter rain.

Once the new generation of moths has emerged from these breeding grounds, they fly up into the warm northerly or north-westerly winds and migrate to the southern and eastern cropping regions during late winter and early spring. Hence, the moths encountered in southern crops during early spring almost certainly have their origins somewhere in the inland of Australia.

Moths live for 2–4 weeks; they rest during the day and become active after sunset, feeding on nectar from flowers and laying eggs on many types of plants (weeds and crops). They fly from plant to plant throughout the night, feeding and laying eggs. They are also capable of flying from paddock to paddock and even from one region to another.





Egg laying

Female moths will begin laying eggs within 3 days of emergence, placing them singly on flower buds, young pods, foliage and stems. The moths prefer the more advanced and succulent portions of crops for egg laying and usually avoid poorly grown areas. Each female can lay about 2000 eggs over several days.

Egg laying is usually confined to the period from flower-bud formation until flowering ends. When moths are exceptionally abundant, infestation can be expected before flowering commences. $^{\rm 40}$

Larval feeding and pupal development

After hatching, the larvae crawl around the plant, feeding from plant surfaces, particularly on tender tissue such as leaves, flowers or pods. They produce fine silken threads, which, with the aid of wind, may be used to distribute them from plant to plant. In some situations, such as adversely hot conditions, the small larvae may burrow straight into pods and seeds. However, they mostly graze on plant surfaces until they grow to 8–12 mm in length, when pod burrowing usually occurs. The larvae complete their development in 3–6 weeks (closer to 3 weeks during warm weather).

Fully grown larvae move off the plants and burrow in the soil from 20 to 150 mm in depth. They build chambers in which the pupae form. The pupal stage lasts about 2 weeks during spring. Late spring or summer pupae may enter a prolonged resting stage in the soil and not emerge until the following season.

7.9.5 Impact

The most notable damage by native budworm is on the pods and seeds. In most situations, pod attack commences with medium-sized larvae entering pods and eating all or part of the seed between pods. Small larvae generally do not enter pods, but 'graze' on the pod and leaf surfaces. Occasionally, the small larvae may enter the pods and remain inside for several days, particularly when conditions are hot and windy after egg hatch. These larvae remain protected from insecticides until they re-emerge. Hence, crop monitoring should include pod inspections.

Larvae will also attack growth points, but this is unlikely to cause major yield losses in grain legumes and oilseeds. Continual monitoring is warranted when high populations exist during early flowering.

7.9.6 Monitoring

Two sampling methods should be used to assess caterpillar numbers:

 Measure numbers on the crop using a sweep net or a beating tray or sheet (a white sheet or tray slid under the vines and shaken to dislodge the caterpillars).

Sampling should commence at early podding. Take a minimum of 5 sets of 10 sweeps. A single sweep of a net should cover an arc of 180° from one side of the sweeper's body to the other. The net should pass through the crop with the net tilted such that the lower lip travels through the crop marginally before the upper lip.

Each set of sweeps should be performed in a different, representative area of the crop. This will provide a more comprehensive estimate of native budworm numbers throughout the crop, avoiding local variations in larval numbers. Local variations (or hot spots) are a common feature of budworm distribution. After completing the sets of sweeps, counts should be averaged to give an overall estimate of abundance.



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⁴⁰ K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0005/284576/</u> <u>Insect-and-mite-control-in-field-crops-2013.pdf</u>



7.9.7 Management

Natural control

Surprisingly high levels of mortality of eggs and caterpillars exist in most situations. The presence of large numbers of moths does not necessarily result in significant crop damage; well over 90% of all eggs and young larvae may die without causing any damage. Eggs and larvae will die if they are dislodged from the plant by wind or rain, or if they are attacked by predators (such as spiders, carabid beetles or predatory bugs), parasites (wasps and flies) or diseases.

The most important natural enemies appear to be the parasites: tachinid flies, the larvae of which parasitise native budworm; and the egg parasite *Trichogramma ivalae*, a minute wasp. The extent of parasitism of native budworm eggs varies from year to year; in grain legumes, it has been measured as high as 60% and low as 5%. However, this egg parasitoid can reduce egg numbers by as much as 90%.

Decision to spray

Spray when caterpillar numbers are at or above the spray threshold. Comprehensive and dynamic economic thresholds have been developed for native budworm in Western Australia, which should also apply to south-eastern Australia. ^{41,42} Note that these methods do not detect caterpillars inside the pod.

Usually, a range for rates is presented on the insecticide label to allow for varying conditions, such as size of caterpillar. Read the label.

Before deciding to spray, consider the following:

- · likely extent and severity of the infestation
- ability of the crop to tolerate caterpillar damage without any significant loss or to replace leaves or fruiting parts lost to the caterpillars
- · value or likely loss if the crop is left untreated
- cost of treatment ⁴³

7.10 Snails

Snail numbers can explode in seasons with wet springs, summers.

As a rule of thumb, if snail numbers are $>5/m^2$ in pulses and oilseeds, grain contamination is likely at harvest. Use header modifications and grain cleaning to eliminate snail contamination of grain.

Snails appear to build up most rapidly in canola, field peas and beans. However, they can feed and multiply in all crops and pastures. Baiting before egg laying is therefore vital. Timing and choice of controls will depend on the season. Baiting should be ceased 8 weeks before harvest to avoid bait contamination in grain.

Understand the factors that determine effectiveness of control. Monitor snails regularly to establish numbers, types, activity and success of controls. To control snails, you will need to apply a combination of treatments throughout the year.

7.10.1 Description

Snails are a mollusc with a rasping tongue and one single muscular 'foot' for movement. Much of their body is encased in a shell, which they secrete as they grow.



GRDC Fact Sheets: Snail management

GRDC Ground Cover: Paddock snapshots inform slug and snail control



⁴¹ G McDonald. Native budworm. PestNotes southern. **cesar**, <u>http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Native-budworm</u>

P Mangano, S Micic. Management and economic thresholds for native budworm. DAFWA, <u>https://www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm?page=0%2C0</u>

⁴³ G McDonald (1995) Native budworm. Agriculture Victoria, DEDJTR, <u>http://agriculture.vic.gov.au/agriculture/</u> pests-diseases-and-weeds/pest-insects-and-mites/?a=223411





AOF: Pointed or conical (Cochlicella acuta) and small pointed (Cochlicella barbara) snails

<u>GRDC: Canola best</u> practice management guide. Snails (p. 52)

GRDC Fact Sheets: Snail management

NIPI: Snails in seedling crops

NIPI: I Spy Manual. Snails (section 4, pp. 65–70)



<u>NIPI: Pests in canola.</u> <u>Mandalotus weevil in</u> <u>canola</u>

NIPI: IPM Guidelines. False wireworms in canola/

NIPI: IPM Guidelines. Soil insects

7.10.2 Symptoms

Snails consume cotyledons and this may resemble crop failure. Shredded leaves, chewed leaf margins, and irregular holes all occur as a direct result of feeding damage by snails.

7.10.3 Impact

Snails can cause damage to emerging canola seedlings, but are predominantly a grain or seed contaminant. The small pointed snail (*Cochlicella barbara*) is especially hard to screen from canola due to similar size.

7.10.4 Control

Free-living nematodes carrying bacteria that cause snail death may help to reduce populations under certain field conditions. Hard grazing of stubbles, cabling and/or rolling of stubbles, stubble burning, cultivation, and removal of summer weeds and volunteers are all effective management options. Molluscicidal baits are effective on mature snails, and IPM-compatible, but can be less effective on juveniles.⁴⁴

7.11 Soil pests

Several soil-dwelling insect pests such as cutworms, wireworms, bronzed field beetle, cockchafers and false wireworms have caused damage to emerging canola seedlings in recent years. In severe cases, plant stands can be thinned to such an extent that the paddock requires re-sowing. Occurrence of these pests is difficult to predict, so advice on their control should be sought prior to sowing if any problems are foreseen. The most severe damage tends to occur in crops following pasture, or if stubble has been retained.⁴⁵

7.11.1 Wireworms and false wireworms

Importance

Wireworms and false wireworms are common, soil-inhabiting pests of newly sown winter and summer crops. Wireworms are the larvae of several species of Australian native beetles, which are commonly called 'click beetles', from the family Elateridae.

False wireworms are also the larval form of adult beetles, some of which are known as 'pie-dish beetles', which belong to another family (Tenebrionidae), and have distinctively different forms and behaviour. Both groups inhabit native grassland and improved pastures, where they cause little damage. However, cultivation and fallow decimates their food supply, and hence, any new seedlings that grow may be attacked and sometimes destroyed. They attack the seedlings at pre- and post-emergence of all oilseeds, grain legumes and cereals, particularly in light, draining soils with a high organic content. Fine seedling crops such as canola and Linola are most susceptible.

The incidence of damage caused by wireworms and false wireworms appears to be increasing with increasing use of minimum tillage and short fallow periods.

7.11.2 False wireworms

In crops, they are mostly found in paddocks with high contents of stubble and crop litter. They may affect all winter-sown crops.

Description

There are many and varied species of false wireworm, but they share some general characteristics. Larvae are cylindrical, hard-bodied, fast-moving, golden brown to black-brown or grey with pointed upturned tails or a pair of prominent spines on the last



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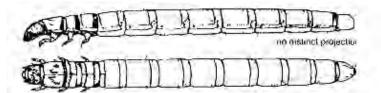
CropPro. Snails. Pests in canola. CropPro, <u>http://www.croppro.com.au/cb_pages/pests_in_canola__in_crop.php?category_id=2382</u>

⁴⁵ P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/_pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>

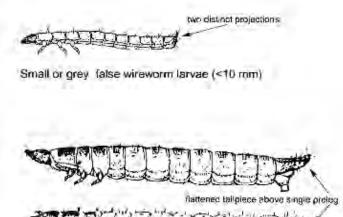


body segment. Several common groups (genera) of false wireworms are found in southeastern Australia:

- The grey or small false wireworm (*Isopteron* (*Cestrinus*) *punctatissimus*). The larvae grow to ~9 mm in length. They are grey-green, have two distinct protrusions from the last abdominal (tail) segment (Figure 21), and tend to have a glossy or shiny exterior. Hence, they are most easily recognised in the soil on sunny days, when their bodies are reflective. The adults are slender, dark brown and grow to ~8 mm in length. The eggs are <1 mm in diameter. There are several species of this pest genus, although *I. punctatissimus* appears to be the species most associated with damage.
- The large or eastern false wireworm (*Pterohelaeus* spp.). These are the largest group of false wireworms. They are the most conspicuous in the soil and grow up to 50 mm in length. They are light cream to tan in colour, with tan or brown rings around each body segment, giving the appearance of bands around each segment (Figure 21). The last abdominal segment has no obvious protrusions, although under a microscope, there are a number of distinct hairs. Adults are large, conspicuous and often almost ovoid beetles with black, shiny bodies (Figure 22).
- The southern false wireworm (Gonocephalum spp.) grows to ~20 mm in length, and has body colours and marking similar to the large false wireworm. Adults are generally dark brown-grey, oval beetles, which sometimes have a coating of soil on the body. Adults have the edges of the body flanged, hence the common name pie-dish beetles.
- The bronzed field beetle (*Adelium brevicorne*) are shiny dark brown, grow to 12 mm long, and are cylindrical with two distinct, upturned spines on the end of the body. Adults are shiny black with a slight bronze appearance, grow to 11 mm long and are present from spring to autumn. There is one generation per year.



Eastern false wireworm larvae (<50 mm)



True wireworm larvae

Figure 21: Two common false wireworm larvae and a 'generalised' true wireworm larva.



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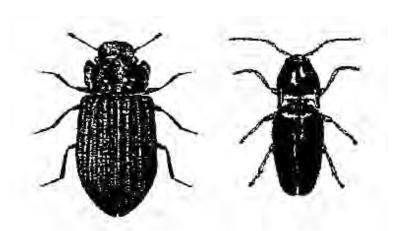


Figure 22: The adult (beetles) of the false wireworm (left) and true wireworm (right). ⁴⁶

Seasonal development and symptoms

Larvae of most false wireworm species prefer to feed on decaying stubble and soil organic matter. When the soil is reasonably moist, the larvae are likely to aggregate in the top 10–20 mm where the plant litter is amassed. When the soil dries, the larvae move down through the soil profile, remaining in or close to the subsoil moisture, and occasionally venturing back to the soil surface to feed. Feeding is often at night when the soil surface becomes dampened by dew.

Nothing is known of the conditions that trigger the switch in the feeding of false wireworms from organic matter and litter to plants. Significant damage is, however, likely to be associated with soils that remain dry for extensive periods. Larvae are likely to stop feeding on organic matter when it dries out, and when the crop plants provide the most accessible source of moisture.

Impact

Affected crops may develop bare patches, which can be large enough to require resowing. Damage is usually greatest when crop growth is slow in cold, wet conditions.

The larvae of the small false wireworm are mostly found damaging canola and other fine seedling crops shortly after germination. They feed on the hypocotyl (seedling stem) at or just below the soil surface. This causes the stem to be 'ring-barked', and eventually the seedling may be lopped off or it wilts under warm conditions. Larger seedlings (e.g. grain legumes) may also be attacked, but the larvae appear to be too small to cause significant seedling damage.

The larger false wireworms can cause damage to most field crops. The larvae can hollow out germinating seed, sever the underground parts of young plants, or attack the aboveground hypocotyl or cotyledons. In summer, adult beetles may also chew off young sunflower seedlings at ground level. Damage is most severe in crops sown into dry seedbeds, and if germination is slowed by continued dry weather.

G McDonald (1995) Wireworms and false wireworms. Agriculture Victoria, DEDJT, <u>http://agriculture.vic.gov.</u> au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/wireworms-and-false-wireworms



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Sampling and detection

The principles for detection and control of false and true wireworms are generally similar, although different species may respond slightly differently according to soil conditions.

Crops should be sampled immediately before sowing. Two methods are available, although neither is 100% reliable. This is because larvae change their behaviour according to soil conditions, particularly soil moisture and temperature:

- Soil sampling. Take a minimum of five random samples from the paddock. Each sample should consist of the top 20 mm of an area of soil 0.50 m by 0.50 m. Carefully inspect the soil for larvae. Calculate the average density per m² by multiplying the average number of larvae found in the samples by 4. Control should be considered if the average exceeds 10 small false wireworm, or 10 of the larger false wireworms.
- 2. Seed baits. Seed baits have been used successfully to sample true and false wireworms in Queensland and overseas but they have not been rigorously tested in Victoria. Preliminary work indicates that they can be used to determine the species of larvae present, and give an approximate indication of density. Presoak ~200–300 g of a large seed bait, such as that of any grain legume, for 24 h. Select 5–10 sites in the paddock, place a handful of the soaked seed into a shallow hole (50 mm), and then cover with about 10 mm of soil. Mark each hole with a stake, and re-excavate after ~7 days. Inspect the seed and surrounding soil for false wireworm larvae. This technique is most likely to be successful when there is some moisture within the top 100 mm of soil.

Control

Crop residues and weedy summer fallows favour survival of larvae and oversummering adult beetles. Clean cultivation over summer will starve adults and larvae by exposing them to hot dry conditions, thus preventing population increases. Suitable crop rotations may also limit increases in populations.

If damage occurs after sowing, no treatment is available, other than resowing bare patches with an insecticide treatment.

7.11.3 True wireworms

These slow moving larvae tend to be less common, although always present, in broadacre cropping regions and are generally associated with wetter soils than is the case for false wireworms.

Description

Larvae grow to 15–40 mm, are soft-bodied, flattened and slow moving. This distinguishes them from false wireworms, which are hard bodied, cylindrical and fast moving. Their colour ranges from creamy yellow in the most common species to red brown; their head is dark brown and wedge-shaped. The tailpiece is characteristically flattened and it has serrated edges (Figure 21). Adults are known as click beetles, because of their habit of springing into the air with a loud click when placed on their backs. They are dark brown, elongated and 9–13 mm long (Figure 22).

Seasonal development and symptoms

There may be one generation or several per year, depending on species. Most damage occurs from April to August and adults emerge in spring. True wireworms prefer low-lying, poorly drained paddocks and are less common in dry soils. Larvae are quite mobile through the soil and they will attack successive seedlings as they emerge. Adults are typically found in summer and autumn in bark, under wood stacks or flying around lights.

Adult click beetles emerge in spring and summer, mate and lay eggs, and then may spend a winter sheltering under the bark of trees. The connection between trees and





adult beetles may explain why damage is often, but not always, most pronounced on tree lines. True wireworms have a long life in the soil and are active all year, even in winter.

Impact

The damage caused by true wireworms is similar to that of false wireworms, except that most damage is restricted to below the soil surface. Larvae eat the contents of germinating seed, and underground stems of establishing plants, causing wilting and death.

Sampling, detection and control

See above discussion on false wireworm for full details. Wireworms and false wireworms can be controlled only if they are detected in the seedbed before sowing. Insecticide can be applied to the soil with fertiliser, or seed can be treated.

7.11.4 Weevils

In canola and related Brassica crops, common weevil pests include: vegetable, Mandalotus, small lucerne, Fuller's rose, grey-banded leaf, and spotted vegetable (or Desiantha) weevils (Table 5, Figure 23). Both adults and larvae of these species are capable of causing damage to canola.

Weevils are a diverse group of beetles that are commonly found in Australian grain crops. Adult weevils appear very different to the larvae. Adults have a hardened body, six prominent legs and an elongated, downward curved head forming a 'snout'. The larvae are legless, maggot-like in shape and may be confused with fly larvae. Weevil larvae possess a small, hardened head capsule. Crop weevils feed on vegetative parts of crop plants including the roots, stems, shoots, buds and leaves. Both adults and larvae can be damaging to plants, depending on the species, crop type and time of year. Typical feeding damage commonly observed is scallop-shaped holes along the edges of leaves. Weevils can be difficult to control with chemicals due to their secretive habits. Several species are also patchy in their distribution within paddocks. For some species, seed treatments and foliar insecticides can provide a level of control. Weevils are typically favoured by minimum tillage and stubble retention. Cultivation, burning and reducing the amount of stubble will reduce the suitable habitat for weevils and reduce their number. Identification of crop weevils is important when making control decisions. The distinctive appearance of weevils makes them unlikely to be confused with other beetles. However, distinguishing between the many species of weevil is challenging. This guide is designed to assist growers in identifying the most commonly observed weevils found in the southern and western cropping regions.47

Weevil damage can occur at any time of the season, but feeding during autumn and early winter is typically the most critical. Inspect paddocks and nearby weeds prior to sowing and monitor crops for signs of seedling damage and bare patches within paddocks. Look for signs of chewing damage on plants, often characterised by scallopshaped holes along the leaf margins, ring-barking of seedlings, as well as a loss of plant vigour. Searches may need to be undertaken during the night. This is when weevils are most active.

Weevils, particularly larvae, can be difficult to control with chemicals because of their subterranean habits, so they remain protected from insecticide exposure. Exceptions are the vegetable and grey-banded leaf weevils, whose larvae also feed on foliage. A limited number of registered products are available for the active stages of several weevil species. Reports suggest that canola paddocks sown with fipronil-treated seed experience less feeding damage from weevils.⁴⁸

48 cesar. Weevil pests. PestFacts south-eastern, issue 2, May 2015, <u>http://www.cesaraustralia.com/</u> sustainable-agriculture/pestfacts-south-eastern/past-issues/2015/pestfacts-issue-no-2-22nd-may-2015/ weevil-pests/



http://www.grdc. com.au/GRDC-BPG-CropWeevils



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⁴⁷ <u>http://www.grdc.com.au/GRDC-BPG-CropWeevils</u>

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Table 5: Description of common weevil species

Weevil species	Adult length (mm)	Distinctive features of adult weevils	Larval head capsule colour
Fuller's rose	8	Yellow/grey stripe on thorax and also abdomen	Light
Grey-banded leaf	8	Pale band on rear of abdomen	Dark
Mandalotus	3-5	Dull brown, paddle-shaped bristles; short snout	Yellow/brown
Sitona	5	3 white strips on thorax; broad snout	Brown
Small lucerne	7	Less distinct lateral stripes than whitefringed	Light
Spinetailes	7	WIng covers taper to spine (females); longer snout	Yellow
Spotted vegetable	5-7	Mottled/specked; longer snouth	Brown
Whitefringed	10-15	Light lateral stripes	Light
Vegetable	10	Light coloured 'V' at rear of abdomen	Brown



Figure 23: Small lucerne weevil (left) and Fuller's rose weevil (right). (Source: cesar)

7.11.5 Earwigs

There are increasing reports of European earwigs (*Forficula auricularia*) causing significant damage to emerging crops. Stubble retention, in combination with wet springs and summers and an early autumn break, appear to favour the buildup of these insects. The damage caused by earwigs can be difficult to identify, and because control can also be difficult, growers should seek advice if they suspect or see earwigs.⁴⁹

Correctly identifying earwig species is important because they have different roles as pests or beneficial species. Not all earwigs found in crop paddocks are pests (Figure 24). Although European earwigs are renowned as pests, other earwigs can be benign or beneficial.

Other common earwig species include:

• Common brown earwig, *Labidura truncata*, which is a native and beneficial species. They are mostly red-brown in colour and range from 10 to 45 mm in length. This species is most common in sandy habitats but occurs across southern Australia and mainly feeds on soft-bodied insects such as caterpillars, lucerne flea and mites.



eastern. Weevil pests



European Earwigs



P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/</u> pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf



It can be distinguished by an orange triangle behind its head on the elytra (wing cases). Males have long slender forceps with a distinctive tooth near the middle of the inner edge.

- Black field earwig, Nala lividipes, which is a minor pest species of broadacre agriculture, only occasionally attacking crops. They are smaller, at about 15 mm long, shiny black, and can be a pest of seeds and seedlings. Adults have wings and can fly; nymphs resemble adults but are wingless. The black field earwig is omnivorous, meaning they can be a pest and a predator. They are known to attack wheat, sorghum, maize and sunflowers. They eat newly sown and germinating seeds and the roots of crops, resulting in poor establishment. Black field earwigs prey upon a range of insects, including wireworms and Helicoverpa spp.
- *Euborellia* spp. are small, dark-coloured earwigs ranging from 10 to 25 mm in size. There are many subspecies, and they can be difficult to distinguish. They are flightless and appear to form mating pairs that maintain a small territory. Male and females will often be found together and, at times, with a brood of young earwigs. Early research has indicated they may not be plant feeders and are likely to be more predatory.



