



# GRDC

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# Canola

Northern Region

August 2015

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 projects

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

Canola can have an important role in northern NSW cropping systems, particularly in the higher rainfall areas of the region. It generally yields 40 to 60% of wheat grown under similar conditions and in normal years, average yields of around 1.5 t/ha should be possible with good management.

- What variety should I grow?**
  - What do the blackleg disease ratings mean?
- What's the latest thinking on optimum sowing rate?**
- How much sulfur should I apply to canola?**
  - New research results for the northern region.
- 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?**

**NO TILL**  
Use no-tillage as it stores more **soil moisture** than conventional fallows

Ensure heavy stubble **does not cover the plant line** as it will impede canola establishment

**P** Phosphate nutrition for canola is very important. Canola can respond to phosphorus on soils where wheat does not

**N** Use similar rates of nitrogen on canola as you would for high protein wheat in the same soil

**WESTERN**  
Suited to **early maturing varieties**  
Always sow on **100cm** of wet soil

**EASTERN**  
Suited to **mid season types**  
Always sow on **80cm** of wet soil

Grow **several varieties** to **spread harvest timing** and the **risk of unfavourable events** e.g. moisture stress and frost

Consider **HERBICIDE TOLERANT VARIETIES** e.g. triazine tolerant (TT) RoundupReady® or Clearfield® where weeds are a problem

**SOW**  
Mid season varieties **EARLY MAY**  
Early varieties **MID MAY**  
to minimise frost risk

Recent seasons have seen high levels of aphids in spring, monitor aphid levels in autumn and spring to reduce the impact of virus transmission and crop stress from feeding.

**APHIDS**

Aim to establish **30-50** plants per square metre, which can be achieved by sowing **2-4** kg of seed/ha

If choosing to windrow prior to harvest this should start when **40-60%** of seeds have changed colour to **red, brown or black**

**ESTABLISHMENT FLOWERING PODDING WINDROWING**

Monitor crops for insect pests during the **critical times**. Take account of **BENEFICIAL INSECT NUMBERS** when making decisions on control options

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.

Canola is best followed with a **WINTER CEREAL**, as disease levels (e.g. crown rot) should be reduced and AM\* (Arbuscular Mycorrhiza, previously known as VAM) is not a high requirement with these crops

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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.).<sup>1</sup>

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(il) L(ow) A(cid).<sup>2</sup>

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) ([CODEX International Food Standards 1999](#)), and are often referred to as 'double low' or 'double zero' varieties.<sup>3</sup>

Australian canola typically contains <10 µmol/g of glucosinolates, 43–45% oil, and 38–40% protein in oil-free meal.<sup>4</sup>

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.<sup>5</sup>

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

<sup>2</sup> CanolaInfo (2015) Where does canola come from? CanolaInfo, <http://www.canola.info/canola/where.php>

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

<sup>4</sup> AEGIC. Australian grain note: canola. Australian Export Grains Innovation Centre, [http://www.australianoilseeds.com/oilseeds\\_industry/quality\\_of\\_australian\\_canola](http://www.australianoilseeds.com/oilseeds_industry/quality_of_australian_canola)

<sup>5</sup> CanolaInfo (2015) Where does canola come from? <http://www.canola.info/canola/where.php>

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.<sup>6</sup>



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.

<sup>6</sup> Canola. Wikipedia, <http://en.wikipedia.org/wiki/Canola>

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  $\mu\text{mol/g}$ . 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 crucifer 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 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. Early-maturing varieties currently have lower oil contents than midseason types and often have slightly lower resistance to blackleg; however, further work is being conducted to improve these types.<sup>7</sup>

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.<sup>8</sup>

### A.1.3 Canola in the northern region

Significant areas of canola were grown in the early 1990s, but the crop suffered from frost damage, a series of drought years and the consequences of not forming arbuscular mycorrhizal associations (J. Slatter, pers. comm.), and so the area dropped away. Yield and oil content were variable and often disappointing. Problems with crop production were often cited as being due to variable climatic conditions, poorly adapted cultivars, poor establishment and inadequate nutrition.

Frost at the early stages of pod filling devastated several commercial crops, which led to the perception that canola was poorly adapted to northern climatic conditions. In addition, in areas with significant summer cropping, it was noted that canola suppressed establishment and growth of subsequent sorghum and other summer crops.<sup>9</sup>

The production area of canola in northern New South Wales has increased in recent years, with canola becoming a more important and stable part of the farming system. Canola best management recommendations from the southern region are a useful starting point; however, they need to be fine-tuned and adapted for conditions and soil types in the northern region (New South Wales and Queensland).<sup>10</sup>

### A.1.4 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

<sup>7</sup> B. Colton, T. Potter. History. Australian Oilseeds Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0010/2701/Chapter\\_1\\_-\\_History.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0010/2701/Chapter_1_-_History.pdf)

<sup>8</sup> D McCaffrey (2009) Introduction. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>9</sup> JF Holland *et al.* Canola in the northern region: where are we up to? Australian Oilseeds Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0018/4446/CANOLA\\_IN\\_THE\\_NORTHERN\\_REGION\\_WHERE\\_ARE\\_WE\\_UP\\_TO.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0018/4446/CANOLA_IN_THE_NORTHERN_REGION_WHERE_ARE_WE_UP_TO.pdf)

<sup>10</sup> GRDC (2004) Canola nutrition in the northern region. GRDC Media Centre, Hot Topics, 28 April 2004, <http://www.grdc.com.au/Media-Centre/Hot-Topics/Canola-nutrition-in-the-northern-region>

should never be retained for sowing because it will not produce true copies of the original hybrid plant.<sup>11</sup>

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 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 marketplace. Canola is the third most important winter grain crop in Australia, behind wheat and barley.<sup>12</sup>

### 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

<sup>11</sup> GRDC (2010) Growing hybrid canola. GRDC Canola Fact Sheet, August 2010, [https://www.grdc.com.au/~/\\_media/D4B939DB8790453FB2D6CBD04CA11B78.pdf](https://www.grdc.com.au/~/_media/D4B939DB8790453FB2D6CBD04CA11B78.pdf)

<sup>12</sup> D McCaffrey (2009) Introduction. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcoft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



and international markets. <sup>13</sup> Table 1 shows production in four states for 2013–14 and estimated production for 2014–15.

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	600,000	900,000	550,000	750,000
Vic	400,000	700,000	400,000	700,000
SA	300,000	500,000	280,000	450,000
WA	1,180,000	1,800,000	1,250,000	1,750,000
Total	2,480,000	3,900,000	2,480,000	3,650,000

<sup>13</sup> D McCaffrey (2009) Introduction. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcoft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## SECTION 1

# Planning/Paddock preparation

## 1.1 Paddock selection

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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). It is desirable to soil-test prior to sowing the crop and to continue to manage broadleaf and grass weeds prior to sowing. In the northern region growers need to soil test later the previous winter as nitrogen readings will change due to summer microbial breakdown and leaching.

When considering the rotation using crops such as wheat or barley prior to sowing canola will allow for increased broadleaf control through more herbicide options and increased crop competition. If a pulse is the prior crop, consider the use of herbicide-resistant varieties to manage broadleaf weeds. Well thought out weed control can have significant benefits, especially where problem weeds are difficult to control in canola.<sup>1</sup>

Many growers are now growing canola to actually control weeds not able to be controlled in wheat. This is through use of Round Up ready or TT varieties.

<sup>1</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



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

### 1.1.1 Soil types

Canola is adapted to a wide range of soil types. Whilst sandy soils can grow canola successfully particularly in areas with winter dominant rainfall, canola is best adapted to red-brown earths and clay soils. These soils generally have higher organic matter and inherent fertility. Canola has a high requirement for Nitrogen that will need to be met by fertilizer application in soils of lower fertility. Canola will perform best on neutral to alkaline soils, with good tilth. Paddocks with a uniform soil type will permit more even sowing depth and seedling emergence and more even crop ripening.

#### Climate and Soils

Avoid growing canola where the following problems occur.

#### *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.

#### *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 hard-setting sodic clay soils may improve seedling emergence and early growth.

#### *Acid soils*

Canola is more susceptible to low pH and aluminium (Al) toxicity than most other crops. If you expect the pH<sub>CaCl2</sub> to be <5.0, have the prospective canola paddock

soil-tested in the previous winter. If acidic subsoil is suspected, take split samples of soil depths 0–10 and 10–20 cm. Where a pH<sub>CaCl2</sub> <4.7 is combined with exchangeable Al level of ≥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 pH<sub>CaCl2</sub> drops to <5.0.

### Sodic subsoils

Soils with a sodic clay subsoil of low permeability become waterlogged when rainfall exceeds their infiltration capacity. 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.<sup>2</sup>

## More information

[Canola best practice management guide for south-eastern Australia](#)

## 1.2 Rotations and paddock history

Canola can reduce but not eliminate the incidence of some cereal root and crown diseases, such as crown rot and take-all. Research has shown canola to be the most effective winter crop for reducing levels of crown rot in subsequent wheat crops.<sup>3</sup>

Canola is not a host for arbuscular mycorrhizal fungi (AMF) and will result in lower levels following the crop. This may disadvantage subsequent crops that are highly dependent on AMF, particularly if environmental conditions and progressive fallows have also reduced AMF levels. Crops with a reliance on AMF 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 lower dependence on AMF, and any reduction can be counteracted through additional phosphate fertiliser application. Because canola reduces AMF levels the same way as long fallows, it should be grown with short (about 6 months) fallows before and after.

Research has shown that wheat yield increases of ~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 New South Wales (NSW). Canola fits well into this system by allowing an additional season for cereal stubble breakdown to occur, therefore reducing the carryover of disease.

<sup>2</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>3</sup> L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

## More information

[Choosing rotation crops—north](#)

[Canola—northern NSW planting guide](#)

[Over the bar with better canola agronomy](#)

[Canola best practice management guide for south-eastern Australia](#)

[Crown rot in winter cereals](#)

Canola should not be included in the rotation more frequently than one in every four years. This reduces the potential for canola disease build-up and also allows for rotation of herbicide and weed control tactics. The use of triazine-tolerant (TT), imadazoline-tolerant (IT) and roundup ready (RR) canola systems can also be used strategically for hard to control weeds.