Figure 24: Top left: European earwig, Forficula auricularia—a pest species. Top right: common brown earwig, Labidura truncata—a native and predatory species. Bottom left: black field earwig, Nala lividipes—a predatory species and minor pest. Bottom right: Euborellia earwig—native and predatory species. (Photos: Denis Crawford, GRAPHIC SCIENCE)

Seasonal development

European earwigs complete one generation per year, although females can produce two broods in some years. They can survive in a range of environments and the length of their life cycle depends on temperature. At 25°C, development from egg to adult takes 9–10 weeks but at 15°C it takes up to 5 weeks longer. In winter, adult females lay batches of 20–80 white oval eggs in burrows in the topsoil, which hatch in 2–3 weeks.

In some years, under favourable environmental conditions, earwigs may lay eggs in late spring to produce a second summer brood. There are several nymphal instars (stages between moults). Female earwigs remain in the burrow, protecting the eggs and nymphs.

Impact

European earwigs mainly attack canola but will also attack cereals, lupins and some legume crops. Damage can be scattered because of their patchy distribution. Earwigs





chew the stems and cotyledons of emerging seedlings, killing plants or slowing plant development. As the plant grows, foliar damage includes shredded leaf tips and jagged holes in leaves.

Earwigs can completely defoliate young seedlings leaving only stems or bare ground in patches. They can also chew through seedpods. Earwigs feed together at night, and in many cases, damage will start along the edges of a paddock. Earwig damage to plant leaves closely resembles feeding damage caused by slugs. Damage has been reported mainly in the medium- and high-rainfall zones including South Australia's Mid North and South East regions, Victoria's Western Districts and the South West Slopes of New South Wales. Nearly all cases of damage have occurred in paddocks where minimum or no-till practices were used with high stubble loads, and often on heavier soils.

Management-windrowing and harvesting

Grain with high numbers of earwigs may require cleaning to meet delivery standards. Trials have shown that earwigs are more likely to be found sheltering under windrowed crops than in standing crops. If windrows are harvested during the heat of the day, the number of earwigs found in the grain is not significantly different from that in a standing crop. During the hottest part of the day, the earwigs remain on the soil surface under the windrows. At night, earwigs move out from under the windrow into the top of the windrow. As a result, grain harvested at night is more likely to contain earwigs and require cleaning.

When windrowing crops, maintain the correct windrow height, ensuring that the swath remains above the ground. If windrows are sitting close to, or are on, the ground, earwigs are more likely to be harvested with the grain. If these windrows are harvested using crop lifters, there will be significantly more invertebrates, such as earwigs, present in the harvested grain than in grain harvested using a belt pick-up front.

Monitoring

It is important to distinguish earwig species in order to make the most appropriate management decision and accurately assess the risk of attack to emerging crop seedlings. Native earwig species can have an important role in IPM and in the control of other insects. Monitoring for earwigs is best conducted at night, using a torch, because they are nocturnal feeders.

Another approach is to set pitfall traps—a small plastic cup buried flush in the soil. A small amount of liquid in the bottom will help to contain the insects that fall into the trap. Traps should be left for at least 24 h and are useful for catching invertebrates.

7.11.6 Black Portuguese millipedes

In the last 5–10 years, the black Portuguese millipede (*Ommatoiulus moreleti*) has been emerging as a sporadic but damaging pest of broadacre agriculture, particularly canola.

The increase has been linked to stubble retention, no-till farming practices and improvements in soil organic matter, which have provided a more favourable habitat for millipedes to survive and reproduce. Recent wet summers have contributed to a population buildup in some parts of southern Australia, and planting of more vulnerable crops has led to increased damage.

The black Portuguese millipede is native to Europe and has been accidentally introduced to other countries, including Australia, where it is now common across south-eastern Australia.



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Figure 25: Black Portuguese millipedes (Ommatoiulus moreleti) generally feed on organic matter; however, their populations and the incidence of crop attack have increased in recent years. (Left photo: © NICK MONAGHAN, LIFEUNSEEN.COM; right photo: © WA Agriculture Authority)

Description

The smooth, cylindrical body of the black Portuguese millipede (Figure 25) distinguishes it from other native species, which often have rougher and more uneven bodies. They are part of the same family as several native Australian millipedes and centipedes, called myriapods, meaning 'many-legged'. Measuring 30–45 mm, adult millipede bodies consist of up to 50 segments with each segment having two pairs of legs. When disturbed, they either curl up in a tight spiral or thrash to escape.

Native millipedes are widespread in low numbers but black Portuguese millipedes are found in large numbers and are quite mobile for their size, especially after opening autumn rains. They can move several hundred metres in a year.

They are transported between properties and to new regions in plant material, infested soil and farm machinery. $^{\rm 50}$

Seasonal development and symptoms

Black Portuguese millipedes start mating in March and April and lay most of their eggs in April and May. Mature females lay about 200 yellowish-white eggs the size of a pinhead, in a small hole they make in the soil.

An immobile, legless stage hatches from each egg and develops into the first active stage of the life cycle after about 7 days (Figure 26). This first stage has only three pairs of legs. Millipedes grow through a series of moults. At each moult, the millipede adds more legs and body segments until it is mature.

During the first year of life, millipedes are quite small and easily overlooked. After the first year, juveniles reach the seventh, eighth or ninth stage of development and they will be about 1.5 cm long. After this, they moult only in spring and summer.

During moulting, millipedes are vulnerable because the new cuticle (outside skin layer) is soft and easily damaged. Black Portuguese millipedes usually mature after 2 years when they are in the tenth or eleventh stage of growth.

Millipedes feed on leaf litter, damp and decaying wood, fungus and vegetable matter such as tender roots, mosses, pollen or green leaves on the ground. They can play a role breaking down organic matter in the soil. As a result, they occur in greater numbers in undisturbed leaf litter and organic mulch and in areas where winter weeds, such as sour sobs and Salvation Jane, form a mostly continuous ground cover. Millipedes are not numerous in cultivated areas or bare ground.



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GRDC (2013) Millipedes and slaters in no-till systems. GRDC Black Portuguese millipedes and slaters Fact Sheet, October 2013, <u>http://www.grdc.com.au/GRDC-FS-Millipedes-Slaters</u>

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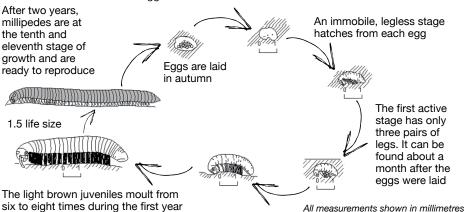


Figure 26: Life cycle of black Portuguese millipede.

Impact

Because black Portuguese millipedes generally feed on organic matter, crop feeding damage is relatively rare. Black Portuguese millipedes occasionally attack living plants by chewing the leaves and stems. It has been suggested that they feed on crop plants when they are seeking moisture, but this has not been confirmed.

Most of the reported damage has occurred in emerging canola crops on black organic soils with heavy stubble loads, but damage has also been observed on lighter soils.

In canola, millipedes remove irregular sections from the leaves and can kill whole plants if damage is severe. Damage to cereals can also occur where the stems of young plants are chewed (Figure 27).

In the southern region, damage has been reported in the medium- and high-rainfall zones including near Wagga Wagga and Henty in New South Wales; the Mid North, Yorke Peninsula and Kangaroo Island in South Australia; and the Western Districts and Wimmera areas of Victoria. In many cases, damage has been worst in areas with high volumes of retained stubble or where plant matter from the previous year was present.

The presence of black Portuguese millipedes does not always mean damage. In many instances, no damage has occurred despite large millipede populations. Millipedes are mostly active and feed at night, which is the best time to check whether they are causing damage to canola plants. ⁵¹



Figure 27: Seedling damage from millipedes. (Photo: K Perry, SARDI)

GRDC (2013) Millipedes and slaters in no-till systems. GRDC Black Portuguese millipedes and slaters Fact Sheet, October 2013, http://www.grdc.com.au/GRDC-FS-Millipedes-Slaters



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Management

Control options for millipedes are limited but some measures will curb populations. There are no insecticides registered to control millipedes in broadacre agriculture.

Cultural

Reducing the amount of trash and stubble over summer and early autumn is likely to be the most effective way to reduce millipede numbers. Other factors to consider in management of crops and rotations include:

- Canola sown into paddocks with high organic matter has a greater risk of millipede damage.
- Burning stubbles may reduce millipede populations.
- Early sowing of high-vigour varieties at a higher seeding rate will help to compensate for seedling losses from pest damage.

Biological

Millipedes have very few natural predators. Their bodies contain rows of glands that secrete a pungent yellowish fluid when they are agitated, and this fluid makes millipedes distasteful to predators such as birds.

A parasitic native nematode, *Rhabditis necromena*, attacks and kills millipedes by reproducing in the millipede's gut. However, the use of nematodes is unlikely to be economically viable for broadacre crop release.

Some spiders and beetles will eat millipedes but these predators will not significantly reduce large populations.

7.11.7 Slaters

Slaters perform an important recycling role in the environment. However, native and introduced slaters have become an increasing pest of broadacre crops and pastures. The move to minimum or no-tillage and stubble retention is likely to have created a more favourable environment in cropping paddocks for slaters. Stubble provides a cool, moist habitat, while crumbly clay soil surfaces and cracking clays aid their survival.

Description and development

Slaters are also known as woodlice, sowbugs and pill bugs. They are crustaceans, related to crabs, lobsters and prawns but are adapted to living on land. They have a hard skeleton on the outside of their bodies, seven pairs of jointed legs, and two pairs of antennae (Figure 28).

Most slaters are detritivores, meaning they feed on decaying vegetation and associated fungi, as well as on dead animal matter such as insects. They can eat living plants, such as seedlings and root vegetables, but only rarely.

Slaters need damp conditions and they will die if exposed to open and dry situations. They tend to be active at night when the risk of dehydration is low.

Female slaters keep their eggs in a pouch until the young hatch. Hatchlings then leave the parent and are completely independent. Slaters grow through a series of moults in which the outer rigid skeleton is shed, allowing growth to the next larger stage and finally to adult stage. When moulting, slaters shed in two stages: the top half of their body first, followed by the remaining half 2 days later. During moulting, the slater is very vulnerable and must find shelter. ⁵²

GRDC (2013) Millipedes and slaters in no-till systems. GRDC Black Portuguese millipedes and slaters Fact Sheet, October 2013, http://www.grdc.com.au/GRDC-FS-Millipedes-Slaters



GRDC Fact Sheet: Millipedes and slaters







Figure 28: Like black Portuguese millipedes, slaters generally feed on organic matter, and their populations and the incidence of crop attack have increased in recent years. (Photo: © NICK MONAGHAN, LIFEUNSEEN.COM)

Species

Several slater species are found in Australia including:

- Common slater (*Porcellio scaber*). Originally introduced from Europe, the species is widespread in Australia. The common slater can grow up to 20 mm in length and is usually pale grey; however, brown, yellow or orange hues have been observed.
- Pill bug (*Armadillidium vulgare*). This is also a European species, introduced to Australia, and gets its name from its ability to roll into a ball when disturbed. It can grow up to 18 mm and is dark brown to black.
- Flood bug (Australiodillo bifrons). Populations of flood bugs have increased in
 parts of New South Wales. The flood bug is ~7–8 mm long and 4 mm wide with an
 oval-shaped and flattened body, light brown, with darker irregular spots and a darkbrown stripe down the middle of the back. It is a lowland, swampy-soil species.
 Areas worst affected in the past by flood bugs are prone to flooding (Figure 29).







Figure 29: Top left: common slater (Porcellio scaber). Top right: pill bug (Armadillidium vulgare); when moulting, slaters shed in two stages—the top half of their body first followed by the remaining half two days later. Bottom: flood bug (Australiodillo bifrons). (Photos: © NICK MONAGHAN, LIFEUNSEEN.COM)



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Symptoms

Little is known about the biology of slaters and their potential to become a widespread agricultural pest in Australia.

Slaters can cause significant feeding damage, particularly on canola, leading to seedling mortality and stunted plant growth. In some situations, crops or parts of paddocks may need to be re-sown. Often, symptoms resemble feeding damage caused by lucerne flea.

Slater feeding on plants results in an uneven, rasping-type damage that can appear similar to slug and snail damage. They can chew the tops of emerging cotyledons or leaves of crop seedlings, leaving only the seedling stumps.

The flood bug in particular has potential to cause rapid damage to crops because of its ability to swarm. A consistent mass of slaters moves along the soil surface, climbing trees or moving into logs or posts (Figure 30). Swarms can contain >100,000 individuals, sometimes up to 1,000,000, and include all life stages, from juveniles to adults.

The size of swarms varies and is likely to be influenced by the time of day, weather conditions and surrounding vegetation. Thousands of seedlings can be eaten in a very short time when swarms are large enough.

Impact

It is uncommon for slaters to attack broadacre crops; however, problems with slaters have increased considerably in the last 5 years. In south-eastern Australia, slaters have caused damage to wheat, oats, canola, lentils and pastures.

The presence of slaters, even in high numbers, in a paddock does not always mean crop damage will occur, because slaters generally feed on decaying organic matter. Feeding on emerging crop seedlings is relatively rare. It is not known what makes slaters suddenly prefer to eat seedlings rather than organic matter.

In south-eastern Australia, damage has been reported in the medium- and high-rainfall zones including South Australia's Mid North and Yorke Peninsula, Victoria's Wimmera and Western Districts, and central New South Wales. In many cases (but not all) damage has been reported where there was an accumulation of stubble or other plant matter, or cracked soils.⁵³

Management

Management options are limited after crop emergence, so prevention is a key part of control. No insecticides are registered to control slaters. Slaters are relatively unaffected by many foliar applications of synthetic pyrethroids and organophosphates to control other crop-establishment pests, even when applied at very high rates.

Managing stubble is likely to be the most effective strategy to reduce slater numbers. Some growers have had success managing slaters ahead of canola rotations by burning crop residues.

GRDC (2013) Millipedes and slaters in no-till systems. GRDC Black Portuguese millipedes and slaters Fact Sheet, October 2013, http://www.grdc.com.au/GRDC-FS-Millipedes-Slaters



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GRDC Fact Sheets: Millipedes and slaters

Figure 30: Typical swarming behaviour of flood bug (Australiodillo bifrons) moving across a wheat paddock. (Photo:: A Weeks, **cesar**)



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SECTION 8

Nematode management

8.1 Cereal cyst nematodes

Only one race of cereal cyst nematode (CCN), *Heterodera avenae*, occurs in Australia and it causes cereal crop damage in South Australia, Southern NSW, Victoria and Western Australia.

Canola is a valuable break crop for CCN which affects wheat, barley, oat and triticale varieties and can cause yield loss of up to 80% in intolerant varieties.

Where CCN levels are moderate to high the best choice is two years of resistant and tolerant cereal or non-host crops such as canola.

While two years is generally accepted to reduce CCN to low levels, exceptions do occur. Monitoring paddocks and the use of diagnostic services to check CCN levels is encouraged. Less than five eggs per gram of soil can produce yield loss for intolerant cereals.

Key management strategies:

- Choose varieties with high resistance ratings, which result in fewer nematodes remaining in the soil to infect subsequent crops.
- Reducing RLN and CCN can lead to higher yields in following cereal crops.
- Healthy soils and good nutrition can, to some extent, ameliorate RLN and CCN damage through good crop establishment, and healthier plants recover more readily from infestation.
- Observe crop roots to monitor development of symptoms.
- Weeds can host parasitic nematodes and control of host weed species and crop volunteers is important.



GRDC Podcast

GRDC Fact Sheet: Managing cereal cyst and root lesion nematodes



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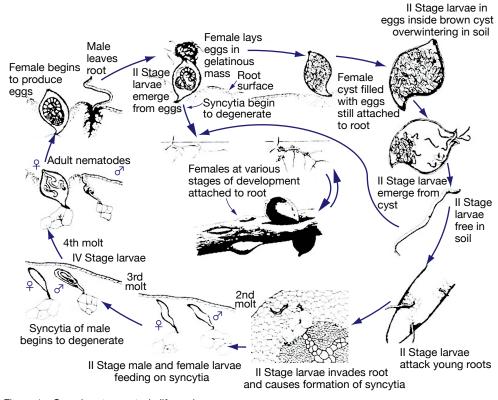




Figure 1: Cereal cyst nematode life cycle.

CCN has one life cycle per season (Figure 1) whereas RLN is polycyclic with three to five generations per year.

8.2 Root-lesion nematodes

Root-lesion nematodes (RLN) can have an impact on canola growth (Figure 2). However, following harvest, levels of the RLN *Pratylenchus neglectus (Pn)* have been found to decline rapidly, due to the release of isothiocyanates from the decomposing root tissue. Sulfur-deficient or stressed crops are more likely to host increasing nematode numbers during the season and have less effect on their decline at the end of the season.¹

The hosting ability of canola is low-medium for *P. thornei* (*Pt*) and medium-high for *Pn*.

Testing soil is the only reliable way to determine whether RLN are present in a paddock. Before planting, soil tests can be carried out by <u>PreDicta B</u> (SARDI Diagnostic Services) through accredited agronomists to establish whether crops are at risk and whether alternative crop types or varieties should be grown. Growing-season tests can be carried out on affected plants and associated soil; contact local state departments of agriculture and <u>PreDicta B</u>.²

² GRDC (2015) Root-lesion nematodes. GRDC Tips and Tactics, February 2015, <u>http://www.grdc.com.au/</u> <u>TT-RootLesionNematodes</u>



Managing root lesion nematodes: how important are crop and variety choice?

GRDC Tips and Tactics: Root-lesion nematodes



L. Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>

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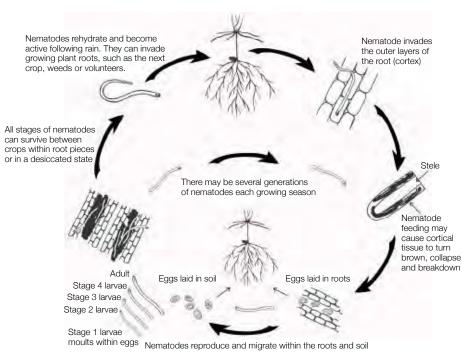


Figure 2: Disease cycle of root-lesion nematode. Adapted from: GN Agrios (1997) Plant pathology, 5th edn. (Illustration by Kylie Fowler)³

8.2.1 What are nematodes?

Nematodes (or roundworms) are one of the most abundant life forms on earth. They are adapted to nearly all environments. In cropping situations, they can range from beneficial to detrimental to plant health.

The RLN are a genus (*Pratylenchus*) of microscopic, plant-parasitic nematode that are soil-borne, ~0.5–0.75 mm in length and will feed and reproduce inside roots of susceptible crops or plants. Of the two common species of RLN in the northern grains region, *Pt* and *Pn*, the former is often described as the cereal and legume RLN. ⁴

Figure 2 is a simplified chart highlighting that the critical first step in the management of RLN is to test the soil and determine whether there is a problem to manage. Where RLN are present, growers should focus on planting tolerant wheat varieties and on increasing the number of resistant crops or varieties in the rotation. ⁵



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³ GRDC (2015) Root-lesion nematodes. GRDC Tips and Tactics, February 2015, <u>http://www.grdc.com.au/</u> <u>TT-RootLesionNematodes</u>

⁴ B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <u>http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication</u>

⁵ B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <u>http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication</u>



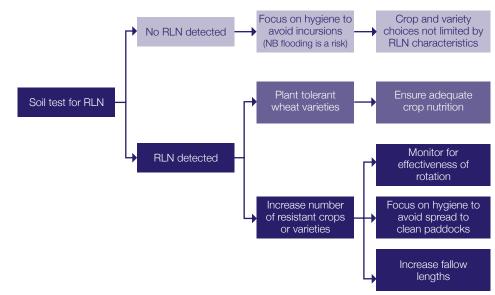


Figure 3: Management flow chart for root-lesion nematode.

8.2.2 Management of RLN

- Nematicides. There are no registered nematicides for RLN in broadacre cropping in Australia. Screening of candidates continues, but RLN are a very difficult target with populations frequently deep in the soil profile.
- Nutrition. Damage from RLN reduces the ability of cereal roots to access nutrients and soil moisture and can induce nutrient deficiencies. Under-fertilising is likely to exacerbate RLN yield impacts; however, over-fertilising is still unlikely to compensate for a poor variety choice.
- Variety choice and crop rotation. These are currently the most effective management tools for RLN. Note that the focus is on two different characteristics: *tolerance*, which is the ability of the variety to yield under RLN pressure; and *resistance*, which is the impact of the variety on the build-up of RLN populations. Varieties and crops often have different tolerance and resistance levels to *Pt* and *Pn*.
- Fallow. RLN populations will generally decrease during a 'clean' fallow, but the process is slow and expensive in lost 'potential' income. Additionally, long fallows may decrease levels of arbuscular mycorrhizal fungi (AMF) and create more cropping problems than they solve. ⁶





Variety choice and crop rotation key to managing root lesion nematodes

Impact of crop varieties on RLN multiplication



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SECTION 9 Diseases

Canola can be infected by a number of pathogens in Australia (Table 1), ranging from root rots to leaf disease and crown to stem infections. As with all diseases, their presence and severity depend on plant susceptibility, presence of the pathogen and favourable climatic conditions. Generally, fungal diseases such as blackleg and Sclerotinia disease are more damaging in higher rainfall regions, but if unseasonably high rainfall occurs in lower rainfall regions, these areas may also experience high levels of disease. Disease control varies for each pathogen, but generally, variety resistance, crop production practices and fungicides are used, either alone or in combination to reduce economic losses. If growers are aware of the disease risks in their area and follow strategic management plans, they should be able to control most canola diseases adequately.