When planning cropping systems on the farm consider placement of future crops in relation to potential insect pest host crops. 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.<sup>4</sup>

### 1.3 Winter and summer fallow weed control

Fallow management is important in all parts of NSW and Queensland. Whether winter- or summer-dominant rainfall the management of weeds throughout the summer has been found to directly add value to the next crop. This is achieved through the storage of moisture, particularly in soils with some clay content, but also by avoiding situations where weeds are tying up nutrients, hosting insect pests, or providing a green bridge for disease.

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.

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

## More information

[Canola volunteer control guide](#)

## More information

[GRDC Integrated Weed Management Manual](#)

[Summer fallow spraying](#)

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.<sup>5</sup>

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, which can include moisture stored from last winter or the summer before in a long fallow, is integral to winter cropping in the northern region, particularly as the climate moves towards summer-dominant rainfall.

The GRDC funded Northern Grower Alliance (NGA) is trialing methods to control summer grasses. Key findings include:

1. Glyphosate-resistant and -tolerant weeds are a major threat to reduced tillage cropping systems.
2. Although residual herbicides will limit re-cropping options and will not provide complete control, they are a key part of successful fallow management.
3. Double-knock herbicide strategies (sequential application of two different weed-control tactics) are useful but the herbicide choices and optimal timings will vary with weed species.
4. Other weed-management tactics can be incorporated, for example crop competition, to assist herbicide control.
5. Cultivation may need to be considered as a salvage option to avoid seedbank salvage.

### *Double-knock strategies*

Double-knock refers to the sequential application of two different weed-control tactics applied in such a way that the second tactic controls any survivors of the first. Most commonly used for pre-sowing weed control, this concept can also be applied in-crop.<sup>6</sup>

Consider the species present, interval timing and water rate. For information on double-knock tactics, download the GRDC Herbicide Application Fact Sheet: [Effective double knock herbicide applications northern region](#).

<sup>5</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>6</sup> C Borger, V Stewart, A Storrie. Double knockdown or 'double knock'. Department of Agriculture and Food Western Australia.

Double-knock herbicide strategies are useful for managing difficult-to-control weeds but there is no 'one size fits all' treatment.

The interval between double-knock applications is a major management issue for growers and contractors. Shorter intervals can be consistently used for weeds where herbicides appear to be translocated rapidly (e.g. awnless barnyard grass, ABYG) or when growing conditions are very favourable. Longer intervals are needed for weeds where translocation appears slower (e.g. fleabane, feathertop Rhodes grass and windmill grass).

Critical factors for successful double-knock approaches are for the first application to be on small weeds and to ensure good coverage and adequate water volumes, particularly when using products containing paraquat. Double-knock strategies are not fail-proof and rarely effective for salvage weed-control situations unless environmental conditions are exceptionally favourable.

### *Important weeds in northern cropping systems*

Weed management, particularly in reduced tillage fallows, has become an increasingly complex and expensive part of cropping in the northern grains region. Heavy reliance on glyphosate has selected for species that were naturally more glyphosate-tolerant or has selected for glyphosate-resistant populations.

### *Awnless barnyard grass*



Figure 2: Awnless barnyard grass. (Photo: Rachel Bowman)

Awnless barnyard grass (Figure 2) has been a key summer grass problem for many years. It is a difficult weed to manage for at least three main reasons:

1. Multiple emergence flushes (cohorts) each season
2. Easily moisture-stressed, leading to inconsistent knockdown control
3. Glyphosate-resistant populations increasingly being found

### Key points

- Glyphosate resistance is widespread. Tactics against this weed must change from glyphosate alone.
- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.
- Try to ensure that a double-knock of glyphosate followed by paraquat is used on one of the larger early-summer flushes of ABYG.
- Restrict Group A herbicides to management of ABYG in-crop and aim for strong crop competition.

### Resistance levels

Prior to summer 2011–12, there were 21 cases of glyphosate-resistant ABYG. Collaborative surveys were conducted by NSW Department of Primary Industries (DPI), Department of Agriculture, Fisheries and Forestry Queensland (DAFF) and NGA in summer 2011–12, with a targeted follow-up in 2012–13. Agronomists from the Liverpool Plains to the Darling Downs and west to areas including Mungindi collected ABYG samples, which were tested at the Tamworth Agricultural Institute with Glyphosate CT at 1.6 L/ha (a.i. 450 g/L) at a mid-tillering growth stage. Total application volume was 100 L/ha.

The main finding from this survey work was that the number of 'confirmed' glyphosate-resistant ABYG populations had nearly trebled. Selected populations were also evaluated in a separate glyphosate rate-response trial. The experiment showed that some of these populations were suppressed only when sprayed with 12.8 L/ha.

Growers can no longer rely on glyphosate alone for ABYG control.

### Residual herbicides (fallow and in-crop)

Several active ingredients are registered for use in summer crops, e.g. metolachlor (e.g. Dual Gold®) and atrazine, or fallow, e.g. imazapic (e.g. Flame®), and these provide useful management of ABYG. The new fallow registration of isoxaflutole (Balance®) can provide useful suppression of ABYG, but this herbicide has stronger activity against other problem weed species. Few (if any) residuals give consistent, complete control. However, they are important tools that need to be considered to reduce the weed population exposed to knockdown herbicides, as well as to alternate the herbicide chemistry being employed. Use of residuals together with camera spray technology (for escapes) can be a very effective strategy in fallow.

### Double-knock control

This approach uses two different tactics applied sequentially. In reduced-tillage situations, it is frequently glyphosate applied first, followed by a paraquat-based spray as the second application or 'knock'. Trials to date have shown that glyphosate followed by paraquat gives effective control, even on glyphosate-resistant ABYG. Note that the most effective results will be achieved from paraquat-based sprays by using higher total application volumes (100 L/ha) and finer spray quality and by targeting seedling weeds.



Several Group A herbicides, e.g. Verdict® and Select®, are effective on ABYG but should be used in registered summer crops such as mungbeans. Even on glyphosate-resistant ABYG, a double-knock of glyphosate followed by paraquat is an effective tool. In the same situations, there has been little benefit from a Group A followed by paraquat application. Note that Group A herbicides appear more sensitive to ABYG moisture stress. Application on larger, mature weeds can result in very poor efficacy.

Timing of the paraquat application for ABYG control has generally proven flexible. The most consistent control is obtained from a delay of ~3–5 days, when lower rates of paraquat can also be used. Longer delays may be warranted when ABYG is still emerging at the first application timing; shorter intervals are generally required when weed size is larger or moisture-stress conditions are expected. High levels of control can still be obtained with larger weeds but paraquat rates will need to be increased to 2.0 or 2.4 L/ha.

### *Flaxleaf fleabane*



Figure 3: *Flaxleaf fleabane*. (Photo: DAF Qld)

There are three main species of fleabane in Australia: *Conyza bonariensis* (flaxleaf fleabane; Figure 3), *C. canadensis* (Canadian fleabane) and *C. albida* (tall fleabane). There are two varieties of *C. canadensis*: var. *canadensis* and var. *pusilla*. Of the three species, flaxleaf fleabane is the most common across Australia.<sup>7</sup>

For more than a decade, flaxleaf fleabane has been the major weed-management issue in the northern cropping region, particularly in reduced-tillage systems. Fleabane is a wind-borne, surface-germinating weed that thrives in situations of low competition. Germination flushes typically occur in autumn and spring when surface-

<sup>7</sup> M Widderick, H Wu. Fleabane. Department of Agriculture and Food Western Australia.

soil moisture levels stay high for a few days. However, emergence can occur at nearly all times of the year.

An important issue with fleabane is that knockdown control of large plants in the summer fallow is variable and can be expensive due to reduced control rates.

#### Key points

- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.
- This weed thrives in situations of low competition; avoid wide row cropping unless effective residual herbicides are included.
- 2,4-D is a crucial tool for consistent double-knock control.
- Successful growers have increased their focus on fleabane management in winter (crop or fallow) to avoid expensive and variable salvage control in the summer.

#### Resistance levels

Glyphosate resistance has been confirmed in fleabane. There is great variability in the response of fleabane to glyphosate with many samples from non-cropping areas still well controlled by glyphosate, whereas fleabane from reduced-tillage cropping situations shows increased levels of resistance. The most recent survey has focused on non-cropping situations, with a large number of resistant populations found on roadsides and railway lines where glyphosate alone has been the principal weed-management tool employed.

#### Residual herbicides (fallow and in-crop)

One of the most effective strategies to manage fleabane is the use of residual herbicides during fallow or in-crop. Trials have consistently shown good efficacy from a range of residual herbicides commonly used in sorghum, cotton, chickpeas and winter cereals. There are now at least two registrations for residual fleabane management in fallow.

Additional product registrations for in-crop knockdown and residual herbicide use, particularly in winter cereals, are being sought. A range of commonly used winter cereal herbicides exists with useful knockdown and residual fleabane activity. Trials to date have indicated that increasing water volumes from 50 to 100 L/ha may improve the consistency of residual control, with application timing to ensure good herbicide-soil contact also important.

#### Knockdown herbicides (fallow and in-crop)

Group I herbicides have been the major products for fallow management of fleabane, with 2,4-D amine the most consistent herbicide evaluated. Despite glyphosate alone generally giving poor control of fleabane, trials have consistently shown a benefit from tank mixing 2,4-D amine and glyphosate in the first application. Amicide® Advance at 0.65–1.1 L/ha mixed with Roundup® Attack at a minimum of 1.15 L/ha and then followed by Nuquat® at 1.6–2.0 L/ha is a registered option for fleabane knockdown in fallow. Sharpen® is a product with Group G mode of action. It is registered for fallow control when mixed with Roundup® Attack at a minimum of 1.15 L/ha but only on fleabane up to a maximum stage of six leaves.

### More information

[Australian glyphosate resistance register: summary](#)

For more information on label rates, visit: [Australian Pesticides and Veterinary Medicines Authority](#).

#### *Double-knock control*

The most consistent and effective double-knock control of fleabane has included 2,4-D in the first application followed by paraquat as the second. Glyphosate alone followed by paraquat will result in high levels of leaf desiccation but plants will nearly always recover.