Blackleg, caused by the fungus *Leptosphaeria maculans*, is the most damaging disease of canola (*Brassica napus*) in Australia and most canola-producing countries throughout the world. Sclerotinia stem rot and damping-off are other damaging diseases. Alternaria disease, white leaf spot, downy mildew and viruses may be common in some seasons but they do not normally cause significant crop damage. Clubroot has been identified in New South Wales and Victoria. ^{1 2}

Table 1: Common diseases of canola

Plant growth stage	Plant part infected	Possible disease
Seedling	Roots	Damping-off
	Hypocotyl	Blackleg
	Leaves	Blackleg, white leaf spot, downy mildew
Rosette	Roots	Damping-off, blackleg, clubroot
	Crown	Blackleg
	Leaves	Blackleg, white leaf spot, downy mildew, white rust
Flowering	Roots	Blackleg, clubroot
	Crown	Blackleg
	Leaves	Alternaria disease, blackleg, white leaf spot, white rust
	Stem and branches	Alternaria disease, blackleg, sclerotinia?
Podding	Roots	Blackleg, clubroot
	Crown	Blackleg
	Stem and branches	Alternaria disease, blackleg, Sclerotinia disease
	Pods	Alternaria disease, blackleg, white rust

S Marcroft, T Hind-Lanoiselet (2009) Diseases of canola and their management. Ch. 10. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

² S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



GRDC Ground Cover: Foliar fungal diseases of pulses and oilseeds

GRDC Update Papers: Viral diseases in canola and winter pulses



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9.1 Blackleg

Blackleg is the most important disease of canola, and management of the disease need not be complex. The most effective strategies to reduce the severity of blackleg include growing varieties with an adequate level of resistance for the district, separating the present year's crop from last year's canola stubble by 500 m, and using a fungicide seed dressing or fungicide-amended fertiliser.

Most spores that infect new-season crops originate from the previous year's stubble. Significant numbers of spores from 2-year-old stubble may be produced if seasonal conditions have been dry or if the stubble is still largely intact. Spores can travel 1–2 km on the wind, but most originate more locally. Use of fungicide seed dressings containing fluquinconazole or fertiliser treated with flutriafol will also assist in minimising the effects of blackleg and protect seedlings from early infection, which later causes stem canker development. Although raking and burning can reduce canola stubble, it is the least effective strategy for managing blackleg and is therefore not generally recommended.³



9.1.1 Symptoms and disease cycle

Blackleg survives on canola stubble, producing fruiting bodies that contain large quantities of airborne spores (capable of travelling several kilometres). These dark-coloured, raised fruiting bodies (pseudothecia) can easily be seen with the naked eye (see Figure 1). The date of spore release from the stubble depends on autumn rainfall. Higher rainfall results in earlier spore release and may lead to increased disease severity.

In the autumn and winter, rainfall triggers spore release from the stubble. Within 2 weeks of spores landing on canola cotyledons and young leaves, clearly visible, off-white lesions develop. Within the lesion, pycnidial fruiting bodies (dark-coloured dots in Figure 2) release rain-splashed spores. Once a lesion has formed, the fungus grows within the plants vascular system to the crown where it causes the crown of the plant to rot, resulting in a canker. Severe canker will sever the roots from the stem (Figure 3), whereas a less severe infection will result in internal infection of the crown, restricting water and nutrient flow within the plant.

In recent years, blackleg symptoms have also been found in the plant roots (Figure 4); this root infection in severe cases appears to cause the entire plant to die prematurely.



Research paper: Dynamics of fungal diseases of canola in Western Australia

<u>GRDC Ground Cover:</u> <u>Foliar fungal diseases of</u> <u>pulses and oilseeds</u>

<u>GRDC Update Papers:</u> <u>Viral diseases in canola</u> <u>and winter pulses</u>

Canola diseases. The Back Pocket Guide

GRDC Update Papers: Blackleg pod infection, resistance group monitoring and sclerotinia

<u>GRDC Update</u> <u>Papers: Canola and</u> <u>pulse management;</u> maintaining the vigilance



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P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/</u> pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf



The root-rot form of the disease is caused by the same blackleg strains that cause the stem canker, and management practices are the same for both forms of the disease.⁴



Figure 1: Stubble with blackleg fruiting bodies that produce wind-borne spores. (Photo: B. Howlett, University of Melbourne)



Figure 2: Blackleg lesion on leaf; the small black dots are fruiting bodies that produce spores spread by rain-splash. (Photo: S. Marcroft, MGP)



Figure 3: Canola plant falling over from stem canker. (Photo: S. Marcroft, MGP)

S Marcroft, C Bluett (2008) Blackleg of canola. AG1352. Revised 2013. State Government Victoria, <u>http://</u> agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ blackleg-of-canola



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GRDC UPDATE PAPER: Blackleg pod infection, resistance group monitoring and sclerotinia



Figure 4: Root-rot form of blackleg (diseased plant on left). (Photo: S. Sprague, CSIRO)

9.1.2 Management

Blackleg can be successfully managed by:

- growing resistant varieties
- avoiding the previous year's stubble
- · using fungicides in high-risk situations

Choose a variety with adequate blackleg resistance

The best defence against blackleg is varietal resistance. The blackleg resistance ratings of all Australian canola varieties are published by the Canola Association of Australia in February each year. To find the most up-to-date ratings, go to the <u>Australian Oilseeds</u> <u>Federation (AOF) website. Click on <u>Commodity Groups</u>, then <u>Canola Association of Australia</u>, then <u>Pests and Diseases</u>.</u>

Blackleg rating data are collected each year from a number of sites in New South Wales, Victoria, South Australia and Western Australia. It is important to consult only the current blackleg-rating guide, because blackleg resistance ratings can change from one year to the next due to changes in the frequency of different blackleg strains.

A rating of MS (moderately susceptible) is considered adequate for lower rainfall regions, whereas a minimum of MR (moderately resistant) is required for medium–high-rainfall areas.⁵

Isolate this year's crop from last year's canola stubble

Varietal resistance alone is not enough to protect your crop from yield loss caused by blackleg. It is also crucial to avoid high levels of disease pressure by reducing exposure to large inoculum loads. In most situations, >95% of all blackleg spores in the atmosphere originate from canola stubble from the previous year's crop. Older stubble does not produce many blackleg spores. Therefore, sow crops away from last year's canola stubble. Disease pressure falls markedly in the first 200 m away from last year's stubble and then continues to decline up to 500 m (Figure 5). There appears to be little advantage in increasing the isolation distance past 500 m.

Block farming has been beneficial in managing blackleg, where groups of adjoining paddocks are sown to canola in the same year.

Agronomist's view

S Marcroft, C Bluett (2008) Blackleg of canola. AG1352. Revised 2013. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/blackleg-of-canola</u>



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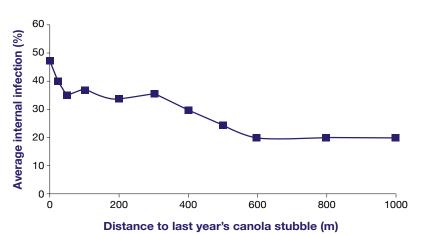


Figure 5: Average internal infection as affected by distance to last year's stubble.

Stubble management such as raking and burning or burial can reduce disease pressure by up to 50%. However, it is not known how much stubble must be destroyed to achieve an economic benefit through decreased blackleg severity. Extending the time between canola crops within a paddock's rotation sequence does not reduce disease severity because of the wind-borne nature of the spores. Paddocks that have been sown into 3-year-old stubble do not have less disease than crops sown in paddocks with a 2-year break from canola. ⁶

Consider fungicide use

Fungicides applied as a seed dressing (e.g. Jockey[®]; active ingredient (a.i.) fluquinconazole) or on the fertiliser (e.g. Titan Flutriafol 250 SC Fungicide, Innova[®] Flutriafol 250, Intake[®] Combi; a.i. flutriafol) reduce the severity of blackleg. Both fungicides give initial protection to canola seedlings, when the plant is most vulnerable to attack from blackleg. However, fungicides may not always give an economic return.

Generally, if varieties with low blackleg resistance ratings are sown in higher rainfall areas or if varieties with good resistance are sown into situations of high disease pressure, then fungicides are more likely to provide an economic benefit. The economic viability of using fungicides in other situations should be determined by monitoring the number of cankered plants in the current season's crop. If >3% of plants are cankered, the use of a fungicide may be warranted in future seasons.⁷

All current canola varieties are assessed for the presence of resistance genes and classified into resistance groups. If the same variety has been grown for two or more seasons, consider changing varieties for this season. Consult the <u>Blackleg management guide 2015</u>. Fact Sheet to determine the resistance group for your current canola varieties and select future varieties that belong to a different group. ⁸

Summary:

- Monitor your crops to determine yield losses in the current crop.
- Choose a cultivar with adequate blackleg resistance for your region.
- Never sow a canola crop into last year's canola stubble.
- Reliance solely on fungicides to control blackleg poses a high risk of fungicide resistance.
- If your monitoring has identified yield loss and you have grown the same cultivar for 3 years, choose a cultivar from a different resistance group.
- ³ S Marcroft, C Bluett (2008) Blackleg of canola. AG1352. Revised 2013. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/blackleg-of-canola</u>
- S Marcroft, C Bluett (2008) Blackleg of canola. AG1352. Revised 2013. State Government Victoria, <u>http://</u> agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ blackleg-of-canola
- ^a P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/</u> pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf

1 More information

Prosaro fungicide in canola

Assess blackleg risk to canola yields before spraying crops

Prosaro[®] 420 SC Fungicide 2013 Product Guide



GRDC: Blackleg management guide 2015 Fact Sheet

GRDC Media: GRDC funding canola stubble screening for fungicide tolerant blackleg

<u>GRDC: Blackleg</u> <u>management guide</u> 2014 Fact Sheet

Managing blackleg and sclerotinia in canola. The Back Pocket Guide

<u>GRDC Ground Cover</u> <u>Supplement: Optimising</u> <u>canola profitability</u>

Oilseeds WA: Assessment of fungicide efficacy against blackleg disease

MFMG: Investigating fungicide best practice management





9.1.3 Four steps to beating blackleg

Step 1. Determine your farm's risk

Use Table 2 to determine your farm's blackleg risk. Combined high canola intensity and adequate rainfall increase the probability of severe blackleg infection.

Table 2: Regional environmental factors that determine risk of severe blackleg infection

Environmental	Blackleg severity risk factor								
factors	High risk			Medium risk			Low risk		
Regional canola intensity (% area sown to canola)	>20	16–20	15	11–14	11–14	10	6–9	5	<5
Annual rainfall (mm)	>600	551–600	501–550	451–500	401–450	351–400	301–350	251–300	<250
Total rainfall March–May prior to sowing (mm)	>100	>100	>100	>100	91–100	81–90	71–80	61–70	<60

Step 2. Determine each crop's blackleg severity in spring

- Assess the level of disease in your current crop. Sample the crop any time from the end of flowering to windrowing (swathing). Pull 60 randomly chosen stalks out of the ground, cut off the roots with a pair of secateurs and, using the reference photos in Figure 6 below, estimate the amount of disease in the stem cross-section. Yield loss occurs when more than half of the cross-section is discoloured.
- A dark-coloured stem is a symptom of blackleg (see Figure 6). Stem cankers are clearly visible at the crown of the plant. Severe cankers may cause the plant to fall over as the roots become separated from the stem.
- If you have identified that you are in a high-risk situation (steps 1 and 2), use steps 3 and 4 below to reduce your risk of blackleg for future seasons.
- If you are in a low-risk situation and you have not identified yield loss due to blackleg infection when you assessed your crop, continue with your current management practices.



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Figure 6: Crop blackleg severity.

20%

Step 3. Management practices can reduce the risk of blackleg infection

If your crop monitoring (see step 2) showed yield loss in the previous year, the following practices can be used to reduce blackleg severity. Complete the following process for each canola paddock to be sown.

For each of the management factors listed in Table 3 below (and in the <u>Blackleg risk</u> <u>management worksheet</u> accompanying the <u>Blackleg management guide 2015 Fact</u> <u>Sheet</u>), circle where each canola paddock fits to determine the risk of blackleg. For example, for 'blackleg rating', if your cultivar is ATR-Stingray, circle 'MR', indicating a low risk of blackleg; or for 'distance from last year's canola stubble', if your proposed canola crop is 200 m away, high risk is indicated.

 Complete all management factors to determine which practices are causing increased risk and how they can be reduced. For example, for 'distance from last year's canola stubble', choose a different paddock, at least 500 m away from last year's stubble, reducing the risk from high to low.



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Table 3: Management factors used to determine which practices are increasing the risk of blackleg infection.

For blackleg rating of cultivar: VS, very susceptible; S, susceptible; MS, moderately susceptible; MR, moderately resistant; R, resistant; see text below (Blackleg rating) for further details

Blackleg rating of cultivar	VS	S-VS	S	MS-S	MS	MR-MS	MB	MR-R	B
Distance from last year's canola stubble	0 m	100 m	200 m	300 m	400 m	500 m	>500 m	>500 m	>500 m
Fungicide use	No fungicide		Foliar applied fungicide		Seed dressing fungicide	Fertiliser applied fungicide	Seed dressing + fertiliser applied fungicide	Seed dressing or fertiliser applied + foliar fungicide	Seed dressing or fertiliser applied + foliar fungicide
Years of same cultivar grown	Same cv. or resistance group for >3 years			Same cv. or resistance group for 3 years			Same cv. or resistance group for 2 years	Same cv. or resistance group for 2 years	Same cv. or resistance group for 2 years
Distance from 2-year-old canola stubble					0 m	100 m	250 m	250 m	250 m
Canola stubble conservation				Inter-row sowing	Disc tillage	Knife- point tillage	Burning or burying tillage	Burning or burying tillage	Burning or burying tillage
Month sown				June-Aug.	15–31 May	1–14 May	15–30 April	15–30 April	15–30 April
Dual purpose grazing canola					Grazing canola				

Step 4. Blackleg resistance groups

Canola cultivars have different combinations of blackleg resistance genes. Over time, growing cultivars with the same blackleg resistance genes has led to changes in the virulence of the blackleg pathogen, which has enabled it to overcome cultivar resistance. By rotating between cultivars with different resistance genes, you can reduce the probability of resistance breakdown and reduce disease severity.

Based on steps 1–3, are you in a high-risk region or have you observed increasing blackleg severity and grown the same cultivar in close proximity for \geq 3 years?

- No. Your current management practices should be sufficient to manage blackleg resistance adequately.
- Yes. You may be at risk of the blackleg fungus overcoming the blackleg resistance of your cultivar. It is recommended that you grow a cultivar with a different combination of blackleg-resistance genes (see table 3 in <u>Blackleg management</u> <u>guide 2015 Fact Sheet</u>). You do not need to change resistance groups (cultivars) every year.⁹

9.1.4 Blackleg rating

Practices to deal with the breakdown of blackleg resistance in intensive canola districts are based on large screening trials. Industry understanding of the blackleg pathogen of canola has progressed substantially over the past few years. An important practical development from this work is that all current commercial cultivars and advanced breeding lines have been screened to determine their complement of blackleg resistance genes. This has enabled researchers to allocate cultivars into one of seven resistance groups.

GRDC (2015) Blackleg management guide, spring 2015. GRDC Fact Sheet, 23 September 2015, http://www.grdc.com.au/GRDC-FS-BlacklegManagementGuide



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Growers are familiar with the rating of crop varieties for susceptibility (S) through to resistance (R) to a specific pathogen. However, the sexually reproducing pathogen causing blackleg is adept at overcoming cultivar resistance, and this compromises a cultivar's blackleg rating. Field observations have found that blackleg resistance is often overcome when the same variety is regularly grown across large areas in a region for >3 years.

Seven resistance rotation groups have been established (named A–G). If there is a risk of high blackleg severity in a location where the same cultivar has been grown for \geq 3 years, then a cultivar from a different resistance group needs to be sown (see <u>Blackleg</u> management guide 2015 Fact Sheet).

One canola cultivar from each of the seven resistance groups has been sown adjacent to National Variety Trials (NVT) sites to monitor how populations of blackleg pathogens evolve to overcome cultivar resistance. In 2011, this blackleg monitoring identified regional differences in infection levels between resistance groups. This information was used as the basis of a pre-sowing, early-warning system to alert growers in a region to the potentially high level of blackleg inoculum able to attack cultivars in a specific resistance group.

There are 32 blackleg-monitoring sites across Australia in Western Australia, New South Wales, South Australia and Victoria. ¹⁰

All varieties are rated according to the independent Australian National Blackleg Resistance rating system, in which all canola-breeding companies are participants. The ratings, based on relative differences between varieties, are as follows:

- resistant: R
- resistant to moderately resistant: R–MR
- moderately resistant: MR
- moderately resistant to moderately susceptible: MR–MS
- moderately susceptible: MS
- moderately susceptible to susceptible: MS-S
- susceptible: S
- susceptible to very susceptible: S–VS
- very susceptible: VS



eXtensionAUS: Blackleg monitoring sites Varieties with a rating of 'resistant' (R) in areas of high blackleg risk and at least 'moderately resistant' (MR) in areas of lower blackleg risk will normally give sufficient disease protection. ¹¹ The blackleg-resistance ratings for all varieties for 2015 are available in the <u>Blackleg management guide 2015 Fact Sheet</u> (see table 3 therein). ¹²

9.2 Sclerotinia stem rot

Sclerotinia stem rot, caused by the fungus *Sclerotinia sclerotiorum*, is a fungal disease that can infect a wide range of broadleaf plants, including canola, peas, beans, sunflowers, pasture species, weeds and lupins. The disease is sporadic, occurring when environmental conditions are favourable for infection. Disease development is favoured by prolonged wet conditions in late winter followed by periods of prolonged leaf wetness during flowering.



¹⁰ GRDC. Advances in blackleg management. 2014-Revised blackleg spring management guide. GRDC Ground Cover Issue 101, <u>http://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS101/Advancesin-blackleg-management</u>

P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/_pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>

¹² GRDC (2015) Blackleg management guide, spring 2015. GRDC Fact Sheet, 23 September 2015, <u>http://www.grdc.com.au/GRDC-FS-BlacklegManagementGuide</u>



Yield losses generally range from nil to 20% in some years, but losses have been as high as 35%. Districts with reliable spring rainfall and long flowering periods for canola appear to develop the disease more frequently. Continual wheat–canola rotations are also very effective at building up levels of soilborne sclerotia.

Burning canola stubble will not control the disease effectively, because *Sclerotinia* survives mainly on or in the soil. Crop rotation with cereals, following recommended sowing times and ensuring that crops do not develop heavy vegetative growth, which is likely to reduce air circulation, are the best means of reducing the impact of the disease.

The inconsistent relationship between the level of stem infection and yield loss makes it difficult to predict an economic response from using foliar fungicides in any one year. The specific environmental conditions for development of Sclerotinia stem rot will not occur every year. For example, in dry conditions, even if the fungus is present, the disease may fail to develop.

The fungicide Prosaro[®] (a.i.s prothioconazole + tebuconazole), and iprodione and some procymidone products, are registered for the management of Sclerotinia stem rot.

Consult your farm adviser and refer to the Sclerotinia stem rot in canola Fact Sheet. ¹³ ¹⁴

9.2.1 Symptoms

The disease infects canola crops from late flowering onwards, with symptoms appearing 2–3 weeks after infection. The fungus produces light brown, discoloured patches on stems, branches and pods. These lesions expand and take on a greyish-white colour. Infected canola plants ripen earlier and stand out as bleached or greyish-coloured plants among green healthy plants. The bleached stems tend to break and shred at the base. When an infected canola stem is split open, hard black bodies (sclerotia) can usually be found inside. Sclerotia are the resting stage of the fungus and resemble rat droppings; they may be round like canola seed, or rod, cylinder or irregular shaped, 2–4 mm in diameter and up to 20 mm long. In wet or humid weather, a white growth resembling cotton wool can develop on lesions and sclerotia may also develop in this white growth.

9.2.2 Disease cycle

Sclerotia remain viable for many years in the soil. When weather conditions are favourable, the sclerotia germinate to produce small, mushroom-shaped structures called apothecia (Figure 7). Apothecia produce thousands of air-borne spores that can be carried several kilometres by the wind. Spores land on canola petals, germinate, and then use the petal as a nutrient source, producing a fungal mycelium. When the petals fall at the end of flowering, they are often caught in the lower canopy of the crop, allowing the fungus to grow from the petal into the plant. The canola flowering period is therefore the critical time for *Sclerotinia* infection. Germination of the spores and infection is enhanced by wet weather at flowering. ¹⁵



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¹³ P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/_pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>

GRDC (2014) Sclerotinia stem rot in canola. GRDC Fact Sheet, 3 March 2014, <u>http://www.grdc.com.au/</u> <u>Resources/Factsheets/2014/03/Sclerotinia-Stem-Rot-in-Canola</u>

¹⁵ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



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GRDC: Sclerotinia stem rot in canola Fact Sheet

Canola diseases. The Back Pocket Guide

GRDC Update Papers: Canola disease update 2015 (NSW)

AOF: Economics and timing of fungicide application to control Sclerotinia stem rot in canola

GRDC Media Centre: Tips and tools for managing Sclerotinia in 2015

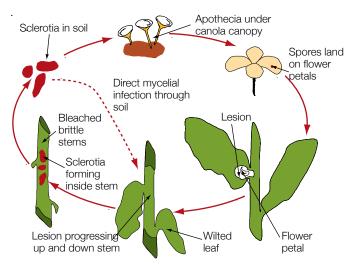


Figure 7: Disease cycle of Sclerotinia stem rot.

Key points for managing Sclerotinia stem rot:

- An outbreak of Sclerotinia stem rot is highly dependent on the season.
- Prolonged wet or humid conditions during flowering favour the disease.
- Consider past outbreaks of the disease as a guide to potential yield loss.
- Avoid growing canola in paddocks with a history of Sclerotinia stem rot over the past 4 years, or in adjacent paddocks.
- Well-timed fungicide treatments, when canola crops are at 20–30% flowering stage, can be highly effective in reducing the level of infection.
- No Australian canola varieties have known resistance to the disease.¹⁶

9.3 Clubroot in canola and B. juncea

Clubroot is caused by the soilborne fungus *Plasmodiophora brassicae* and is not considered common or a serious risk. It has generally been found in the northern canola-growing regions of Western Australia.

In Australian vegetable brassicas, clubroot is widespread and causes significant yield losses. However, the Australian oilseed industry has been somewhat protected from clubroot because the major production areas for vegetable and oilseed brassicas are usually separated from each another. In addition, most Australian pathotypes of clubroot are able to cause disease only in the warmer months and require irrigation water for dispersal, except in Tasmania and some parts of New South Wales where disease is observed year-round.¹⁷

9.3.1 Symptoms

Swollen, galled roots are the most typical symptom of infected plants (Figure 8). This ranges from tiny nodules to large, club-shaped outgrowths. The galls are at first firm and white but become soft and greyish brown as they mature and decay. Affected roots have an impaired ability to transport water and nutrients.¹⁸



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¹⁶ GRDC (2014) Canola disease management in the northern region. GRDC Media Centre, 21 March 2014, <u>http://grdc.com.au/Media-Centre/Hot-Topics/Canola-disease-management-in-the-northern-region</u>

¹⁷ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

¹⁸ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>





Figure 8: Canola roots with severe clubroot.

9.3.2 Disease cycle

Resting spores of the fungus can survive in soil for many years, even in the absence of a susceptible host. Infection can occur at any stage of growth and is restricted to the roots. In the presence of susceptible roots, the spores germinate and release tiny motile spores, which swim in free water to the surface of the rootlets, penetrate and form a fungal colony (plasmodium) inside the root cells. The fungus causes cells to enlarge and divide rapidly, resulting in the characteristic galls. Late in the season, resting spores develop in the infected roots and they are released into the soil as the galls decay. Fields become infested mainly by the movement of soil on cultivation equipment and by seedling transplants.¹⁹

9.3.3 Management

- In the Australian vegetable brassica industry, several methods of control have been developed that may be useful for oilseed brassicas.
- Use a 5-year rotation. Infested fields are kept free of susceptible crops and weeds for at least 5 years, to allow sufficient natural decay of the long-lived spores.
- Do not move cultivating equipment from infested to non-infested areas before thoroughly cleaning the equipment.
- Clubroot thrives in acid soils (pH <7.0), and liming to increase soil pH (7.0–7.5) has been successful for vegetable brassicas. However, this would be cost-prohibitive in most areas growing oilseed brassicas.²⁰

9.4 Rhizoctonia, damping-off

Damping-off is usually caused by the fungus *Rhizoctonia solani*. Other fungi including *Fusarium spp.*, *Pythium* spp., *Phytophthora spp.*, *Alternaria spp.* and the blackleg fungus, *Leptosphaeria maculans*, can also cause damping-off. Symptoms and crop management are similar for all of these pathogens, so they are grouped together here in reference to damping-off.

All species are common inhabitants of the soil and cause damage when conditions are not ideal for early seedling growth. Problems are usually seen when seed is sown dry, close to the autumn break (within a couple of weeks of a normal break), or if weather conditions become cool and damp. Yield loss is unusual unless plant numbers are severely reduced or patchy establishment occurs.²¹



¹⁹ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

²¹ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



Seed fungicide treatments such as Maxim XL[®] (a.i.s fludioxonil + mefenoxam) or Apron XL[®] (mefenoxam) at sowing can also reduce damage caused by *Rhizoctonia* and/or *Pythium*. See your agronomist and/or <u>www.apvma.gov.au</u>.

9.4.1 Symptoms

Damping-off symptoms range from pre-emergence rot (failure of plants to emerge) to post-emergence damping-off (plants emerge and collapse at ground level). If affected plants survive, they are normally stunted and may flower and mature prematurely. Once past the seedling stage, canola plants are not adversely affected by damping-off. Damping-off, both pre- and post-emergent, occurs in patches, and affected areas can spread quickly during cold, wet conditions. Leaves of plants affected by post-emergent damping-off may become discoloured, turning orange, purple and/or chlorotic. In some cases, the taproot is dark in colour and shrivelled at ground level. These symptoms should not be confused with insect damage where root or stem tissue has been removed.²²

9.4.2 Disease cycle

Damping-off fungi are soilborne and survive in the soil by forming resistant resting structures when no host is present. These resting structures germinate with the break of the season and the fungi grow through the soil until they find a susceptible host plant. Dry seeds become vulnerable to attack as soon as they begin to germinate. Once in the plant, the fungi multiply, causing decay that damages or kills the seedling. Damping-off fungi are usually weak pathogens (except blackleg), able to infect only young, succulent tissue. At the 2–4-leaf stage, belowground parts of canola plants become woody enough to withstand further infections. Therefore, most damage occurs when wet and cold weather slows plant growth. Temperature and soil moisture affect disease development. Loose, cold and dry soils favour *Rhizoctonia solani*, whereas cold damp soils favour *Fusarium spp.* and wet, heavy soils favour *Pythium spp.*²³

9.4.3 Management

- Yields are affected only when plant numbers are severely reduced. If seedling loss is uniform throughout the crop, surrounding plants can often compensate by growing larger. If seedling loss is patchy and large areas die, re-sowing may be required.
- Damping-off fungi will germinate with the opening rains of the season. Once germinated, they are very successfully controlled by soil tillage. Therefore, dry-sown crops or crops sown very close to the opening rains may be more severely affected. If crops are re-sown, the sowing tillage will generally control the fungi.
- Application of a seed fungicide treatment (e.g. Maxim XL[®]) at sowing can reduce damping-off damage. ²⁴

9.5 Downy mildew, powdery mildew

Downy mildew is very common in canola crops across Australia, but is rarely found after the vegetative stage and tends to have little effect on crop performance.

Downy mildew is a common disease of canola throughout the world, and is caused by the fungus Peronospora parasitica. Infection occurs under cool moist conditions where leaves or cotyledons are in contact with the soil or other leaves. Although seedlings can be severely attacked by the disease, significant yield loss does not usually occur.



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S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

²³ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

²⁴ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



Downy mildew is rarely found beyond the rosette stage and crops normally grow away from it with the onset of warmer weather.²⁵

9.5.1 Symptoms

Chlorotic or yellow areas on the upper leaf surface are the first symptoms to occur. These can be seen on young seedlings when cotyledons or first true leaves are present. With moist conditions or long dew periods, a white, mealy fungal growth can be seen on the underside of the leaf beneath these spots. Infected cotyledons tend to die prematurely. As the disease develops, individual spots join to form large, irregularshaped blotches. These necrotic lesions may cause a large part of the leaf to dry out and the upper surface of the leaf to develop a yellow–red colour.²⁶

9.5.2 Disease cycle

The fungus is both soil- and seed-borne and can persist in the soil for a long time. Infection is favoured by cool, wet weather, and under ideal conditions, new infections can develop in as little as 3–4 days. The fungus is related to white rust, with specialised spores (oospores) probably responsible for primary infections. Conidial spores produced on the underside of the infected leaf are then responsible for the secondary spread of the disease.²⁷

9.5.3 Management

- Downy mildew does not usually affect yield; therefore, control measures are not generally warranted unless plant densities are severely reduced on a regular basis.
- Where downy mildew is a severe problem, fungicides containing copper as the active ingredient are registered for use in Australia.
- Crop rotation and the control of cruciferous weeds between canola crops can reduce disease severity.²⁸

9.6 White leaf spot

White leaf spot is caused by the fungus *Mycosphaerella capsellae* (also called *Pseudocercosporella capsellae*). The disease has a worldwide distribution and a wide host range among cruciferous weeds. In Australia, white leaf spot commonly infects canola seedlings. Usually, it is not severe enough to cause yield loss.²⁹

White leaf spot is more common in wetter years. The disease is generally present on leaves of young canola plants (Figure 9); however, with prolonged wet weather, it continues to progress up in the canopy and can affect stems and pods during flowering.

White leaf spot is not generally considered serious unless pods are affected. Some yield loss can be expected if leaf lesions join and cause premature defoliation.

White leaf spot can be managed through rotations and cultural practices. Currently, no fungicides are registered for the control of white leaf spot.

- S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>
- ²⁶ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>
- ²⁷ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>
- ²⁸ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>
- ²⁹ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



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Figure 9: White leaf spot on a leaf.

9.6.1 Symptoms

Leaf, stem and pod lesions are greyish-white to light brown. Unlike blackleg lesions, white leaf spot lesions do not contain pycnidial fruiting bodies (black dots) and usually have a more granular surface, compared with the smooth surface of blackleg lesions. Leaf lesions often have a brown margin when they mature; they can be up to 1 cm in diameter and often join to form large, irregular-shaped lesions. Nutrient-deficient crops have been reported as more severely affected by the disease. In severe epidemics, infections can defoliate susceptible varieties.³⁰

9.6.2 Disease cycle

The fungus survives on canola stubble as thick-walled mycelium. When prolonged wetweather conditions prevail during autumn-winter, wind-borne spores are produced that cause primary leaf lesions on canola. These initial lesions go on to produce new windborne spores that cause the rapid spread of disease throughout the crop. The disease is not usually seed-borne but can be spread by infected seeds or infected debris with the seed.³¹

9.6.3 Management

- · White leaf spot infection is not usually severe enough to warrant control.
- Crop rotation and isolation from the previous year's canola stubble will prevent infection from wind-borne spores.
- · Control cruciferous weeds and volunteer canola.
- Provide adequate nutrition to reduce crop stress.³²

9.7 White rust or staghead

White rust is caused by the fungus *Albugo candida*. The disease is uncommon on *B. napus* (Australian canola varieties) but does infect *B. juncea* (juncea canola or Indian mustard) and the weed shepherds purse (*Capsella bursa-pastoris*).³³

- ³¹ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>
- ³² S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>
- ³³ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



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³⁰ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



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9.7.1 Symptoms

White–cream-coloured pustules form on the underside of leaves and on floral parts. These pustules rupture the host epidermis, exposing a white chalky dust. On the upper surface of the leaves, the infected areas are bleached and thickened. Systemic infections of the growing tips and flower heads give rise to stagheads, which are very conspicuous in the crop as swollen, twisted and distorted flower heads that produce little to no seed and become brown and hard as they mature. Symptoms for white rust should not be confused with symptoms of severe calcium deficiency, which cause flowering stalks to collapse, resulting in the withering death of the flower head.³⁴

9.7.2 Disease cycle

Resting spores (oospores) of the fungus can survive in infected plant material or as a seed contaminant for many years when conditions remain dry. When conditions become moist, the resting spores are able to infect plants directly. However, they usually produce tiny motile spores, which can swim in free water to infect seedlings, causing cream–white pustules to form. Inside the pustules, new swimming spores are formed and then distributed throughout the canopy by rain splash to form secondary infections. They do this by growing through stomata into adjacent cells, causing systemic infections and then stagheads if the growing tips of plants become infected. The resting spores can be formed in any infected tissues but are present in larger numbers in stagheads. When the crop is harvested, stagheads break, releasing resting spores that contaminate harvested seed or blow out to contaminate the soil.³⁵

9.7.3 Management

- Obtain seed from disease-free or low-disease crops.
- Control cruciferous weeds.
- Extended rotations will allow crop residues to decompose and reduce the risk of infections.
- If appropriate, consider growing *B. napus* rather than *B. juncea*. ³⁶

9.8 Alternaria leaf and pod spot

Alternaria disease is usually caused by the fungal pathogen *Alternaria brassicae*, and occasionally by *Alternaria brassicicola*. Canola cultivars are more resistant to *A. brassicicola*. The severity of the disease varies between years and locations depending on seasonal conditions. The disease is favoured by warm, humid conditions during spring. Yield loss is unusual and is normally associated with the shattering of infected pods. If infected seed is sown, seedling blight may occur (refer to above discussion of damping-off).³⁷

Moderate temperatures and frequent rainfall during spring favour this disease. Disease is both seed- and stubble-borne and can be managed by sowing clean seed and avoiding sowing close to infected residues. No fungicides are registered for the control of *Alternaria* spp. in canola.

³⁷ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



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³⁴ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

³⁵ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

³⁶ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



9.8.1 Symptoms

Alternaria infects all growth stages of canola plants. However, as plants mature from mid-flowering onwards, they are more susceptible to infection. Symptoms can be found on all parts of the plant including leaves, stems and pods. Spots on leaves and pods have a concentric or target-like appearance and are brown, black or greyish white with a dark border. Lesions on green leaves are often surrounded by a chlorotic (yellow) halo. Severe pod infections may cause seed to shrivel and the pods to ripen prematurely and shatter. Stem spots are elongated and almost black. Pod symptoms of Alternaria disease are similar to those of blackleg and the two can be difficult to distinguish in the field.³⁸

9.8.2 Disease cycle

Alternaria spp. survive the intercropping period on infected canola stubble, on cruciferous weeds and, to a lesser extent, on seed. Seed infections can cause seedlings to rot, resulting in a seedling blight that reduces plant establishment. Initial crop infections are caused by wind-blown spores. Spores remain intact on susceptible plants until moisture from dew or rain allows them to penetrate into the tissue and cause a lesion. These lesions produce further spores, and infections can then be spread throughout the crop by either wind or rain. Mild, humid conditions favour disease development, and the disease cycle will continue throughout the season under favourable conditions. Hot and dry conditions interrupt epidemics, the absence of moisture greatly reducing spore production. Major outbreaks are not common in Australia because weather conditions are normally hot and dry throughout podding, and this is unfavourable for prolonged infection.³⁹

9.8.3 Management

- Alternaria disease is very common in canola crops but is not usually severe enough to warrant control.
- In Australia, there are no registered fungicide seed treatments for this pathogen.
- If pods were infected in the previous season, obtain fresh, disease-free seed.
- In areas where Alternaria disease is a problem, select paddocks isolated from last year's canola stubble because spores are easily transported by wind and they can spread into areas that have not grown canola for several years. ⁴⁰

9.9 Managing viruses

Management of viruses centres on implementing best agronomic practice:

- Retain standing stubble to deter migrant aphids from landing.
- Sow at the optimal seeding rate and sowing time, because earlier sown crops are more prone to aphid attack.
- Control in-crop and fallow weeds to remove the in-crop and nearby sources of virus infection.⁴¹

Beet western yellows virus (BWYV) is a persistently transmitted virus that infects a wide range of crops and weeds. Its main vector is the green peach aphid (*Myzus persicae*).

⁴¹ GRDC (2014) Canola disease management in the northern region—details. GRDC Ground Cover, 21 March 2014, http://grdc.com.au/Media-Centre/Hot-Topics/Canola-disease-management-in-the-northern-region/ <u>Details</u>



³⁸ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

³⁹ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

⁴⁰ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://</u>agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ canola-diseases



Virus-control strategies should be based on preventing infection, because infected plants cannot be cured. Preventive measures to avoid BWYV infection in canola include seed treatment with systemic insecticides that are effective for green peach aphid control and sowing into standing wheat stubble.⁴²

What to look for

Paddock

Discoloured, sometimes stunted plants occur in patches, in thinner crop areas or the edge of the paddock, and gradually spread.

Plant

- First signs are red, yellow or purple colours at the ends or edges of older leaves, then yellowing in the middle of the leaf.
- Colours are more intense between leaf veins and on the upper side of the leaf.
- Petioles and leaf veins are green or pale.
- Discoloured leaves become thickened and may cup inwards.
- Infected plants are often stunted and pale, and produce few flowers or seeds.
- Late-infected plants show leaf symptoms but are not stunted and have lower yield loss. ⁴³

Growers are advised to check canola crops early in the season for presence of aphids. If aphids are found, an effective insecticide should be applied.

There is no indication that the occurrence of BWYV in canola poses a threat to neighbouring pulse crops. ⁴⁴

Of the three virus species recorded in canola in Australia, BWYV is the most common and has potential to cause yield losses. Commercial canola varieties appear resistant to *Turnip mosaic virus* (TuMV). However, some lines of condiment mustard and juncea canola (both *B. juncea*) have been severely affected by TuMV in trials in northern New South Wales. The importance of *Cauliflower mosaic virus* (CaMV) in canola and *B. juncea* is not known.

All three viruses are spread by aphids from weeds, which act as hosts. BWYV can come from a range of weed, pasture and crop species. Turnip weed, wild radish and other *Brassica* weeds are important hosts of TuMV. Substantial yield losses from viruses, particularly BWYV, can occur even when there are no obvious symptoms.

Seed treated with an imidacloprid product or Poncho[®] Plus (imidacloprid + clothiandin) is recommended to protect crops from early infestation with aphids. ⁴⁵

9.9.1 Disease cycle

These viruses are not seed-borne. They survive in weeds or volunteer host plants during summer and they are then spread from these plants into crops by aphids, which act as the vector for transmission. BWYV is termed a persistent virus. Persistent viruses are carried in the aphid's body and can be transmitted to healthy plants during feeding. Aphids will often remain infective throughout their life. CaMV and TuMV are non-persistent viruses, being retained in the aphid mouthparts for <4 h.⁴⁶

- ⁴³ B. Coutts (2015) Diagnosing beet western yellow virus in canola. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-beet-western-yellow-virus-canola</u>
- eXtensionAUS. Latest on canola disease 2015 GRDC Update Papers. eXtension, <u>http://www.extensionaus.com.au/2015-grdc-update-canola-papers/</u>
- ⁴⁵ P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/______data/assets/_pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf</u>
- ⁴⁶ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



GRDC Update Papers: Beet western yellows virus (synonym: Turnip yellows virus) and green peach aphid in canola

Canola diseases. The Back Pocket Guide

GRDC Media Centre: Watch for chickpea viruses near canola



NSW DPI: Virus diseases in canola and mustard

<u>GRDC Resources:</u> <u>Reducing aphid and</u> <u>virus risk</u>

GRDC Update Papers: Virus development in canola crops during 2014 in New South Wales and implications for the oilseed and pulse industry

GRDC

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⁴² eXtensionAUS. Latest on canola disease – 2015 GRDC Update Papers. eXtension, <u>http://www.extensionaus.com.au/2015-grdc-update-canola-papers/</u>



Autumn is the critical infection period, so the earliest sown crops usually have the highest infection incidence. Yield loss is greater in crops that have been infected as seedlings. Infections can occur past the rosette stage of canola growth but these probably have little effect on yield.⁴⁷

9.9.2 Management

- Control broadleaf weeds (especially over summer), which can act as reservoirs for the viruses.
- Sow at recommended times; earlier sown crops usually have a greater incidence of viral infection.
- Monitor aphid numbers in crops (aphids are usually found under leaves) and consider using an insecticide as a foliar (a.i. pirimicarb) or seed treatment (a.i. imidacloprid) to control aphids on seedlings and young canola plants. ⁴⁸

There has been resistance to pirimicarb in green peach aphid so growers would need to use Transform or another new generation insecticide when targeting GPA. This is less of an issue if other aphids like cabbage and turnip are the main pest.

Agronomist's view



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⁴⁷ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>

⁴⁸ S Marcroft, C Bluett (2008) Canola diseases. AG1354. Revised 2010. State Government Victoria, <u>http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/canola-diseases</u>



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SECTION 10

Plant growth regulators and canopy management

Not applicable for this crop.



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11.1 Weedmaster DS



Figure 1: Nufarm's Weedmaster® DST® is the only glyphosate product registered for pre-harvest weed control in canola, providing another tool to reduce weed seed set. Photo: WeedSmart

In some grain producing areas clethodim has been observed to suppressing rather than controlling ryegrass.

A GRDC funded trial carried out by Dr Chris Preston, University of Adelaide investigated the pre-harvest use of a number of herbicides, looking at efficacy, crop safety and residue levels. The trials concluded that only glyphosate was effective and safe to use for pre-harvest weed control in canola, resulting in a recommendation that Nufarm's Weedmaster® DST® be registered for pre-harvest application in canola.

Dr Preston cautions that pre-harvest weed control with glyphosate must not be overused in the rotation. It is essential that many other non-glyphosate measures are also being used in a weed management strategy."

Keep track of how often you are applying glyphosate across the rotation and include as much diversity as possible. For example, if you use glyphosate for pre-harvest control in canola it would be wise to use a different harvest weed seed control tactic in your cereal crop and consider paraquat as a better choice to crop top pulses.

Both over the top and under the windrow applications are equally effective as weed seed set control measures. Efficacy is reduced in hot, dry weather conditions so an over the top crop topping application offers some extra flexibility provided growers have



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access to a self-propelled boom with sufficient clearance. In some situations this will make direct harvesting a more practical option as well.

Figure 2: For optimal ryegrass control and no impact on yield, wait until at least 20 per cent of the canola seed has changed to dark brown or black before a pre-harvest application of glyphosate in a standing crop. Photo: WeedSmart

A harvest weed seed operation, such as narrow windrow burning, will also assist to remove any survivors and help prolong the efficacy of glyphosate across the rotation.

The timing of the application is critical and must not occur before there has been a minimum of 20% grain colour change across the paddock as going in too early will cause yield reductions. No withholding period applies when the product is applied under the windrow but direct harvest must not occur until five days after application to a standing crop.

While annual ryegrass is a key target weed for this use pattern, other key target weeds controlled include wild radish, sow thistle and many other annual grass and broadleaf weeds. $^{\rm 1}$

11.2 Chemical desiccation

Chemical desiccation is an alternative to windrowing and very effective where crops have lodged or where weeds have emerged in maturing crops. The most commonly used desiccant is diquat (Reglone[®]), which is registered for aerial application on canola crops (refer to product label for application rates).

(For information on windrowing, see Section 12. Harvest.)

Desiccation can be a useful strategy on variable soil types; for example, where heavier soil types or drainage lines keep the crop greener for longer, a desiccant can hasten harvest of these areas and reduce the risk of problems arising from high moisture. It can also be used where windrowing contractors are not available.

Desiccants have no detrimental effects on the seed or its oil quality if applied at the correct time. They work through contact action and require almost complete coverage

WeedSmart (2015), Options for crop topping canola, <u>http://www.weedsmart.org.au/bulletin-board/crop-topping-canola/</u>



Options for croptopping canola

Nufarm: Weedmaster now registered for use in canola







Pre-harvest herbicide use. Fact Sheet.

Harvest options for canola—windrowing timing, direct heading, desiccation with Reglone and treatment with Pod-Ceal. Effects on yield and oil percentages. of the plant to work effectively. An experienced aerial operator can apply a crop desiccant to ensure uniform coverage with minimal spray drift.

The correct time for desiccation is when 70–80% of seeds have changed colour in middle pods, which is when the crop has passed its optimal windrowing stage. The crop will be ready to harvest within 4–7 days after the desiccant is applied, depending on the size and density of the crop.

Desiccate only an area of crop that can be harvested over a period of 1–2 days. The harvester must be ready within 3 days of a desiccant being applied to minimise the potential of losses from shattering. Withholding periods should be adhered to.

Desiccation is generally considered a special-purpose management aid to be used when problems with windrowing, weeds or harvesting are anticipated. Specialist agronomic advice should be sought. 2



2

P Carmody (2009) Windrowing and harvesting. Ch. 14. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>



SECTION 12 Harvest

Canola crops can be either windrowed (Figure 1) or direct-harvested. The method chosen depends on the availability and cost of contract windrowing, the type of harvesters available and the relative risk of adverse weather in a particular locality. Some of the advantages of windrowing are: uniform ripening, earlier harvesting (7–10 days), less exposure to spring storms and rain, reduced shattering losses during harvest, and less hail and wind loss. Harvesting can usually continue 'around the clock'. ¹ Some advantages of direct heading include cost, availability of headers on the farm, and a higher harvest index on low-yielding crops. There is also a problem with windrows in lower yielding crops being susceptible to being blown around by wind, causing extensive losses.