### **i** More information

[Flaxleaf fleabane—a weed best management guide](#)

[Integrated Weed Management of Feathertop Rhodes Grass 2014](#)

Timing of the second application in fleabane is generally aimed at ~7–14 days after the first application. However, the interval to the second knock appears quite flexible. Increased efficacy is obtained when fleabane is actively growing or if rosette stages can be targeted. Although complete control can be obtained in some situations (e.g. summer 2012–13), control levels will frequently reach only ~70–80%, particularly when targeting large, flowering fleabane under moisture-stressed conditions. The high cost of fallow double-knock approaches and inconsistency in control level of large, mature plants are good reasons to focus on proactive fleabane management at other growth stages.

#### *Feathertop Rhodes grass*



Figure 4: Feathertop Rhodes grass. (Photo: Rachel Bowman)

Feathertop Rhodes grass (Figure 4) has emerged as an important weed-management issue in southern Queensland and northern NSW since ~2008. This is another small-seeded weed species that germinates on, or close to, the soil surface. It has rapid early growth rates and can become moisture-stressed quickly. Although FTR is well established in central Queensland, it remains largely an 'emerging' threat further south. Patches should be aggressively treated to avoid whole-of-paddock blowouts.

#### *Key points*

- Glyphosate alone or glyphosate followed by paraquat has generally poor efficacy.
- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.

- A double-knock of Verdict® followed by paraquat can be used in Queensland prior to planting mungbeans where large spring flushes of FTR occur.
- Treat patches aggressively, even with cultivation, to avoid paddock blowouts.

#### *Residual herbicides (fallow and in-crop)*

This weed is generally poorly controlled by glyphosate alone, even when sprayed under favourable conditions at the seedling stage. Trials have shown that residual herbicides generally provide the most effective control, a similar pattern to that seen with fleabane. Currently registered residual herbicides are being screened and offer promise for both fallow and in-crop situations. The only product currently registered for FTR control is Balance® (isoxaflutole) at 100 g/ha for fallow use.

#### *Double-knock control*

Although a double-knock of glyphosate followed by paraquat is an effective strategy on ABYG, the same approach is variable and generally disappointing for FTR management. By contrast, a small number of Group A herbicides (all members of the 'fop' class) can be effective against FTR but need to be managed within a number of constraints:

- Although they can provide high levels of efficacy on fresh and seedling FTR, they need to be followed by a paraquat double-knock to get consistent, high levels of final control.
- Group A herbicides have a high risk of resistance selection, again requiring follow-up with paraquat.
- Many Group A herbicides have plant-back restrictions to cereal crops.
- Group A herbicides are generally successful at a narrower range of weed growth stages than herbicides such as glyphosate; that is, Group A herbicides will generally give unsatisfactory results on flowering and/or moisture-stressed FTR.
- Not all Group A herbicides are effective on FTR.

For information on a permit (PER12941) issued for Queensland only for the control of FTR in summer fallow situations prior to planting mungbeans, see: [Australian Pesticides and Veterinary Medicines Authority](#).

Timing of the second application for FTR is still being refined, but application at ~7–14 days generally provides the most consistent control. Application of paraquat at shorter intervals can be successful, when the Group A herbicide is translocated rapidly through the plant, but has resulted in more variable control in field trials. Good control can often be obtained up to 21 days after the initial application.

### Windmill grass



Figure 5: Windmill grass. (Photo: Maurie Street)

Whereas FTR has been a grass-weed threat coming from Queensland and moving south, windmill grass is more of a problem in central NSW but is spreading north. Windmill grass (Figure 5) is a perennial, native species found throughout northern NSW and southern Queensland. The main cropping threat appears to be from the selection of glyphosate-resistant populations, with control of the tussock stage providing greatest management challenges.

#### Key points

- Glyphosate alone or glyphosate followed by paraquat has generally poor efficacy.
- Preliminary data suggest that residual chemistry may provide some benefit.
- A double-knock of quizalofop-p-ethyl (e.g. Targa®) followed by paraquat can be used in NSW.

#### Resistance levels

Glyphosate resistance has been confirmed in windmill grass with three documented cases in NSW, all located west of Dubbo. Glyphosate-resistant populations of windmill grass in other states have all been collected from roadsides, but in Central West NSW, two were from fallow paddock situations.

#### Residual herbicides (fallow and in-crop)

Preliminary trials have shown a range of residual herbicides with useful levels of efficacy against windmill grass. These herbicides have potential for both fallow and in-crop situations. Currently, there are no products registered for residual control of windmill grass.

#### Double-knock control

Similar to FTR, a double-knock of a Group A herbicide followed by paraquat has provided clear benefits compared with the disappointing results usually achieved by glyphosate followed by paraquat. Constraints apply to double-knock for windmill grass control similar to those for FTR.

For information on a permit for NSW only for the control of windmill grass in summer fallow situations, visit: [Australian Pesticides and Veterinary Medicines Authority](#).

Timing of the second application for windmill grass is still being refined, but application at ~7–14 days generally provides the most consistent control. Application of paraquat at shorter intervals can be successful, when the Group A herbicide is translocated rapidly through the plant, but has resulted in more variable control in field trials and has been clearly antagonistic when the interval is  $\leq 1$  day. Good control can often be obtained up to 21 days after the initial application.<sup>8</sup>

## More information

[Herbicide resistance in summer grasses](#)

## 1.4 Herbicide plant-back periods

Canola is particularly susceptible to a range of residual herbicides. Under dry seasonal conditions or in alkaline soils, residues from a 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 herbicide-tolerant (TT or Clearfield®) canola varieties coupled with their companion 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.<sup>9</sup>

Plantback periods do not begin until there has been a significant rainfall event.