<u>GRDC: Direct heading</u> canola. Fact Sheet

AOF: Better canola. Module 7. Harvest management

Figure 1: Windrowing prior to harvest is the more common practice. (Photo: Rebecca Jennings)

12.1 Windrowing

Key points:

- Physiological maturity occurs when the seed moisture content reaches 35-45%.
- Check the crop regularly from 14 days after the end of flowering (10% of plants with flowers).
- Look for colour change across the whole plant, particularly in crops with lower plant populations.
- Sample from representative areas of the paddock, and check all varieties for change in seed colour; it will vary within a district.
- L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>



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- Book a contractor early in the season and contact again when the crop has reached the end of flowering.
- Optimal windrowing stage lasts for 4–6 days in most areas.
- When seed losses are obvious on the windrower, stop and consider direct harvesting. Planning is critical for a smooth harvest operation. Less experienced growers are advised to organise a contractor or an experienced neighbour to carry out the windrowing.



Figure 2: Windrowed canola near Binalong, NSW. (Photo: Gregory Heath)

Canola is an indeterminate plant, which means it flowers until limited by temperature, water stress or nutrient availability. As a result, pod development can last over 3–5 weeks, with lower pods maturing before higher ones. Consequently, canola is often windrowed to ensure that all pods are mature at harvest (Figure 2).

Older varieties of canola had a lengthy flowering period, but growers now have access to a greater range of varieties with differing maturities and more tolerance to pod-shattering.

Some early-maturing varieties have been developed with shorter flowering and pod maturity periods. Direct harvesting (instead of windrowing) is more of an option for these shorter statured and earlier maturing varieties in some regions.

Whether the crop is windrowed or direct-harvested will depend on the varieties grown, soil types, seasonal conditions, availability of windrowers, and the size and variability of the crop. Canola crops that are variable in their maturity or show significant differences in the maturity of the top and bottom pods ideally are windrowed to minimise shattering losses. The plant should be windrowed before the lower pods approach shattering stage.

Like hay cutting, windrowing of canola hastens the maturity of the crop, allowing the top pods to be harvested at the same time as the lower pods. By cutting the crop and placing it in a windrow on the stubble, the pods and seeds can dry faster than a standing crop (by as much as 8–10 days). Windrowed canola is less susceptible than a standing crop to wind, rain and hail damage, although agronomists query this effect in light crops. In the windrow, seeds will reach a uniform harvest moisture content of 8% within 6–10 days of being cut.



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Several harvester-front options are available for canola. A belt front, for example, can be used to windrow or direct-head a crop, but with minor modifications, it can also be used to harvest a windrowed crop. Various pick-up attachments or crop lifters can be used on existing open-front headers to harvest canola windrows.

For most canola-production areas, windrowing has several advantages:

- allowing earlier harvest (8-10 days) because seed matures more evenly
- hastening maturity (in higher rainfall areas)
- evening maturity where soil types are variable in individual paddocks
- reducing losses from hail and excessive winds (except in light crops)
- providing flexibility for the grower with large areas, because the timing of harvest is not as critical
- reducing shattering losses during harvest
- around-the-clock operation to cover large areas
- helping to control escaped or herbicide-resistant weeds in some cases ²

12.1.1 When to windrow

Windrowing should start when 50–70% of seeds have changed colour to red, brown or black (Figure 3). The crop is usually ready for windrowing 20–30 days after the end of flowering, and should be regularly checked for changes in seed colour. The end of flowering is considered to be when only ~10% of plants have any flowers left on them.

Windrowed crops should be ready to harvest 5–14 days after windrowing, depending on the weather. The moisture content of the grain should be $\leq 8\%$.³

In warmer, drier areas, windrowing is better done when seed reaches 50–60% seedcolour change. Under higher temperatures, the windrowed plant dries too rapidly to allow seeds to mature fully in the pods and oil content can be lower.



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P Carmody (2009) Windrowing and harvesting. Ch. 14. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC Canola Guide All 1308091.pdf</u>

L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>



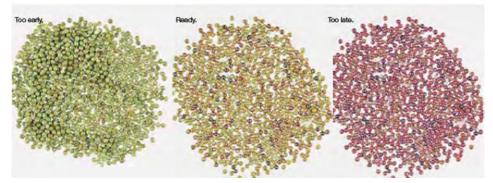


Figure 3: Changes in seed colour determine the optimum time for windrow timing. (Photo: DAFWA)

In summary, windrowing too early can result in lower yields and oil contents, and too late will lead to shattering losses.

The optimum time for windrowing is when the top third of the plant has mostly green seeds. These should be firm but pliable when rolled between the thumb and forefinger. The middle section of the plant will have 80% of seed green or green-red and be very firm but pliable; the other 20% may be red-brown to light brown. The bottom third of the plant will have dark brown to black seeds.

The time from the end of flowering to windrowing will vary with season, paddock and variety. Check each crop every year to determine the best windrowing time.

If using a contractor, ensure that they are booked well in advance. Noting the end of flowering will help the grower and the contractor to determine approximately when the crop will be ready to windrow. It is most important that a decision to windrow is made based on assessment in a representative area of the paddock.

The optimal windrowing stage for canola lasts ~4–6 days, depending on temperature and humidity. Each day that windrowing is delayed past the optimum time will make the crop more susceptible to shattering losses. These can be minimised by operating at night or when humidity is high after dew or rain. However, where shattering losses during windowing are obvious, growers are advised to change strategy to direct harvesting or to desiccation followed by direct harvesting.

Windrowing too early, for example, by 4–5 days, can lead to yield losses of up to 10% and reduced oil content. A canola crop should never be windrowed before seed colour has changed, because it will result in significant yield loss. Rollers can be attached to the back of windrowers to help push the windrow down into the stubble and minimise wind damage. Note: withholding periods of pesticides relate to windrowing, not to harvest, if windrowing operations occur. ⁴

12.2 Direct heading

Direct harvesting is cheaper than windrowing and can be done with an open front with an extended platform or with a belt-front attachment. Canola is ready to harvest when almost all pods are dry and rattle when shaken, pods are pale brown, and the seeds are dark brown to black and have <8% moisture content. ⁵

Direct heading of canola can often be carried out sooner than generally accepted; although the crop stalks may still be green, crop delivery is based on grain moisture, not plant moisture.



GRDC Ground Cover: Revisiting canola management can lift returns



P Carmody (2009) Windrowing and harvesting. Ch. 14. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> <u>au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf</u>

⁵ L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/__data/assets/pdf,_file/0016/148300/canola-northern-NSW-planting-guide.pdf</u>



1 More information

<u>GRDC: Direct heading</u> canola. Fact-Sheet

<u>GRDC Media Centre:</u> <u>Direct heading canola</u> <u>delivers at Devenish</u>

GRDC Update Papers: The benefits of disc seeders direct heading canola and on-farm storage

GRDC Update Papers: Harvest options for canola—windrowing timing, direct heading, desiccation with Reglone and treatment with Pod Ceal. Effects on yield and oil percentages

GRDC Update Papers: Harvesting canola in 2013—to windrow or direct head

<u>GRDC Update Papers:</u> <u>Canola harvest: is direct</u> <u>heading a serious option</u>

GRDC Ground Cover: Early planning the key to canola direct harvesting

To download the Grain Orana Alliance 'Canola harvest loss calculator', visit: <u>http://www.</u> grainorana.com.au/ documents. Most headers are capable of direct heading of canola. Many machines are built for European agriculture, where direct heading of crops is regularly practiced.

It is essential to set up the header front correctly, according to the manufacturer's instructions.

Common draper fronts can be used to direct-harvest canola, but can be problematic when there is uneven flow of the crop into the machine. When canola is cut and fed onto the mat, it tends to bounce and fluff up and feed through in lumps. To counter this, a top-cross auger can be fitted to sit across the back of the header front above the belt. When the canola fluffs up, it hits the auger, which then flicks it towards the centre to even out the feed into the header.

Conventional, 'tin front' headers that have an auger at the bottom of the table are also capable of direct heading of canola.

The crop takes virtually no threshing to get the grain out of the pods, so machines can be set wide open to handle a significant amount of crop residue.

Incorrect setting up of the reel can cause significant losses in direct-headed canola. The reel on the header comes into play only when the crop is not feeding easily into the machine, so it should be set high, well forward and only slightly faster than the machine's ground speed. The reel is not for raking the crop into the header front, because this will create losses from seed shatter.

Harvesters should have sharp cutter bars so that they cut the crop cleanly rather than 'gnawing' it off.

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12.3 Comparison of windrowing and direct heading

GRDC Grower Solutions Group, the Grains Orana Alliance (GOA) examined the timing and adoption of pre-harvest practices in the Central West of New South Wales (Table 1). Research findings include the following:

- Yield loss due to shattering with later windrowing has proved not as severe as previously thought.
- Windrowing timing can have a significant positive effect on yield and profitability of canola.
- Relatively short delays in windrowing of only 8 days can lead to yield increases of up to 0.5 t/ha.
- Timing of windrowing has a limited effect on oil potential in canola.
- Direct heading is a viable option for harvesting canola and in many cases could maximise profitability.
- An economic benefit of >\$200/ha can be gained from choosing the best method and timing of canola harvesting.⁶

M Street (2013) Harvesting canola in 2013—to windrow or direct head. GRDC Update Papers, 22 August 2013, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/08/Harvesting-canola-in-2013-to-windrow-or-direct-head</u>



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Table 1: Canola harvest treatments, windrow timing and crop maturity ⁷

Treatment	Windrowing timing	Assumptions of crop maturity	Proportion of crop physiologically mature	At risk of not reaching potential
Early windrow	10% seed-colour change in middle third of the main stem	Assume bottom third mature, plus 10% of middle third, nil top third	36% seed potentially already mature	64%
Ideal windrow	50% seed-colour change in middle third of main stem	Assume bottom third mature plus 50% of middle third and 10% of top third	53% seed potentially already mature	47%
Late windrow	70% seed-colour change in middle third of the main stem	Assume bottom third mature plus 70% of the middle main stem and 50% of top third	72% seed potentially already mature	28%
Reglone®	70% of all pods have changed colour	70%	70%	30%
Direct head	All seeds mature	100%	100%	0%

From these trials, it could be concluded that timing of windrowing has limited effect on oil percentages in canola. Delaying windrowing or direct heading resulted in significant increases in yields of canola. These yield variations may be explained by the proportion of immature seed present at cutting and the risk that this seed will not fill its potential. For this seed to mature, it must draw on stored substrate, which may be influenced by cutting height, time of day, or even variability of the level of maturity within the crop. These aspects require further investigation.

The differences in yield, coupled with additional costs, contribute to significant increases in net returns for some treatments. Figure 4 depicts the relative benefits of the treatments, taking into account average yields, additional costs, and oil penalties or bonuses.

The limited nature of these trials does not allow a recommendation of ideal timing of windrowing. However, the trials do demonstrate the potential economic benefit of making the right decision. Paddocks, seasons and risk-averseness of growers will all differ. When formulating a time to windrow, remember that there are potential advantages to allowing immature seed in the paddock to mature before windrowing or desiccation. By ceasing the plant's growth during the filling of these seeds, yields could be reduced.

Therefore, a balance must be found between potential yield maximisation by delaying windrowing or desiccation, and potential increases in loss of yield through shattering. This should be considered in view of the grower's risk-averseness, or other advantages offered through windrowing. Potential risk in terms of pod shattering may be managed by use of products such as Pod CealTM.

Further investigations may be warranted into:

- time of day of windrowing and its effect on maturation of immature seed
- windrowing height—more stem may leave more substrate available to facilitate grainfill and hence reduce yield losses and variability



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M Street (2010) Harvest options for canola – windrowing timing, direct heading, desiccation with Reglone™ and treatment with Pod Ceal™. Effects on yield and oil percentages. GRDC Update Papers, 30 September 2010, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/Harvestoptions-for-canola-windrowing-timing-direct-heading-desiccation-with-RegloneTM-and-treatment-with-Pod-CealTM-effects-on-yield-and-oil-percentages

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 quantifying potential sources of losses—standing crop, windrowing losses, losses while in the windrow ⁸



GRDC Update Papers: Harvesting canola in 2013—to windrow or direct head

GRDC Update Papers: Harvest options for canola—windrowing timing, direct heading, desiccation with Reglone and treatment with Pod Ceal. Effects on yield and oil percentages

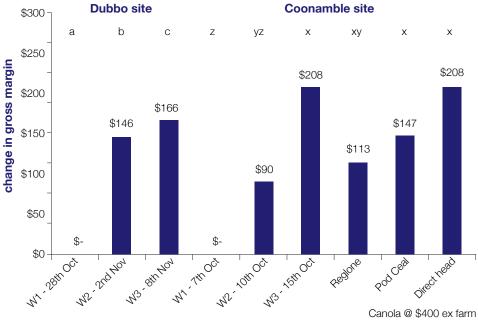


Figure 4: Relative cost–profit difference of various harvest options compared with windrow timing 1 (W1) at the Dubbo and Coonamble canola harvest trials. Treatment values headed by the same letter are not significantly different ($\alpha = 0.05$). ⁹

12.3.1 Windrowing

This technique is likely to be the most widely used. The majority of canola is currently windrowed, however this is quickly changing. The objective in windrowing is to lay the cut material on top of the lower stem material to allow air movement under the windrow to assist in the drying process (Figure 5).

Advantages of cutting the crop and placing it in a windrow on the stubble:

- The pods and seeds will ripen faster than a standing crop (by as much as 8–10 days).
- Windrowed canola is much less susceptible to wind and hail damage than is a thin, standing crop, especially if it has been desiccated with diquat (Reglone[®]).
- Seeds will reach a uniform harvest moisture content of 8% earlier than with desiccation or direct heading.
- It can help in the management of uncontrolled or herbicide-resistant weeds.
- Even, well-made windrows will speed up the harvest operation

Disadvantages:

- There are additional costs.
- In very wet seasons, the crop can deteriorate in a windrow.
- The optimum timing only lasts 4–6 days depending on the temperature and humidity.



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³ M Street (2010) Harvest options for canola – windrowing timing, direct heading, desiccation with Reglone[™] and treatment with Pod Ceal[™]. Effects on yield and oil percentages. GRDC Update Papers, 30 September 2010, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/Harvestoptions-for-canola-windrowing-timing-direct-heading-desiccation-with-RegloneTM-and-treatment-with-Pod-CealTM-effects-on-yield-and-oil-percentages

⁹ M Street (2012) Windrow timing and direct heading in canola—effects on yield and oil. GRDC Update Papers, 12 April 2012, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/ Windrow-timing-and-direct-heading-in-canola-effects-on-yield-and-oil



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- The use of contractors may compromise timing.
- Timing of windrowing is determined by percentage change in seed colour, which is a compromise to allow for variability in the weather post-windrowing.
- Windrowing too early can lead to yield losses of up to 30% and reduced oil content, whereas too late makes the crop far more susceptible to shattering losses.
- Poorly made, uneven windrows resulting in 'lumps' or 'haystacks' will slow the harvesting process, and any blockages that occur can be time-consuming and costly to clear, especially where contractors charge on a machine-hour basis.
- If the cut plants are 'pushed' down onto the ground during the windrowing operation, the dry-down time may be increased, especially if moderate to heavy rain is received before harvesting starts. Lighter windrows are prone to movement in strong winds.



Figure 5: Windrowed crop prior to harvest. The cut material is laid on top of the lower stem material to allow air movement.

Timing

Collect pods from the main stem of a number of plants and from different positions in the canopy to determine the optimum timing for windrowing. The top third of the plant will have mostly green seeds that are firm but pliable; the middle third, ~80% of seeds green or green-red and very firm but pliable, and 20% red-brown to light brown; and the bottom third, dark brown to black seeds.¹⁰

Check withholding periods when using Reglone[®]. See: <u>Australian Pesticides and</u> <u>Veterinary Medicines Authority.</u>

12.3.2 Direct heading

Recent research into direct cutting of canola has shown it to be a viable harvest alternative to windrowing in some circumstances. Favourable conditions for direct heading include having a crop canopy that is slightly lodged and knitted together, even maturity across the paddock, and few, green weeds (or when sprayed with a desiccant).

Advantages of direct heading:

- There are no windrowing or desiccation costs.
- J Midwood (2013) Canola harvest: is direct heading a serious option? GRDC Update Papers, 6 February 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Canolaharvest-Is-direct-heading-a-serious-option





- Crops dry out faster after wet weather than do windrowed crops.
 - Crops are allowed to maximise yield potential and oil contents.
- It suits rocky areas, which can be a problem when windrowing, and reduces the risk of harvester blockage that can occur with windrows.

Disadvantage:

 In crops that are variable, the wait for ripening can expose the crop to wind damage, and thicker crops can take a considerable time to ripen evenly.

Timing

The general colour of the crop is a poor guide of when to harvest; use seed moisture content. The addition of pod sealants is a management aid when direct harvesting; it helps by reducing pod shattering and by allowing crops to achieve their full yield potential but is an added cost. When sprayed onto the crop pod sealant provides a unique, elastic, semi-permeable membrane over the filling pods. Timing is earlier than the optimum time for windrowing.¹¹

12.3.3 Desiccation followed by direct heading

The most common desiccant is diquat (Reglone[®]), which is registered for aerial and ground application such as using a self-propelled boom.

Advantages:

- The technique is useful on variable soil types because it allows more even crop ripening.
- It is ideal for weedy crops.
- Crops dry out faster after wet weather than a windrowed crop.

Disadvantages:

- There are shedding losses if a ground rig has to be used.
- Shattering losses can be very high in windy conditions.
- It is expensive, especially if the desiccant is applied by air.

Timing

The correct time for desiccation is when 70–80% of seeds have changed colour in the middle pods; this is when the crop has passed its optimal windrowing stage. The crop will be ready to harvest within 4–7 days after the desiccant is applied, depending on the size and density of the crop.

Other desiccants such as glyphosate are regularly used pre-harvest on canola in the southern grains region of Australia, Canada and Europe. This provides far slower senescence of the plants, considerably reducing pod shattering and providing superior end-of-season grass-weed control. ¹² Weedmaster DST now registered for pre-harvest use on canola in Australia. Agronomists report it has much wider use than Reglone[®] due to lower cost and weed control benefits.



Options for croptopping canola

Nufarm: Weedmaster now registered for use in canola



J Midwood (2013) Canola harvest: is direct heading a serious option. GRDC Update Papers, 6 February 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Canolaharvest-ls-direct-heading-a-serious-option

¹² J Midwood (2013) Canola harvest: is direct heading a serious option. GRDC Update Papers, 6 February 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Canolaharvest-Is-direct-heading-a-serious-option



12.4 Wet harvest issues and management

Canola generally withstands extended wet harvest periods better than other crops such as wheat. Severe windstorms can cause seed shatter more readily in canola; however, newer varieties have been selected to improve this characteristic. ¹³

12.5 Receival standards

Canola receival standards as described in the Australian Oilseeds Federation standards manual are presented in Table 2.¹⁴

Table 2: Commodity standards-canola

Parameter	Specification
Oil (%)	42.0 base level; 1.5% premium or deduction for each 1% above or below 42 $$
Free fatty acid (%)	1.0 base level; 2% deduction for each 1% over the base level, rejectable over 2.5
Moisture max. (%)	8.0; 2% deduction for each 1% over maximum
Test weight min. (kg/hL)	62.0; rejectable under this limit
Protein	Unlimited
Seed retention	Unlimited
Germination	Unlimited



AOF: Quality standards, technical information and typical analysis, 2014/15

GRDC: Integrated Weed Management Hub

Links to GRDC Update papers and reports on weed management are available from the <u>Grain</u> <u>Orana Alliance</u>.



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¹³ L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/ data/assets/pdf, file/0016/148300/canolanorthern-NSW-planting-guide.pdf</u>

AOF (2014) Quality standards, technical information and typical analysis. Section 1. In Standards manual 2014/15. Australian Oilseeds Federation, <u>http://www.graintrade.org.au/sites/default/files/file/Commodity%20</u> Standards/AOF_Standards_201415_Final.pdf



SECTION 13 Storage

13.1 Canola storage at a glance

- For safe storage and optimum quality, canola should be stored 'cool and dry'.
- Aim to store canola seed with 42% oil content at <7.0% moisture content. Samples with high oil content (50%) can be stored safely at <6.0% moisture content.
- Clean out storage facilities, grain-handling equipment and headers to reduce carryover of storage pests from one season to the next. This minimises early infestation pressure.
- Aeration to promote uniform, cool storage conditions is a key strategy for maintaining oil and seed quality. During summer, aim for stored canola temperatures in the range 18°–23°C.
- For oilseeds, monitor storages fortnightly and keep records. Sieve grain and use probe traps to detect insect pests. Make visual inspections and smell the canola. Check canola temperature at a number of locations in the storage.¹





Storing oilseeds—Grain Storage Fact Sheet

Cool and dry conditions maintain canola guality—Farming Ahead



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13.2 Storing oilseeds

Storage of oilseeds on-farm requires attention to detail, because limited tools are available compared with cereal grain storage. Oilseeds are also more susceptible to quality deterioration and have fewer insect-control options. To retain the canola's market value, care must be taken to maintain oil quality, visual appearance, and freedom from moulds, insect pests and unregistered chemicals.²

The decision to store oilseeds requires planning, careful management and a suitable storage system. $^{\scriptscriptstyle 3}$

Points to consider when storing oilseeds such as canola:

- Limited chemical control options for insect pests in stored oilseeds increase the importance of careful management and planning.
- Aeration cooling is required when storing oilseeds to maintain seed and oil quality, limit insect reproduction and reduce risk of mould development.
- Seek advice about the appropriate fan size to use to aerate canola. Canola's small seed size will reduce fan output by 40–50% or more. In some situations, the fan may fail to produce any airflow.
- Moisture content in oilseeds must be much lower than in cereal grains. The high oil content increases the risk of moulds and quality damage.
- Successful phosphine fumigation requires a gas-tight, sealable silo.
- To prevent residues on canola, do not use the standard chemical insecticide structural treatments. Use diatomaceous earth (DE) products such as Dryacide[®].

13.3 Seed quality and moisture content at storage

Windrowing canola may have advantages over direct harvesting of the standing crop. It hastens and evens out the drying rate of ripe canola. If direct harvesting, harvest at <7% moisture content to allow for paddock variability with respect to crop maturity.

Timing of harvest and header settings—drum speed, concave gap and fan speed—have a significant impact on minimising trash and impurities and seed damage. If admixture in the seed sample is high, fines can concentrate directly below the storage fill-point, leading to heating and fire risk. Larger pieces of crop trash may also concentrate along silo walls, leading to mould development.

The presence of damaged seeds is more attractive to storage pests such as the rustred flour beetle (*Tribolium castaneum*).

Safe moisture content for storage depends on temperature and oil content. The higher the oil content and storage temperature, the lower the moisture content must be for safe storage. At 25° C, canola with an oil content of 45% is safe to store at <7.0% moisture content. Canola with 50% oil content is safe at <6.0% moisture content (see Figure 1).

The aim is to store the canola in conditions that achieve an equilibrium relative humidity of <60% in the storage (see Figure 1). This reduces the risk of mould development, canola self-heating and oil quality deterioration.

Use of aeration to cool seed temperatures to ${\leq}20^{\circ}\text{C}$ is a key aid to reliable canola storage. $^{\text{5}}$



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² P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf</u>

³ GRDC (2014) Storing oilseeds. GRDC Stored Grain Information Hub, <u>http://storedgrain.com.au/storing-oilseeds/</u>

⁴ GRDC (2014) Storing oilseeds. GRDC Grain Storage Fact Sheet, July 2014, <u>http://storedgrain.com.au/wp-content/uploads/2014/09/GSFS-9_Oil-Seed-July14.pdf</u>

⁵ P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf</u>

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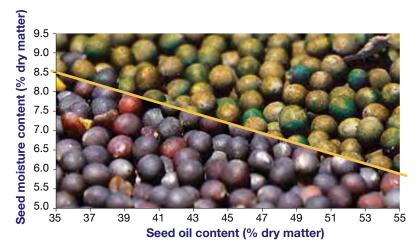


Figure 1: Safe storage conditions for canola at 60% equilibrium relative humidity. The relationship between seed moisture content and oil content is shown at 25°C (yellow line). Canola stored at conditions above the line is at potential risk of seed and oil quality loss. (Source: CSIRO Stored Grain Research Laboratory)

13.4 Types of storage

Ideal storage for canola is a well-designed, cone-based, sealable silo fitted with aeration (Figure 2). The storage should be designed for minimum damage to seed, ease of cleaning and hygiene for empty storages, and suitability for effective use of aeration cooling.

If seed requires insect pest control, the silo is then sealed (gas-tight) for the required period as stated on the product label (usually 7–10 days) to enable effective phosphine fumigation. For all storage types, extra caution should be taken to prevent rain/water ingress into storages.⁶



Figure 2: Aerated, sealable silos.



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P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, http://www.australianoilseeds.com/ data/assets/pdf file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf



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13.5 Hygiene-structural treatment

Most common insecticide treatments for storage surfaces are not to be used on storages for holding canola. **Warning**: if unregistered chemical residues are detected by grain buyers, it can have serious long-term consequences for domestic and export markets.

Diatomaceous earth (amorphous silica) or inert dust is a naturally occurring, mined product with insecticidal properties. Products such as Dryacide[®] can be applied as a dust or slurry spray onto internal surfaces of storage areas and equipment. Once old grain residues have been physically removed or washed out of storages and equipment, Dryacide[®] can be applied as a non-chemical treatment to reduce insect pest carryover.

Insect pests survive in any sheltered place with grain residues—in grain hoppers, augers, field bins and inside headers. All of these attractive locations require attention.

Some products based on pyrethrin + piperonyl butoxide (e.g. Rentokil's Pyrethrum Insecticide Spray Mill Special[®] or Webcot SPY[®] natural pyrethrum Insecticide) are registered for moth control in oilseed storage areas or storage sheds. They can be used as a structural-surface spray or fogging–misting treatment. They are not to be applied as a grain treatment. Use only as labels direct and only use products registered for use in the state or territory as stipulated on the label. Discussion with grain buyers and traders prior to use of any products is also important.⁷

13.6 Aeration

Aeration should be considered an essential storage tool for canola. Correctly managed, it creates uniform, cool conditions in the seed bulk and slows most quality-deterioration processes.

Aeration:

- helps maintains oil quality— low free fatty acid content / rancidity, good colour and odour;
- · reduces the risk of 'hot spots', moisture migration and mould development;
- slows or stops breeding cycles of storage insect pests (e.g. rust-red flour beetle) by maintaining grain temperatures at <20°C; and
- maintains germination and seed vigour for longer when kept cool and dry.⁸

Canola, being a much smaller seed than cereal grains, adds significantly more backpressure to the aeration fan. This means that an aeration cooling system set up to produce airflows of 2–4 litres per second per tonne (L/s.t) in cereal grain will typically produce only 40–60% of that when used in canola.

When setting up storages to cater for cereals and canola, seek advice about the fan sizes and number required to achieve the 2-4 L/s.t.

Other factors that affect the amount of airflow through the grain:

- depth of the grain in storage
- amount of fine admixture and foreign plant material in the grain
- design and size of fan ducting and venting on top of the silo

The area and type of ducting must be adequate to disperse the air through the storage and not to be blocked by the small canola seeds. Avoid splitting airflow from one fan into multiple silos, because the back-pressure in each silo will vary and incorrectly



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P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf</u>



apportion the amount of airflow to each. This will be exacerbated if different grains are stored in each silo, such as canola in one and a cereal in the other.⁹

13.6.1 Aeration cooling

Fans providing low airflow rates of $\sim 2-4$ L/s.t can both cool seed and provide uniform seed temperature and moisture conditions in the storage. Always check that the fan's design and capacity is suitable for the small canola seed. In some cases, an aeration fan may not be able to create any airflow through canola.

Well-managed cooling aeration typically makes seed temperature fall safely to ~ \leq 20°C within days. Regular checking of canola in storage is essential. Make visual inspections, check seed moisture, use a temperature probe to monitor bulk seed temperature, and sieve for insects. ¹⁰

13.6.2 Automatic controllers

Often, 'aeration cooling' fans are simply turned on and off manually or a timer clock is used. However, much can be gained by investing \$5000–7000 in an automatic controller that selects the optimum run-times and ambient air conditions under which to turn on the fans. The controller continually monitors air temperatures and relative humidity and may select air from only 2 or 3 days in a week or fortnight. One unit has the capacity to control fans on multiple silos. ¹¹

13.6.3 Operation of aeration fans

- Run fans constantly during the first 4–5 days when grain is first put into the silo. This removes the 'harvest heat'. Smell the air coming from the silo top-hatch. It should change from a warm, humid smell to a fresh, cool smell after 3–5 days. The first cooling front has moved through.
- For the next 5–7 days, set the controller to the 'rapid' setting. This turns fans on for the coolest 12 h of each day to reduce the seed temperature further.
- Finally, set the controller to the 'normal' mode. The fans are now turned on for ~100 hours per month, selecting the coolest air temperatures and avoiding high-humidity air.¹²

13.6.4 Aeration drying

Well-designed, purpose-built, high-flow-rate aeration-drying systems with airflow rates of 15–20 L/s.t can dry seed reliably. During aeration drying, fans should force large volumes of air through the grain bulk for many hours each day. This ensures that drying fronts are pushed quickly through so that seed at the top of the silo is not left sitting at excessively high moisture contents (Figure 3).

Seeds from oilseed crops are generally well suited to this form of drying when correctly managed. Utilise all ambient air available with relative humidity <70% to provide a low average relative humidity for each run time. This can reduce moisture content without the risk of heat damage to seed oil quality. Monitor regularly and take care that seed in the bottom of the silo is not over-dried. Seek advice when undertaking aeration drying for the first time.



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⁹ GRDC (2014) Storing oilseeds. GRDC Stored Grain Information Hub, <u>http://storedgrain.com.au/storing-oilseeds/</u>

¹⁰ P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf</u>

¹² P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, http://www.australianoilseeds.com/_data/assets/pdf_ file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf

Do not use aeration fans with low airflow rates when attempting to dry high-moisture seed.

Automatic controllers for aeration drying are also available to run fans at optimum ambient air conditions. Some controller models provide the option to switch to either cooling or drying function. Ensure that the controller is fitted with a good-quality relative humidity sensor.¹³

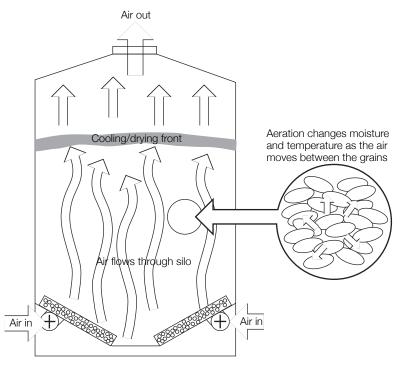


Figure 3: Cooling-drying fronts in the aeration process. (Source: C. Newman, DAFWA)

13.6.5 Heated air drying

For hot-air drying of canola seed, fixed-batch, recirculating-batch or continuous-flow dryers are all suitable for reducing moisture content. Always consider the blending option first if low-moisture canola seed is available. Canola seed dries very rapidly compared with cereal grains, so close attention must be given to temperature control and duration to ensure that seed is not over-dried. It is wise to use the minimum amount of additional heat:

- Use air temperatures in the 40–45°C range.
- Stay nearby and monitor moisture content every 15 min. Over-drying of canola seeds can occur rapidly. Seek advice if drying canola for first time.
- For batch-dryers when moisture content readings reach 8.5%, turn off the heat source and move to the seed-cooling phase with fan only. Retest once cooled.
- Use belt conveyors or run the auger full when moving seed to reduce seed damage.
- Aim to make good use of storage aeration fans, before and after the drying process.¹⁴

13.6.6 Fire risk

The dust and admixture associated with oilseeds presents a serious fire risk. Harvesting and drying are high-risk operations where constant vigilance is required. Good



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¹³ P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-Safe_Storage_of_Canola_Philip_Burrill_-V2_Sep_2012.pdf</u>

¹⁴ P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, http://www.australianoilseeds.com/_data/assets/pdf_ file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf



housekeeping in and around equipment and close observation of problem sites will reduce the threat.

In case of fire, ensure that appropriate equipment is at hand and a plan of action understood by operators. Without careful management, canola seeds in storage with high moisture content and/or high levels of admixture pose a risk of mould formation, heating and fire through spontaneous combustion.¹⁵

13.7 Insect pest control

Several insect pests will infest stored oilseeds, usually favouring the grain surface. These are the rust-red flour beetle (Figure 4), Indian meal moth (*Plodia interpunctella*) (Figure 5), warehouse moths (*Ephestia* spp.) and psocids (*Liposcelis* spp.)



Figure 4: Rust-red flour beetle (Tribolium castaneum).



Figure 5: Indian meal moth (Plodia interpunctella).

These pests multiply rapidly given food, shelter, and warm, moist conditions. They can complete their full life cycle in about 4 weeks under optimum breeding temperatures of \sim 30°C.



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¹⁵ P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf</u>



Only a few treatments are registered for insect control in oilseeds. Always check labels prior to use and abide by use restrictions for different states and territories in Australia. For most states, treatments include phosphine, pyrethrins, DE, and ethyl formate as Vapormate[®]. Use of pyrethrins and DE should be limited to storage-area treatments, and Vapormate[®] is restricted for use by licensed fumigators only. This leaves phosphine as the key farm storage treatment for oilseed storage pests.

Phosphine fumigation must take place in a gas-tight, well-sealed silo. If the silo passes the standard pressure test, it shows that there are no serious leakage points. Given this, phosphine gas can be held in the silo at high enough concentrations for sufficient time to kill all life stages of the pest (eggs, larvae, pupae, adults).

Several silo manufacturers make aeratable, sealable silos that pass the Australian Standard Pressure Test—AS 2628. Like most oilseeds, canola seed has the ability to adsorb phosphine gas, and so it is important to use the full, correct label dose rate.

By using phosphine bag-chains, belts or blankets, placement and removal of the treatment is simplified. If using the standard phosphine tablets, ensure that tablets are kept separate from the canola seed by using trays so the spent tablet dust can be removed following fumigation.

If aeration cooling has been in use and the seed temperature is $<25^{\circ}$ C, ensure that the fumigation exposure period is \geq 10 days. See product label for details.

Once the fumigation is completed, release the seal, vent the gas, and return the stored canola to aeration cooling. $^{\rm 16}$

13.8 Further reading

Stored Grain Information Hub for Grain Storage, Quality Control, Insect & Pest Management. GRDC, <u>www.storedgrain.com.au</u>

Storing oilseeds. Stored Grain Information Hub. GRDC, <u>http://storedgrain.com.au/</u> storing-oilseeds/

Vigilant monitoring protects grain assets. Stored Grain Information Hub. GRDC, <u>http://storedgrain.com.au/monitoring-protects-grain/</u>

Northern and Southern Regions. Stored grain pests—identification. Stored Grain Information Hub. GRDC, <u>http://storedgrain.com.au/stored-grain-pests-id-ns/</u>

Hygiene & structural treatments for grain storage. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/hygiene-structural-treatments/

Aerating stored grain, cooling or drying for quality control. Stored Grain Information Hub. GRDC, <u>http://storedgrain.com.au/aerating-stored-grain/</u>

Performance testing aeration systems. Stored Grain Information Hub. GRDC, <u>http://storedgrain.com.au/testing-aeration/</u>

Fumigating with phosphine, other fumigants and controlled atmospheres. Stored Grain Information Hub. GRDC, <u>http://storedgrain.com.au/fumigating-with-phosphine-and-ca/</u>

Pressure testing sealable silos. Stored Grain Information Hub. GRDC, <u>http://storedgrain.</u> <u>com.au/pressure-testing/</u>

Grain storage facilities: planning for efficiency and quality. Stored Grain Information Hub. GRDC, <u>http://storedgrain.com.au/grain-storage-facilities/</u>

Phone enquiries: grain storage specialists: 1800 weevil (1800 933 845)



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¹⁶ P Burrill (2012) Safe storage. Module 8. In Better canola—canola technology update for growers and advisors. Australian Oilseeds Federation, <u>http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE 8 - Safe Storage of Canola Philip Burrill - V2 Sep 2012.pdf</u>



SECTION 14

Environmental issues

Frost, moisture stress and heat stress can all have an impact on grain yield, oil content and oil quality. Frost can occur at any time during the growth of the canola plant, but the most damaging frosts occur when pods are small. Pods affected at this time have a green to yellowish discoloration, then shrivel and eventually drop off. Pods affected later may appear blistered on the outside of the pod and usually have missing seeds.

Moisture stress and heat stress are linked; the plant will suffer heat stress at a lower temperature if it is also under moisture stress. Flower abortion, shorter flowering period, fewer pods, fewer seeds per pod and lower seed weight are the main effects, occurring either independently or in combination.¹

Catastrophic events

Farming is a risky enterprise, with great uncertainty about production and profitability from season to season. Australia has a wide variety of climates, each with high variability, which means exposure to great variation in yields. Australian farmers are generally very good at managing this variation. However, a sudden shock may put systems for managing variation to the test.

Recent events of frost and disease in the grain-production regions of south-eastern Australia have tested growers' resolve for managing catastrophes. A catastrophe is a sudden and widespread disaster, and in farming, the potential causes of catastrophe are numerous. In a cropping context, returns can be severely affected by external factors over which growers have no control.

Growers cannot avert a catastrophic event but they can spread risk to minimise its effect. No single strategy will cope with a catastrophic event; multiple strategies are required.

When confronted with a catastrophic event, growers may be in a state of shock. Decision-support tools can be useful for focusing on what can be done to salvage the situation.²

GRDC's new approach to frost

Frost has been estimated to cost Australian growers ~\$360 million in yield losses both direct and indirect every year. The Grains Research and Development Corporation (GRDC) has long acknowledged the severe impacts of frost on crop production, and since 1999 has invested ~\$13.5 million in more than 60 frost-related projects.

By 2014, GRDC increased investment in frost research to establish the National Frost Initiative (NFI). This 5-year, national initiative is tackling frost from several angles and aims to deliver growers a combination of genetic and management solutions to be combined with tools and information to improve prediction of frost events.



<u>Managing the</u> <u>catastrophes – for-</u> <u>example, frost, BWYV,</u> <u>pests</u>



Grains Research & Development Corporation

T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, <u>http://www.grdc.com.</u> au/uploads/documents/GRDC Canola Guide All 1308091.pdf

² T McClelland, H van Rees (2014) Managing the catastrophes—for example; frost, BWYV, pests. GRDC Update Papers, 18 September 2014, <u>http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/09/Managing-the-catastrophes-for-example-frost-BWYV-pests</u>



The three-pronged initiative addresses:

- 1. Genetics. The aim is to rank current wheat and barley varieties for frost susceptibility and identify more frost-tolerant wheat and barley germplasm
- 2. Management. Are there management practices or preventive products that growers could use to reduce the impact of frost?
- Environmental prediction. Focus is on predicting the impact of frost events on crop yields and mapping frost events at the farm scale to enable better risk management.³

Listen to GRDC Driving Agronomy podcasts:

- New GRDC-funded research will seek to find out whether applying additional potassium to a crop will help it resist the stress of drought and frost.
- 2015 will see the introduction of frost-tolerance ratings in cereal crops. On this
 program, GRDC Managing Director, John Harvey, explains how it came about and
 talks about some other research and development highlights.

More information on GRDC Driving Agronomy:



http://grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2014/02/Potassium-Frost-and-Drought

http://grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2013/12/Frost-Tolerance-Ratings-on-the-Way

14.1 Frost

Canola is least tolerant to frost damage from flowering to the clear watery stage (~60% moisture).

Symptoms include:

- yellow-green discoloration of pods (Figure 1)
- scarring of external pod surfaces
- abortion of flowers (Figure 2)
- shrivelling of pods
- pods eventually dropping off (Figure 3)
- shrivelling and absence of seeds (Figure 4)
- T March, S Knights, B Biddulph, F Ogbonnaya, R Maccallum, R Belford (2015) The GRDC National Frost Initiative. GRDC Update Papers, 10 February 2015, <u>http://www.grdc.com.au/Research-and-Development/</u> <u>GRDC-Update-Papers/2015/02/The-GRDC-National-Frost-Initiative</u>



Frost-damaged crops – where to from here?

Frost and cropping

What's going on with frost?

The GRDC National Frost Initiative

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Figure 1: Yellow-green discoloration of pods, compared with healthy green pods.



Figure 2: Canola plant showing various stages of pod loss and flower abortion.



Figure 3: Stunted pods that have dropped off.







1 More information

Diagnosing frost damage in canola

Pulse and canola frost identification. The Back Pocket Guide



<u>Cautious optimism for</u> <u>frost-tolerance advance</u>

More

wheat crops

information

Sowing date, heat stress

and frost risk in irrigated

Figure 4: Missing and shrivelled seeds.

Canola flowers for a 30–40-day period, allowing podset to continue after a frost. Open flowers are most susceptible to frost damage, whereas pods and unopened buds usually escape. If seed moisture content is <40% when frost occurs, oil quality will not be affected. ⁴

Once established, canola is relatively frost-tolerant, but damage can occur during the cotyledon stage and the seedlings can die if frosted. Plants become more frost-tolerant as they develop.

Seedling growth and vigour are reduced at temperatures <7°C, and occasionally seedlings will die.

Soluble carbohydrates accumulate when there is a rapid reduction in leaf temperature. This accumulation suppresses photosynthesis, and therefore seedling growth rates, during the cooler winter months. 5

14.1.1 Frost damage in crops—where to from here?

- Frost is a relatively rare occurrence but some areas are more prone to it.
- Frost frequency has increased in many areas in the last 20 years.
- Minor agronomic tweaks might be necessary in some frost-prone areas but for most growers it should be 'steady as she goes'.
- In the event of severe frost, monitoring needs to occur up to 2 weeks afterwards to detect all of the damage.

A small survey conducted by the Department of Environment and Primary Industries, Victoria (DEPI) in October–November 2013 showed that 68% of 111 respondents in south-eastern Australia were very or moderately concerned about frost damage in cereals. For frost damage in canola, the percentage was less, at 40%, and in pulses 57%. ⁶

- ⁶ D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, <u>https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</u>



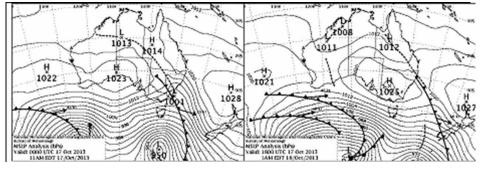
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⁴ C White (2000) Pulse and canola—frost identification. The Back Pocket Guide. Reprinted 2003. Department of Agriculture, Western Australia/GRDC, <u>https://www.grdc.com.au/Resources/Bookshop/2012/01/Pulse-Canola-Frost-Identification-The-Back-Pocket-Guide-GRDC046</u>



What causes frost?

Clear, calm and dry nights following cold days are the precursor conditions for a radiation frost (or hoar frost). These conditions are most often met during winter and spring where high pressures follow a cold front, bringing cold air from the southern ocean but settled, cloudless weather. When the loss of heat from the earth during the night decreases the temperature at ground level to 0°C, a frost occurs (Figure 5). Wind and cloud reduce the likelihood of frost by reducing the loss of heat to the atmosphere. The extent of frost damage is determined by how quickly the temperature reaches 0°C, the length of time its stays below 0°C, and the how far it drops below 0°C.⁷



A cold front passes through, injecting cold air in from the Southern Ocean the day before the frost. Overnight the high stabilises over SE Australia meaning clear skies and no wind. Frost happens.

Figure 5: Common weather patterns experienced prior to frost occurrence.

Frost effect on the plant

Two types of frost are experienced in Victoria, 'white' and 'black'. White frost occurs when the air around the plant is moist and the temperature around the plant is $\leq 0^{\circ}$ C. Ice crystals form on the surface of the plant (hence, 'white'). The water between plant cells freezes and draws water out of surrounding cells to form more ice. When frost melts slowly (e.g. in winter), damage is minor and the plants repair themselves. Often, the least damage is in the shadows of trees where the thaw is slower, or on the side of the grain head away from the sun. The visual effect is similar to drought stress because plants can temporarily appear wilted. In spring, the thawing can be rapid and damage can be severe.