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

[Soil behaviour of pre-emergent herbicides in Australian farming systems: a reference manual for agronomic advisers](#)

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) (see Table 1). 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.<sup>10</sup>

<sup>8</sup> R Daniel (2013) Weeds and resistance—considerations for awnless barnyard grass, *Chloris* spp. and fleabane management. Northern Grower Alliance, <http://www.nga.org.au/module/documents/download/225>

<sup>9</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>10</sup> B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf)

Table 1: Residual persistence of common pre-emergent herbicides, and noted residual persistence in broadacre trials and from paddock experience <sup>11</sup>

Sources: CDS Tomlinson (Ed.) (2009) *The pesticide manual* (15th edn), British Crop Protection Council; Extoxnet, <http://extoxnet.orst.edu/>; California Department of Pesticide Regulation Environmental Fate Reviews, [www.cdpr.ca.gov/](http://www.cdpr.ca.gov/)

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high pH soils. Weed control commonly drops off within 6 weeks
Glean® (chlorsulfuron)	28–42	High. Persists longer in high pH soils. Weed control longer than triasulfuron
Diuron	90 (range 1 month–1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Has had observed, long-lasting activity on grass weeds such as black/stink grass ( <i>Eragrostis</i> spp.) and to a lesser extent broadleaf weeds such as fleabane
Atrazine	60–100, up to 1 year if dry	High. Has had observed, long-lasting (>3 months) activity on broadleaf weeds such as fleabane
Simazine	60 (range 28–149)	Medium–high. 1 year residual in high pH soils. Has had observed, long-lasting (>3 months) activity on broadleaf weeds such as fleabane
Terbyne® (terbuthylazine)	6.5–139	High. Has had observed, long-lasting (>6 months) activity on broadleaf weeds such as fleabane and sow thistle
Triflur® X (trifluralin)	57–126	High. 6–8 months residual. Higher rates longer. Has had observed, long-lasting activity on grass weeds such as black/stink grass ( <i>Eragrostis</i> spp.)
Stomp® (pendimethalin)	40	Medium. 3–4 months residual
Avadex® Xtra (triallate)	56–77	Medium. 3–4 months residual
Balance® (isoxaflutole)	1.3 (metabolite 11.5)	High. Reactivates after each rainfall event. Has had observed, long-lasting (>6 months) activity on broadleaf weeds such as fleabane and sow thistle
Boxer Gold® (prosulfo carb)	12–49	Medium. Typically quicker to break down than trifluralin, but tends to reactivate after each rainfall event
Sakura® (pyroxasulfone)	10–35	High. Typically quicker breakdown than trifluralin and prosulfo carb; however, weed control persists longer than with prosulfo carb

## More information

[Australian Pesticides and Veterinary Medicines Authority](#)

[Using pre-emergent herbicides in conservation farming systems](#)

[Weed control in winter crops](#)

[Sulfonylurea spray contamination damage to canola crops](#)

## More information

[Canola best practice management guide for south-eastern Australia](#)

[Lifting productivity in retained stubble systems](#)

## 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. <sup>12</sup>

<sup>11</sup> B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf)

<sup>12</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)



Figure 6: The hard canola seed needs good seed–soil contact to germinate.

## 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 approximately 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-to-volume 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 2).

Table 2: 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.<sup>13</sup>

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 and timing of rainfall during the growing season
- the ability of the soil to absorb water, store it, and make it available for plants

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.

<sup>13</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

#### More information

[Is there a place for canola on irrigation?](#)

[Yield of wheat and canola in the high rainfall zone of south-western Australia in years with and without a transient perched water table](#)

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 water-storage 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.<sup>14</sup>

## 1.7 Yield and targets

Average canola yields in NSW vary over a range of around 1t/ha in the drier regions but up to 3-4 t/ha in the more favourable growing areas or on irrigation. Canola has traditionally yielded approximately half of what wheat would yield in the same situation. Said another way it achieves only half the water use efficiency of that of wheat (kg of grain per mm of water available).

More recently with improved varieties and the agronomy and management of the crop many farmers are now targeting 60-70% of typical wheat yields.

As discussed in [Section 2](#), varieties vary in yield performances. However, several generalisations can be made:

- TT varieties will often perform less well than conventional, Clearfield or Roundup Ready varieties as there is a fitness penalty integral to breeding herbicide tolerance. This is often referred to as yield drag and quoted as up to 15% compared to conventional varieties. However some agronomists believe this is over-estimated in some regions and it must be remembered that the TT tolerance allows control of weeds that could otherwise not be controlled. TT varieties often have less seedling vigour which can hinder establishment and this can have ramifications through to harvest.
- Hybrid varieties generally have higher yield potential than open pollinated varieties. This is achieved through the hybridization process, enabling coupling of strong and desirable traits from the parent varieties. Many breeding or seed companies are also investing greater effort into hybrid varieties as gains are easier and quicker to achieve as well in ensures seed sales each year.