Black frost occurs when the temperature drops below 0°C but the surrounding air is dry (e.g. in drought conditions). Ice cannot form on the plant surface and the water between cells freezes quickly and forms large crystals. These large crystals 'pop' holes in the cells, causing permanent damage. Once thawed, the plant parts affected immediately look floppy, spongy and discoloured. If that plant part is a flower or a developing ovary, the result can be detrimental to yield.

Frost damage occurs to canola pods, flowers and seeds. Podding canola is very sensitive to frost. $^{\rm 8}$

Are frosts becoming more frequent?

- In southern regions of Australia, despite global warming, the number of spring frosts has increased and the period of frost occurrence has changed (i.e. broadened over the southern New South Wales (NSW), Victoria and part of South Australia and become later over Western Australia and western parts of South Australia).
- Frost occurrence is linked to a long-term, southerly shift in position and intensification of the band of high pressure typically located over Central Australia in spring.



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D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here

⁸ D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, <u>https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</u>



- Over many parts of NSW, the length of the frost season has increased by as much as 40 days.
- Subsequent studies have shown that this current level of risk is expected to continue over the next 20 years despite continued increases in mean temperatures.

In the DEPI survey, 66% of respondents thought that frost occurred 1–3 years in 10, but the spread of responses between 'never' and 'every year' was large. Geographic viewing of the data might help to elucidate this for the different regions.

It is ironic that as temperatures (particularly those in winter and spring) are increasing, frost remains a major issue. CSIRO researchers have discovered that in some areas of Australia, the frost number is rising (greatest in August) (Figure 6). Eyre Peninsula, Esperance, northern Victorian Mallee and Central West NSW were the only major cropgrowing areas to be less affected by frost in the period 1961–2010 (Crimp *et al. 2014*). Contributing factors are thought to be that the latitude of the subtropical ridge of high pressure is drifting south (causing more stable pressure systems) and the existence of more El Niño conditions during this period. ¹⁰

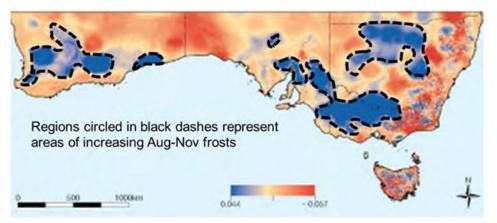


Figure 6: Regions of increasing frosts in August–November. (Source: Steven Crimp)

Key management strategies

Paddock selection is critical for canola. Avoid sowing canola on paddocks with high frost risk because frost damage is irreversible.

Risk may be reduced by:

- · later sowing or choosing varieties to spread flowering time of crops
- · avoiding potassium deficiency
- early grazing
- · sowing more tolerant crops in frost-prone paddocks
- inspecting crops between grainfill and prior to swathing timing if night air temperature (recorded 1.2 m aboveground) falls below –1°C
- checking low-lying, light-coloured soil types and known frost-prone areas, followed by other areas



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⁹ S Crimp, D Gobbet, D Thomas, S Bakar, U Nidumolu, P Hayman, G Hopwood (2015) 'Jack' of frosts – recent trends and drivers of change. GRDC Update Papers, 17 February 2015, <u>http://www.grdc.com.au/ Research-and-Development/GRDC-Update-Papers/2015/02/Jack-of-frosts-recent-trends-and-drivers-ofchange</u>

D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, <u>https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</u>



To identify frost damage, open up pods and check for mushy or shriveled grain. Often, these pods will have a scarred or blistered surface when inspected closely. ¹¹

The importance of sowing time and flowering dates

To maximise frost-risk resilience, you need a mix of sowing dates and maturity types to avoid damage from the late frosts. In years of severe frost, it may be impossible to prevent damage. ¹²

A simulation study at locations in southern NSW in 2014 showed that slower developing spring varieties had their highest yield from early sowing (early–mid April), whereas faster developing spring varieties were at flowering/early podfill before and during the harsh frost period of early August if sown early, which reduced grain yield at frosty sites.

This is because pod development is the stage at which canola is most sensitive to frost damage. The youngest water-filled pods (>60% water) are the most sensitive to frost damage; however, they have also demanded less energy at this stage, so the loss of these pods may not significantly limit yield if time and favourable seasonal conditions are sufficient for compensation. The older and more developed the seed within the pod, the lower the water content and the more frost-tolerant it becomes, but also the greater energy it has used to develop. When temperatures are cold enough to damage these pods, there is generally a much greater yield loss to the plant due to less ability to compensate, especially in low rainfall environments. ¹³

The DEPI survey asked growers and advisors what they currently do to mitigate frost damage (Table 1). Most respondents use crop types and maturity length regularly, but few will mix their sowing times to manipulate frost risk exposure. Even fewer choose to sow later. Some do treat frost-prone areas differently or grow smaller areas of the susceptible crops. ¹⁴

 Table 1: Results of DEPI survey regarding growers' methods of mitigation of frost damage (n = 111)

	All the time	Most of the time	Some of the time	Never	Other
Sowing a mix of crop types	26%	36%	28%	10%	
Sowing a mix of crop maturities	20%	33%	37%	10%	
Sowing at a mix of times	5%	16%	46%	32%	
Delaying sowing	3%	2%	37%	59%	
Treating frost-prone areas differently	9%	10%	32%	49%	
Growing less of the most susceptible crops	7%	13%	48%	32%	
Other					3%

14.1.2 Issues that can be confused with frost damage

Many other problems can be confused with frost damage. The main ones are those causing distortion of the plant, absence of the seeds or unusual colour (see examples in Figures 7–9). Management and recent environmental conditions should be taken into account when identifying any crop disorder.



Early sowing of canola in southern NSW



Driving Agronomy podcasts. New frost ratings

What to do with a frosted crop

Cold problem in the hot seat

Frost: no room for complacency

Driving Agronomy Podcasts. Frost to stay



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¹¹ DAFWA (2015) Diagnosing frost damage in canola. MyCrop. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-frost-damage-canola</u>

¹² D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, <u>https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</u>

¹³ R Brill, J Kirkegaard, J Lilley, I Menz, D McCaffery, C McMaster (2015) Early sowing of canola in southern NSW. GRDC Update Papers, 17 February 2015, <u>http://www.grdc.com.au/Research-and-Development/</u> <u>GRDC-Update-Papers/2015/02/Early-sowing-of-canola-in-southern-NSW</u>

¹⁴ D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, <u>https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here</u>

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Figure 7: Aphids on canola flower stem.



Figure 8: Sulfur deficiency and aphids. Flower petals retained; pods stunted with yellowing-reddening.



Figure 9: Herbicide damage in canola. Photo: Harm van Rees



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It is important to remember that frost damage is random and sporadic, and not all plants (or parts of plants) will be affected, whereas most disease, nutrient and moisture-related symptoms will follow soil type. ¹⁵

The optimum temperature range for leaf development of canola is $13^{\circ}-22^{\circ}$ C. At higher temperatures, growth is faster, and the period of leaf development is therefore shorter. Lower temperatures do not reduce yield in early growth, except when heavy frosts occur, but they do slow the rate of development. As temperatures increase to >20°C in July and August, yields are reduced.

For frost injury, ice must form between or inside the cells. Water surrounding the plant cells will freeze at 0°C, but water inside the cells needs to be a few degrees cooler to freeze. The length of exposure of the plant to cold is another important factor. Plants can be cold-hardened by repeated exposure over several days. They can survive -8° C to -12° C in Canada, but exposure to warm weather will reverse this hardening, making the plants susceptible to temperatures of -3° C to -4° C. ¹⁶

14.2 Waterlogging and flooding

14.2.1 Symptoms of waterlogging

Paddock symptoms:

- Poor germination or purple-yellow plants can occur in areas that collect water, particularly on shallow duplex soils.
- Bare wet soil and/or water-loving weeds are present.
- Plant lodging and early death occur in waterlogging-prone areas.
- Saline areas are more affected.

Plant symptoms:

- Waterlogged seedlings can die before emergence or show symptoms similar to nitrogen deficiency.
- Lower leaves turn purple-red to yellow, then die.
- Prolonged waterlogging causes root death and eventually death of the whole plant; plants are more susceptible to root disease.
- Waterlogging of adult plants causes yellowing of lower leaves.
- Salinity magnifies waterlogging effects, with more marked stunting and oldest leaf marginal necrosis and death.¹⁷

14.2.2 Effect on yield

Canola roots need a good mix of water and air in the soil. When the amount of water exceeds the soil's water-holding capacity, waterlogging may occur. Canola is susceptible to waterlogging and shows a yield reduction after only 3 days.

The severity of yield loss depends on the growth stage at the time of waterlogging, the duration of waterlogging, and the temperature (Figure 10).



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information All not lost if dry spring thwarts N uptake

¹⁵ C White (2000) Pulse and canola—frost identification. The Back Pocket Guide. Reprinted 2003. Department of Agriculture, Western Australia/GRDC, <u>https://www.grdc.com.au/Resources/Bookshop/2012/01/Pulse-</u> Canola-Frost-Identification-The-Back-Pocket-Guide-GRDC046

⁶ J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0004/516181/Procrop-canola-growth-anddevelopment.pdf</u>

¹⁷ DAFWA. Diagnosing waterlogging in canola. MyCrop. Department of Agriculture and Food Western Australia, <u>https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-canola</u>

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Should waterlogged crops be topdressed with N fertiliser?

Over the bar with better canola agronomy



Diagnosing waterlogging in canola

Alleviation of waterlogging damage by foliar application of nitrogen compounds and tricyclazole in canola

<u>Growing canola on</u> raised beds in southwest Victoria

Nitrogen and sulfur for wheat and canola protein and oil

APSIM Canola

Waterlogging and canola

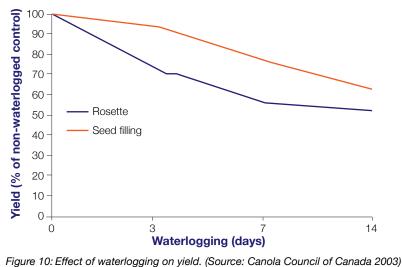
Waterlogging in Australian agricultural landscapes: a review of plant responses and crop models

Crop production potential and constraints in the high rainfall zone of southwestern Australia: Yield and yield components

Improving canola establishment to reduce wind erosion



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Wet soils will slow or prevent gas exchange between the soil and atmosphere, causing oxygen deficiency. High temperatures cause high respiration rates in roots and soil microorganisms, so soil oxygen is consumed more quickly.

Soil texture also affects the time at which critical levels of soil oxygen are reached. This is due to the oxygen-carrying capacity of soils. Coarser textured soils can hold more oxygen, increasing the amount of time before oxygen levels are reduced to a critical point.

Other effects of waterlogging are reductions in root growth, plant growth, plant height, dry matter production and nutrient uptake. ¹⁸

14.2.3 Germination

Canola is sensitive to waterlogging during germination. When soils become waterlogged, the oxygen supply in the soil solution rapidly decreases. Oxygen is essential for seed germination. Without oxygen, seeds cannot continue their metabolic processes, and germination ceases. Prolonged waterlogging can kill canola seeds and seedlings.¹⁹

14.2.4 Seedfill

During seed-filling, waterlogging for >7 days decreases individual seed weight and oil content. High temperatures exacerbate the effects of waterlogging on canola yield.

The impact of waterlogging is greater if it occurs at the rosette stage. The longer the period of waterlogging, the greater the impact.²⁰

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¹⁸ J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/___data/assets/pdf_file/0004/516181/Procrop-canola-growth-anddevelopment.pdf</u>

¹⁹ J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, <u>http://www.dpi.nsw.gov.au/______data/assets/pdf__file/0004/516181/Procrop-canola-growth-anddevelopment.pdf</u>



SECTION 15 Marketing

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

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 factors that are difficult to quantify in order to establish the target price and then working towards achieving that target price.

These factors 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 (Figure 1).

The skills that growers have developed to manage variability and costs can be used to manage and overcome price uncertainty.

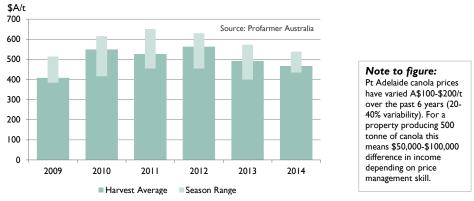


Figure 1: Annual price variation (season average and range) for Port Adelaide canola.

15.1.1 Be prepared

Being prepared and having a selling plan are essential for managing uncertainty. The steps involved are forming a selling strategy and having a plan for effective execution of sales. A selling strategy consists of when and how to sell.



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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 depends more on external market factors including:

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

The key selling principles when considering sales during the growing season are described in Figure 2.

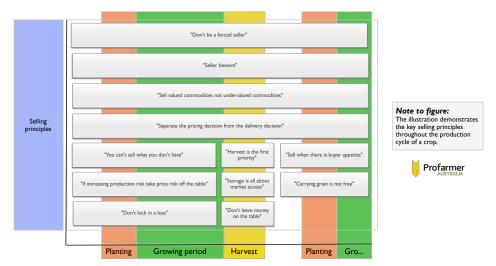


Figure 2: Grower commodity selling-principles timeline.

15.1.2 Establishing 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 of a cropping enterprise, and how those risks may be quantified during the production cycle, are described in Figure 3.

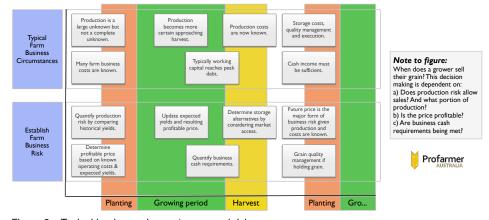


Figure 3: Typical business circumstances and risk.





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.' Do not increase business risk by overcommitting production.

Establish a production risk profile (Figure 4) by:

- collating historical average yields for each crop type and a below-average and an above-average range
- assessing the likelihood of achieving average, based on recent seasonal conditions and seasonal outlook
- · revising production outlooks as the season progresses

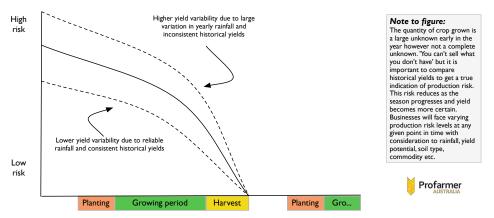


Figure 4: Typical production risk profile of a farm operation.

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 that the price is profitable.

Steps to calculate an estimated profitable price based on total cost of production and a range of yield scenarios are provided in Figure 5.



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1,200 ha	, Step 1: Estimate your production potential.
,∠00 na	The more uncertain your production is,
.45 t/ha	the more conservative the yield estimate should be. As yield falls, your cost of
1,740 t	production per tonne will rise.
100,000	Step 2: Attribute your fixed farm business costs. In this instance if 1,200 ha reflects
\$80,000	1/3 of the farm enterprise, we have
\$70,000	attributed 1/3 fixed costs. There are a number of methods for doing this (see M
\$60,000	Krause "Farming your Business") but the
\$30,000	most important thing is that in the end all costs are accounted for.
	costs are accounted for.
\$48,000	
168,000	
\$84,000	Step 3: Calculate all the variable costs attributed to producing that crop. This can
\$36,000	also be expressed as \$ per ha x planted
\$48,000	area.
\$18,000	
742,000	
\$426 /t	 Step 4: Add together fixed and variable costs and divide by estimated production
\$3 /t	Step 5: Add on the "per tonne" costs like
\$12 /t	levies and freight.
\$22 /t	Step 6: Add the "per tonne" costs to
\$37 /t	\sim the fixed and variable per tonne costs calculated at step 4.
\$463.44	× .
\$93.00	Step 7: Add a desired profit margin to arrive at the port equivalent target profitable
\$556.44	price.
	1,740 t 1,740 t 100,000 \$80,000 \$60,000 \$30,000 \$30,000 \$48,000 \$48,000 \$48,000 \$48,000 \$48,000 \$48,000 \$42,000 \$40,0000 \$40,0000 \$40,0000 \$40,0000 \$40,0000 \$40,0000 \$40,00

Figure 5: Steps to calculate an estimated profitable price for canola.

The GRDC manual '<u>Farming the business</u>' also provides a cost-of-production template and tips on skills required for grain selling, as opposed to grain marketing.¹

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.

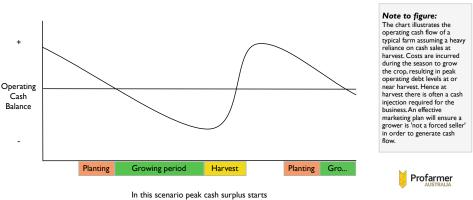
A typical cash flow to grow a crop is illustrated in Figure 6. Costs are incurred upfront and during the growing season, with peak working capital debt incurred at or before harvest. This will vary depending on circumstances and enterprise mix. Figure 7 demonstrates how managing sales can change the farm's cash balance.

M Krause (2014) Farming the business. Sowing for your future. GRDC, <u>http://www.grdc.com.au/</u> FarmingTheBusiness

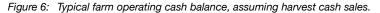


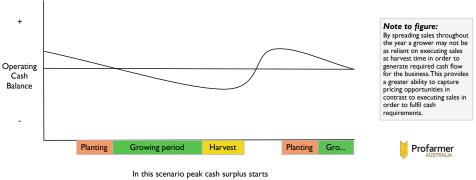






higher and peak cash debt is lower





lower and peak cash debt is higher

Figure 7: Typical farm operating cash balance, with cash sales spread throughout the year.

Summary

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

This is the second part of the selling strategy.

Methods of price management

The pricing methods for products provide varying levels of price risk coverage (Table 1).



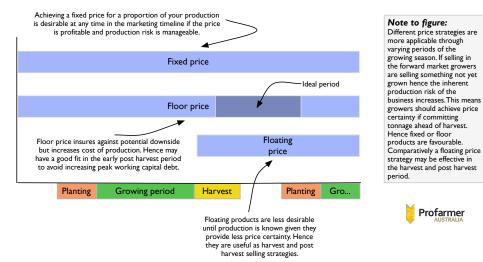
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Table 1:	Pricing methods and how they are used for various crops

	Description	Wheat	Barley	Canola	Sorghum	Maize	Faba beans	Chick peas
Fixed price products	Provides the most price certainty	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash	Cash
Floor price products	Limits price downside but provides exposure to future price upside	Options on futures, floor price pools	Options on futures	Options on futures	Options on futures	Options on futures	none	none
Floating price products	Subject to both price upside and downside	Pools	Pools	Pools	Pools	Pools	Pools	Pools

Figure 8 below provides a summary of when 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) (Figure 9). It provides some certainty around expected revenue from a sale because 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.



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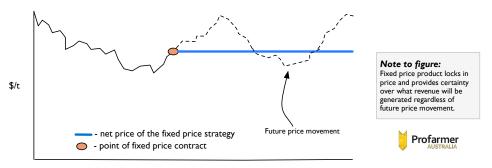


Figure 9: Fixed-price strategy.

Floor price

Floor price strategies can be achieved by utilising 'options' on a relevant futures exchange (if one exists), or via a managed sales program product by a third party (i.e. a pool with a defined floor-price strategy). This pricing method protects against potential future downside while capturing any upside (Figure 10). The disadvantage is that the price 'insurance' has a cost, which adds to the farm businesses cost of production.



Figure 10: Floor-price strategy.

Floating price

Many of the pools or managed sales programs are a floating price, where the net price received will move both up and down with the future movement in price (Figure 11). Floating price products provide the least price certainty and are best suited for use at or after harvest rather than pre-harvest.



Figure 11: Floating-price strategy.

Summary

Fixed-price strategies include physical cash sales or futures products and provide the most price certainty; however, 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; however, they cost more.

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



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15.1.4 Ensuring access to markets

Once the selling strategy is organised, the storage and delivery of commodities must be planned to ensure timely access to markets and execution of sales. At some point growers need to deliver the commodity to market; hence, planning where to store the commodity is important in ensuring access to the market that is likely to yield the highest return (Figure 12).

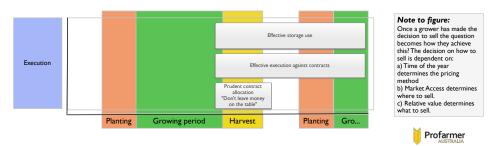


Figure 12: Effective storage decisions.

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 (Figure 13).

Principle: 'Harvest is the first priority.' Getting the crop into 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. feedlot, 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 that the grower may have to suffer the cost of taking the load elsewhere, while 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 that 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 about on-farm storage alternatives and economics, refer to <u>GrowNotes Canola Southern Region. Chapter 13. Grain storage</u>.



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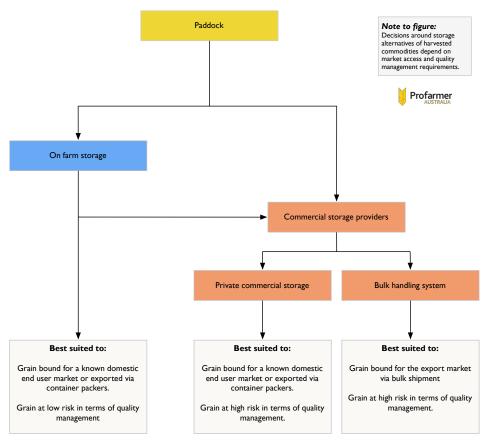


Figure 13: Grain storage decision-making.

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 per month are typically \$3-4/t, consisting of:

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

The price of carried grain therefore needs to be 3-4/t per month higher than was offered at harvest. The cost of carry applies to storing grain on-farm because there is a cost of capital invested in the farm storage plus the interest component. A reasonable assumption is 3-4/t per month for on-farm storage.

Principle: 'Carrying grain is not free.' The cost of carrying grain needs to be accounted for if holding grain and selling it after harvest is part of the selling strategy (Figure 14).



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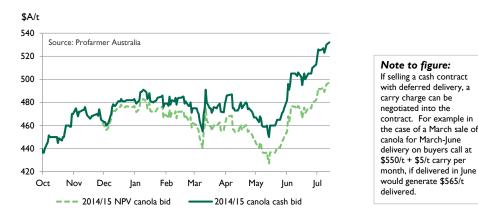


Figure 14: Port Adelaide canola cash v. net present value (NPV).

Summary

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

15.1.5 Executing tonnes into cash

Below are 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; and other market information pertinent to the particular commodity.
- 2. Professional services. Grain-selling professional service offerings and cost structures vary considerably. An effective grain-selling professional will put their clients' best interests first by not having conflicts of interest and by investing time in the relationships. 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 that utilise exchanges such as CBOT (Chicago Board of Trade) can add significant value.