<sup>14</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

## More information

[NSW climate summary](#)

[Seasonal crop outlook – wheat](#)

[Grain marketing – wheat, canola and barley outlook](#)

[Agribusiness Outlook 2015](#)

[Canola agronomy research in central NSW](#)

[Irrigated canola - Management for high yields](#)

[Growing hybrid canola](#)

## More information

[GRDC Update paper: Pushing the production barriers](#)

[GRDC Update paper: Finely irrigated wheat, canola and faba beans systems results 2014](#)

- GMO varieties, specifically Round Up Ready or glyphosate-tolerant varieties, promise improved yield potential and performance but at present these varieties are achieving only average performance, not withstanding weed management benefits.

In setting yield targets or expectations, growers also need to take into account sowing date, seasonal conditions (particularly rainfall and fallow moisture) and disease and pests. In southern regions Blackleg, and more sporadically Sclerotinia, can impact heavily on crop performance but the northern region does not seem to experience the same level of disease particularly Blackleg so this should not in many cases be too much of a yield barrier.

### 1.7.1 Seasonal outlook

The NSW DPI provides a seasonal outlook to assist grain growers. The [Seasonal Conditions and Climate Change Summary e-newsletter](#) will let you know as soon as the monthly report is published. [Subscribe now](#).

### 1.7.2 Fallow moisture

Like wheat, canola will benefit from stored subsoil moisture, particularly in marginal cropping areas where winter and spring rainfall is unreliable. Manage fallows efficiently to maximise the amount of moisture at sowing.<sup>15</sup>

### 1.7.3 Nitrogen- and water-use efficiency

Nitrogen fertiliser can increase the water-use efficiency (WUE) of early-sown canola. 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.<sup>16</sup>

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. (However, trials by the Grain Orana Alliance (GOA) didn't show this, more details will be available in 2016.)

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.<sup>17</sup>

<sup>15</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>16</sup> P Hocking, R Norton, A Good (1999) Crop nutrition. Australian Oilseeds Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0013/2704/Chapter\\_4\\_-\\_Canola\\_Nutrition.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0013/2704/Chapter_4_-_Canola_Nutrition.pdf)

<sup>17</sup> 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, <https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Nitrogen-and-water-use-efficiency-of-canola-and-mustard-in-South-Australia>

### 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.

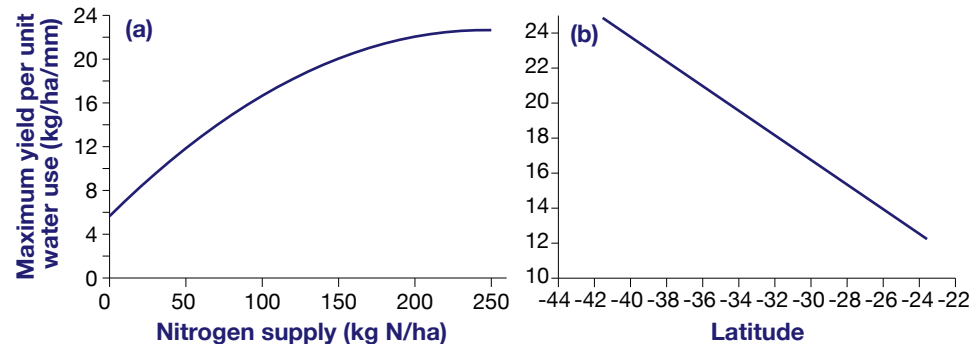


Figure 7: Maximum yield per unit water use (kg/ha.mm) as a function of (a) nitrogen and (b) location.

#### Step 1

Use the data in Figure 7a 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 about 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.

#### Step 2

Use the line in Figure 7b to correct for location. For a latitude of  $-41.5^\circ$  (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  $-23.5^\circ$  (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 graphically using the line in Figure 6b.

#### 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  $-27.1^\circ$ ) 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.<sup>18</sup>

<sup>18</sup> V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. GRDC Integrated Weed Management Hub, <http://www.grdc.com.au/GRDC-Booklet-WUE>

Table 3: Water-use efficiency based on total biomass (WUE<sub>dm</sub>) or grain yield (WUE<sub>gy</sub>) 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	WUE (kg/ha.mm)		Source
		WUE <sub>dm</sub>	WUE <sub>gy</sub>	
Canola	Victoria	24.0 (17.1-28.4)	6.8 (4.7-8.9)	Norton and Wachsmann 2006
Canola*	NSW		13.4	Robertson and Kierkegaard 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

### More information

[Water use efficiency of grain crops in Australia](#)

[Nitrogen and water use efficiency of canola and mustard in South Australia](#)

[Nitrogen use efficiency in canola](#)

[Water-use efficiency of canola in Victoria](#)

There are intrinsic differences in the WUE of crops (Table 3), 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 compared with 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.<sup>19</sup>

## 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. Blackleg is found in crops in northern NSW but at a lower incidence due to the lower frequency of canola in the rotation and overall area grown.

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

<sup>19</sup> V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. GRDC Integrated Weed Management Hub, <http://www.grdc.com.au/GRDC-Booklet-WUE>

provides only limited benefits in reducing the disease level because not all of the infected stubble and old roots are destroyed.