For current financial members of Grain Trade Australia including buyers, independent information providers, brokers, agents, and banks providing over-the-counter grain derivative products (swaps), go to: <u>http://www.graintrade.org.au/membership</u>.

For a list of commodity futures brokers, go to: <u>http://www.asx.com.au/prices/find-a-futures-broker.htm</u>.

How to sell for cash

Like any market transaction, a cash grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components, with each component requiring a level of risk management (Figure 15):

• **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 management of execution 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.

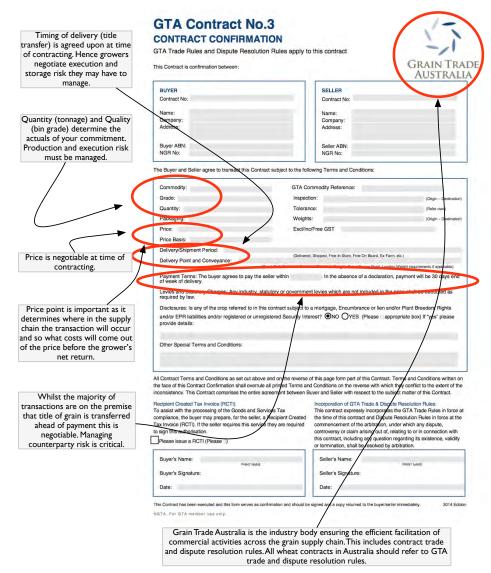


Figure 15: Typical cash contracting as per Grain Trade Australia standards.

The pricing point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. Figure 16 shows 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.



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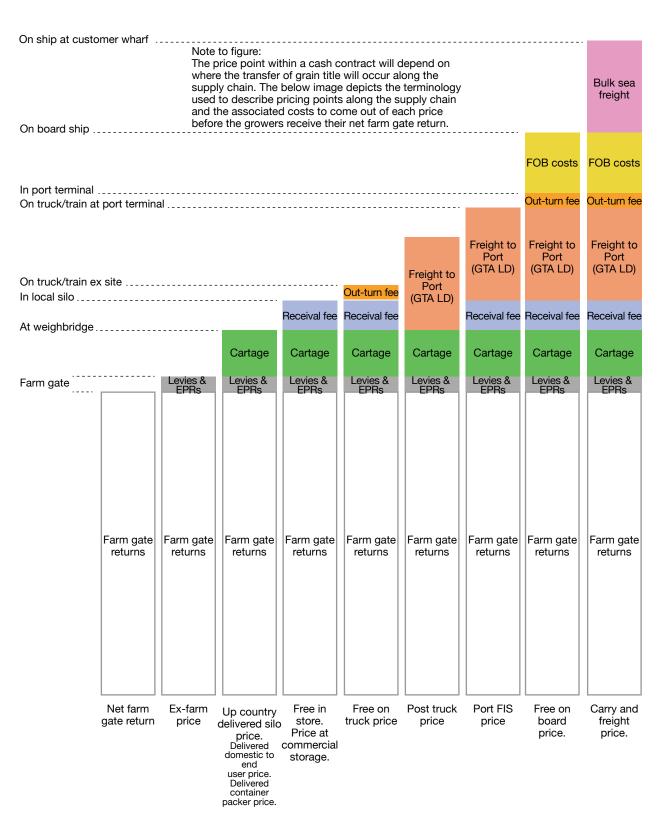


Figure 16: Costs and pricing points throughout the supply chain.



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GTA Guide to taking out contracts

GTA Contracts and vendor declarations

GTA Trading standards

GrainTransact Resource Centre

GrainFlow Network

Emerald Grain customer and grower logins

Clear Grain Exchange terms and conditions

<u>Clear Grain Exchange</u> <u>getting started</u>



GTA Grain contracts managing counterparty_ risk

<u>Clear Grain Exchange</u> <u>title transfer model</u>

GrainGrowers Guide to managing contract risk

Counterparty risk management: A producer perspective— Leo Delahunty Cash sales generally occur through three methods:

- 1. **Negotiation via personal contact.** Traditionally, prices are posted as a 'public indicative bid'. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and is available for all commodities.
- 2. 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 transferring the grain online to the buyer. The availability of this depends on location and commodity.
- 3. **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.' Selling for an extra \$5/t is not a good deal if you do not get payment.

Counterparty risk management includes the following principles:

- · Deal only with known and trusted counterparties.
- Conduct a credit check (banks will do this) before dealing with a buyer you are unsure of.
- Sell only 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 whereby the grower maintains title of grain until payment is received from the buyer, and then title and payment are settled simultaneously.

Above all, act commercially to ensure that the time invested in a selling strategy is not wasted by poor counterparty risk management. Achieving \$5/t more and not receiving payment is a disastrous outcome.



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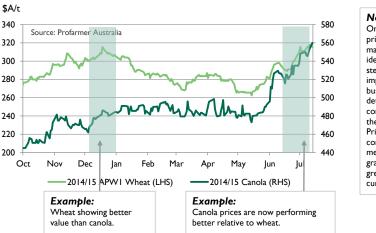


Relative commodity values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well and to hold commodities that are not well priced at any given time; that is, give preference to the commodities 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 while 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. Do not sell the cheaper commodity for a discount.

An example based on wheat and canola production system is provided in Figure 17.



Note to figure: Once the decision to take price protection has been made a grower needs to identify the appropriate steps to achieve this. It is important to use a whole business approach when determining which commodities to sell and the best time to do so. Price relativities between commodities is one method of assessing which grain types 'hold the greatest value' in the current market.

Figure 17: Melbourne Australian Premium White (APW1) wheat v. canola (AU\$/t).

If the decision has been made to sell canola, Intercontinental Exchange[®] (ICE) canola may be the better alternative if the futures market is showing better value than the cash market (Figure 18).

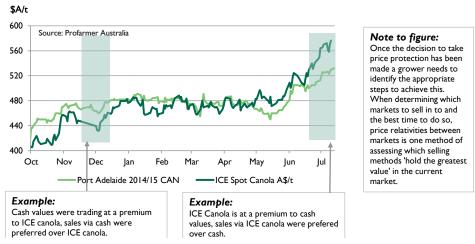


Figure 18: Port Adelaide CAN v. Intercontinental Exchange® (ICE) canola (AU\$/t).



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Contract allocation

Contract allocation means choosing which contracts to allocate your grain against at delivery time. Different contracts will have different characteristics (price, premiums–discounts, oil bonuses, etc.), and optimising your allocation reflects immediately on your bottom line (Figure 19).

Principle: 'Don't leave money on the table.' Contract allocation decisions do not take long, and can be worth thousands of dollars to your bottom line.

Because the majority of Australian canola cash contracts pay price premiums and discounts based on oil for clean seed tonnes, to achieve the best average canola price, growers should allocate:

- · their worst loads (lowest oil and highest admix) to lower priced contracts, and
- their best loads (highest oil and lowest admix) to higher priced contracts.

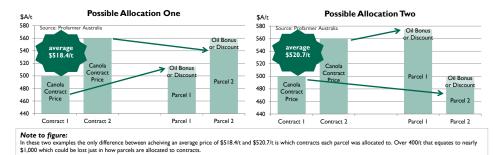


Figure 19: Examples of contract allocation of grain.

Read market signals

The appetite of buyers to purchase 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 as 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 at \$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.

Summary

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



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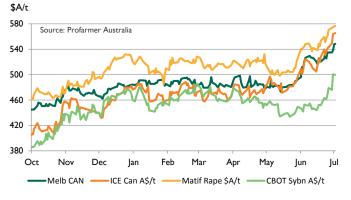
15.2 Southern canola – market dynamics and execution

15.2.1 Price determinants for southern canola

Australia is a relatively small player in terms of world oilseed production, contributing about 5% to global canola production. However, in terms of world trade, Australia is a major player, exporting approximately 75% of the national canola crop, which accounts for about 23% of global canola trade.

Given this dynamic, Australian farm-gate prices are influenced by global price volatility. This makes offshore markets such as the ICE canola contract and Euronext (often referred to as Matif) rapeseed useful indicators of where the Australian canola price will trade (Figure 20).

In addition, global canola values are influenced by supply and demand of other global oilseeds such as soybeans and palm oil. This is because the different oilseed types can be substituted for various uses.



Note to figure: Global canola values and soybeans often trade in similar directions as they act as substitutes for various uses.

Figure 20: Melbourne canola v. offshore markets (AU\$/t).

Figure 21 highlights some of the seasonal factors influencing global canola prices throughout each year. Because of Australia's export focus, the timing of harvest in major exporting and importing countries has considerable influence on prices.

Global Canola Crop Calendar

		J	F	М	A	M	J	J	A	S	0	N	D	J	F	M	A	M	J	J		
Northern	Canola							larvest (EU)		Planting (EU)												
hemisphere	Soybean, Canola						anting nada, China	ı)			larvest anada, China)								n ting ada, China)		Note to figur	
	Canola					Pi (Ai	anting Istralia)						arvest ustralia)					Pla (Au	nting stralia)		demand, which ca during periods of harvests, it can pi lower. When pro-	an happen f large ush prices
Southern	Soybean					arvest Argentina)						i nting Argentina)						arvest Argentina)			uncertain risk pro- be built into price values higher.	emiums ca
	Aussie wheat marketing timeline			Early	pre harv	est sales			Spr	ing marketi	ng window		Harvest sa	les	P	ost-harves	sales				Profar	mer
		J	F	М	A	M	J	J	A	S	0	N	D	J	F	M	A	M	J	J		

Figure 21: Seasonal factors influencing global canola prices.



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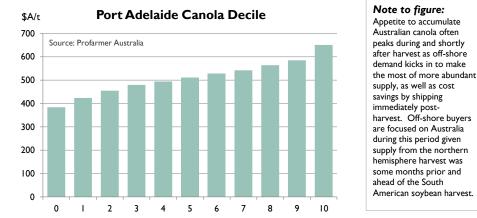


Figure 22: Decile chart illustrating the price distribution for Port Adelaide canola (AU\$/t).

15.2.2 Ensuring market access for southern canola

The majority of South Australian canola is exported in bulk for human consumption (Figure 23); therefore, the bulk handling system is often the most cost-effective pathway to get canola to offshore customers. The bulk storage provider should gain scale efficiencies when moving the bulk commodity grade CAN1.

In Victoria, demand is greater than production in most years; hence, canola from New South Wales is transported over the border to service the relatively large domestic Victorian market. As a result, private commercial and on-farm storage should play a significant role in access to container export and domestic end-user markets. The level of canola export in containers from Victoria remains low, at ~5% of production; however, price premiums can be provided for specific grades because a container can access niche offshore markets. This particularly applies to off-spec (i.e. low oil, high admix) or genetically modified (GM) canola.

For growers that are well positioned to service domestic crushers, these markets can generate premiums over the bulk export markets and provide a return to on-farm storage. Canola crushers are in Melbourne and Numurkah in Victoria, and in Wagga Wagga in southern New South Wales.

	Vict	oria	South A	ustralia	National Total			
	Implied tonnes	% of production	Implied tonnes	% of production	Implied tonnes	% of production		
Bulk	520,000	85%	370,000	94%	2,300,000	74%		
Container	30,000	5%	10,000	3%	90,000	2%		
Domestic Use	320,000	52%	30,000	8%	750,000	24%		

Source: Australian Crop Forecasters

Figure 23: Market destinations for canola—Victoria and South Australia, and national 5-year averages.

Supply-chain flow options are illustrated in Figure 24.



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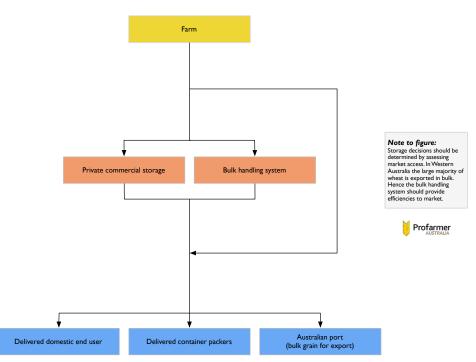


Figure 24: Australian supply-chain flow for canola.

15.2.3 Executing tonnes into cash for southern canola

The key to executing sales effectively is determining which grades to sell and which grades to hold. Niche canola grades such as GM canola are often best sold during harvest or shortly after because buyer appetite often drops away post-harvest, there being fewer buyers for GM canola then conventional. For example, the EU, a major offshore market for Australian canola, does not accept GM product. Hence, once buyers with a specific use for these canola grades have filled their requirements, price discounts to conventional CAN1 can increase (Figure 25). Export pace is strongest shortly after harvest (Figure 26).

Storing canola for domestic markets can provide premium returns, although it is important to monitor buyer appetite. Selling for a future delivery date with a per-month carry built into price can be effective in capturing existing market premiums and generate a return on farm infrastructure without running the risk of the domestic buyers adequately covering their requirements.

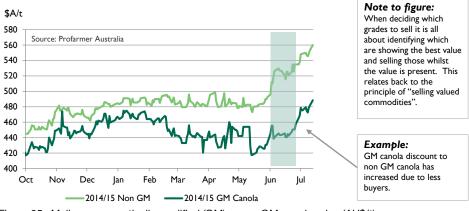


Figure 25: Melbourne genetically modified (GM) v. non-GM canola price (AU\$/t).



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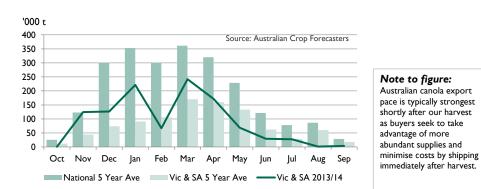


Figure 26: Monthly export pace of canola.

15.2.4 Risk management tools available for southern canola

An Australian cash price has three components: futures, foreign exchange, and basis (Figure 27). Each component affects price. A higher futures and basis and a lower exchange rate will create a higher Australian grain price.



Figure 27: Components of pricing.

Table 2 outlines products available to manage canola prices; the major difference in products is the ability to manage the individual components of price.



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	Description	Advantages	Disadvantages				
Spot cash	Futures, foreign	Simple to use.	Immediate grain delivery required.				
contracts	exchange, basis all locked at time of	Locks in all components of price.	Sales after harvest require storage which incur				
	contracting	Cash is received almost immediately (within payment terms).	costs. Locks away three pricing components at the same time.				
			Risk of counterparty default between transfer and payment.				
Forward cash	Futures, foreign	Simple to use.	Often inflexible and difficult to exit.				
contracts	exchange, basis all locked at time of contracting	Locks in all components of price (no uncovered price risk).	Locks away the three pricing components at the same time.				
		No storage costs.	Future delivery is required resulting in production				
		Cash income is a known ahead of harvest	risk.				
Futures	Futures, foreign	Liquid markets enable easy entry and	Counterparty default risk must be managed. Requires constant management and monitoring.				
contracts	exchange, basis are able to be managed	exit from the marketplace.	Margin calls occur with market movements creating cash-flow implications.				
	individually	price, hence more flexible than cash contracts.	Grain is required to offset the futures position, hence production risk exists.				
		Price determined by the market, and is completely transparent.	Cash prices may not move in line with futures, hence some price risk.				
		No counterparty risk due to daily clearing of the contracts.	You still have to sell the underlying physical grain.				
Over-the- counter	Futures, foreign exchange, basis are able to be managed individually	Based off an underlying futures market so reasonable price transparency.	Costs vary between \$5-10/t at the providers discretion.				
bank swaps on futures		Liquid markets enable easy entry and exit from the marketplace.	Requires constant management and monitoring.				
contracts		Locks in only some components of	Grain is required to offset the futures position, hence production risk exists.				
		price, hence more flexible than cash contracts.	Cash prices may not move in line with futures, hence some price risk.				
		Counter party risk is with the bank, hence it is low.	You still have to sell the underlying physical grain.				
		The bank will manage some of the complexity on behalf of the grower, including day to day margin calls.					
Options on futures	Futures, foreign exchange, basis are	No counterparty risk due to daily clearing of the contracts.	Options can be costly and require payment upfront.				
contracts	able to be managed individually	No margin calls.	The value of options erode overtime as expiry				
		Protects against negative price moves	approaches - depreciating asset.				
		but can provide some exposure to positive moves if they eventuate.	Perceived to be complicated by growers.				
		Liquid markets enable easy entry and exit from the marketplace.	Move in option value may not completely offset move in cash markets.				
		Price risk can be reduced without increasing production risk.	You still have to sell the underlying physical grain.				
		Price determined by the market, and is completely transparent.					

Table 2: Advantages and disadvantages of the products available to manage canola prices

1 More information

For more information and worked examples on how each pricing component affects canola price, refer to the GRDC publication: <u>Grain Market Lingo—what does it all mean?</u>

AOF: Oilseeds industry—delivering high quality products to local and global markets



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SECTION 16 Current research

Project Summaries of GRDCsupported 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. A review of Research Projects supported by the GRDC in 2013-14

Feedback



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



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SECTION 17 Key contacts

Keith Pengilley (Chair)

Keith Pengilley is the general manager of a dryland and irrigated family farming operation at Conara in the northern midlands of Tasmania, operating a 7000-hectare mixed-farming operation over three properties. He is a director of Tasmanian Agricultural Producers, a grain accumulation, storage, marketing and export business. Keith is the chair of the GRDC Southern Regional Panel, which identifies and directs the GRDC's RD&E investments in the southern grains region. M 0448 015 539 E kgpengilley@bigpond.com

Mike McLaughlin (Deputy chair)

Based in Adelaide, Mike McLaughlin is a researcher with the University of Adelaide and CSIRO at the Waite campus. He specialises in soil fertility and crop nutrition, as well as contaminants in fertilisers, wastes, soils and crops. Mike manages the Fertiliser Technology Research Centre at the University of Adelaide and has a wide network of contacts and collaborators nationally and internationally in the fertiliser industry and in soil fertility research. M 0409 693 906

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John Bennett

Based at Lawloit, between Nhill and Kaniva in Victoria's west Wimmera, John Bennett and his wife, Allison, run a mixedfarming operation across diverse soil types. The farming system is 70 to 80 per cent cropping, with cereals, oilseeds, legumes and hay grown. John serves on the GRDC High-Rainfall Zone Regional Cropping Solutions Network and the Birchip Cropping Group Wimmera Advisory Committee. John has a strong desire to see the agricultural sector promoted as an exciting career path for young people and to see R&D investments promote resilient and sustainable farming systems that ultimately deliver more profit to the grower. M 0429 919 223









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Peter Kuhlmann

Peter Kuhlmann is a grower at Mudamuckla near Ceduna on SA's western Eyre Peninsula. He uses liquid fertiliser, no-till and variable-rate technology to assist in the challenge of dealing with low rainfall and subsoil constraints. He has been a board member and chaired the Eyre Peninsula Agricultural Research Foundation and the South Australian Grain Industry Trust. In 2012 Peter won the ABC Rural and Kondinin Group Australian Farmer of the Year award.

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Bill Long

Bill Long is an agricultural consultant and grower on SA's Yorke Peninsula. He has led and been involved in many RD&E programs and was one of the founding members of the Yorke Peninsula Alkaline Soils Group and is a former chair of Ag Excellence Alliance. He has a strong interest and involvement in farm business management and communication programs within the GRDC. He is a Churchill Fellow. M 0417 803 034

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Jon Midwood

Jon Midwood has worked in agriculture for the past 28 years, both in the UK and Australia. He graduated from Harper Adams University in the UK and then spent 13 years working for a large UK farm management company. In 2004 he moved to Geelong, Victoria, and managed Grainsearch, a grower-funded company evaluating European wheat and barley varieties for the high-rainfall zone. Jon set up his own consulting business in 2007, which included managing the commercial contract trials for Southern Farming Systems (SFS). In 2010 he became chief executive of SFS, one of the largest farming systems groups in the southern region with five branches covering southern Victoria

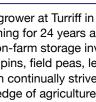
(Gippsland and the western district) and Tasmania. In 2012, Jon became one of the initial members of the HRZ Regional Cropping Solutions Network set up by the GRDC. M 0400 666 434

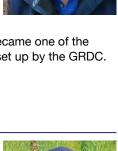
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Rohan Mott

A fourth-generation grain grower at Turriff in the Victorian Mallee, Rohan Mott has been farming for 24 years and is a director of Mott Ag. With significant on-farm storage investment, Mott Ag produces wheat, barley, lupins, field peas, lentils and vetch, including vetch hay. Rohan continually strives to broaden his understanding and knowledge of agriculture, is passionate about the sustainability of Australian agriculture, and has a keen interest in new technology and value-adding. M 0429 701 170

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Rob Sonogan

From Swan Hill in north-west Victoria, Rob Sonogan is an extension agronomist who has specialised within government agencies in the areas of soil conservation, resource conservation and dryland farming systems. Over three decades he has been privileged to have had access to many growers, businesses, consultants, rural industry and agribusiness advisers. Rob also has been closely involved in rural recovery and emergency response into issues as diverse as locusts, fire, mice, flood and drought. Rob is employed part-time within the Mallee consultancy group AGRIvision Consultants. M 0407 359 982



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Mark Stanley comes from a mixed-farming background and has had extensive experience in field crops development and extension and in natural resources management within state and Australian governments and with industry. He operates his own project-management business, Regional Connections, on SA's Eyre Peninsula. Mark leads a large carbon farming outreach and extension project with the Australian Department of Agriculture, and provides executive leadership to Ag Excellence Alliance, supporting farming groups across SA. He is on the board of the Eyre Peninsula Agricultural Research Foundation and is a committee member of the Lower Eyre Agricultural Development Association.



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Kate Wilson is a partner in a large grain operation in Victoria's southern Mallee region. Kate's husband, Grant, is a thirdgeneration grower in the area and, with their two children, they grow wheat, canola, lentils, lupins and field peas. Kate has been an agronomic consultant for more than 20 years, servicing clients throughout the Mallee and northern Wimmera. Kate is passionate about growing high-quality grain, while enhancing the natural ability of the soil to do so. Having witnessed and implemented



much change in farming practices over the past two decades, Kate is also passionate about research and the extension of that research to bring about positive practice change to growers.

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Tanya Howitt

Tanya Howitt joined the GRDC in August 2014 as the executive manager of corporate services, coming from the Australian Fisheries Management Authority where she held two roles over her time there – chief finance officer and general manager corporate. The aim of corporate services is to be the enabler for the GRDC's services and products for stakeholders. Corporate services plays a key role in the GRDC: improving systems and processes, to simplify and automate where possible and to enhance the GRDC's ability to respond to stakeholder requirements.



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