Figure 8: *Sclerotinia* is a major cause of canola stem rot. Photo: Cox Inall Communications

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 - Managing the disease in 2013](#)

Sclerotinia stem rot is an intermittent problem in many canola-growing districts, particularly central and southern NSW. It has a wide host range of broadleaf plants 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.<sup>20</sup>

Sclerotinia infection occurs when there is rainfall around petal drop but only when those petals have sclerotinia spores on them. Predicting infection is difficult but fungicides can be applied to combat the infection. The economic benefits of this approach in the northern region are questionable.

<sup>20</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## 1.9 Nematode status of paddock

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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](#).<sup>21</sup>

To organise testing and sending of soil samples, visit the [PreDicta B](#) website.

For testing and interpretation of results contact:

Rob Long, Crown Analytical Services  
0437 996 678  
[crownanalytical@bigpond.com](mailto:crownanalytical@bigpond.com)

For more information, see [GrowNotes Section 8. Nematodes](#).

### More information

[Variety choice and crop rotation key to managing root lesion nematodes](#)

<sup>21</sup> GRDC (2015) Root-lesion nematodes. GRDC Tips and Tactics, February 2015, <http://www.grdc.com.au/TT-RootLesionNematodes>

## SECTION 2

# Pre-planting

## More information

[Winter crop variety sowing guide 2015](#)

[Canola: northern NSW planting guide](#)

## More information

[Canola variety trials](#)

[Baker Seed Co. Newsletter](#)

[Optimal canola establishment to maximise yields](#)

## 2.1 Varietal performance and ratings yield

The main features to consider when selecting a variety are maturity, yield, oil content, herbicide tolerance and disease resistance. Early-maturing varieties are generally more suited to drier western areas, and midseason types are suited to higher rainfall areas.<sup>1</sup>

Fifty-two canola varieties and one *Brassica juncea* variety were released to the market in New South Wales (NSW) for 2015.

There are 12 new releases for NSW:

- Nuseed: Monola® 515TT, Monola® G11 and Nuseed® Diamond
- Pacific Seeds: Hyola® 600RR and Hyola® 725RT
- DuPont Pioneer: Pioneer® 44Y26(RR), Pioneer® 45Y25(RR) and Pioneer® 44Y89(CL)
- AGFSeeds: SF Edimax CL
- Bayer: IH51RR and IH52RR
- Seednet: DG 550RR

Outclassed, but still available:

- Hyola® 555TT, Hyola® 505RR, Hyola® 971CL, Monola 605TT

Withdrawn:

- Pioneer®45Y22(RR), Crusher TT, GT Cobra, GT Viper, Hyola® 433, IH50RR, Monola 413TT, Tawriffic TT, Thumper TT, Victory® V5002RR<sup>2</sup>

<sup>1</sup> L Serafin, J Holland, RBambach, DMcCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-Canola-Northern-NSW-Planting-Guide.pdf>

<sup>2</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)



## 2.1.1 Maturity

The relative maturity of varieties may vary depending on location and sowing time. The maturity groupings listed in Table 1 are intended as a guide only, and they relate to physiological maturity.<sup>3</sup>

Table 1: Variety maturities for canola

Note: winter types for graze and grain are not included; their maturity is generally considered late-very late

	Lower rainfall north < 550 mm, centre/south < 500 mm		Higher rainfall north > 500 mm, centre/south > 450 mm	
	Early-maturing	Early-mid maturing	Mid-maturing	Mid-late maturing
Conventional	Nuseed® Diamond	Victory® V3002	AV-Garnet AV-Zircon Hyola® 50	
Triazine tolerant (TT)	ATR-Stingray Monola® 314TT Pioneer® SturtTT	ATR-Bonito ATR-Gem Hyola® 450TT	ATR-Wahoo Hyola® 559TT Pioneer® Atomic TT Monola® 515TT	Hyola® 650 TT
CLEARFIELD®	Pioneer® 43C80(CL) Pioneer® 43Y85(CL) Pioneer® 44C79(CL) Pioneer® 44Y84(CL)	Carbine Hyola® 474CL Pioneer® 44Y87(CL) Pioneer® 44Y89(CL) XCEED® VT Oasis CL	Hyola® 575CL Hyola® 577CL Pioneer® 45Y86(CL) Pioneer® 45Y88(CL)	Archer
Roundup Ready®	Hyola® 400RR IH30 RR Nuseed® GT-41 Pioneer® 43Y23(RR)	Hyola® 404RR Monola® 513GT Pioneer® 44Y24(RR) Pioneer® 44Y26(RR)	DG 550RR Hyola® 500RR Monola® G11 Nuseed® GT-50 Pioneer® 45Y25(RR) IH51RR IH52RR	Hyola® 600RR®
Roundup Ready® plus Triazine tolerant (Dual tolerance)			Hyola® 525RT®	Hyola® 725RT®

## 2.1.2 Yielding ability

Tables 2 and 3 present the relative performances of mid-maturing and early-maturing canola varieties from trials conducted in 2010–14, under the National Variety Trials (NVT) program. Note that new varieties have fewer data supporting the 5-year dataset and hence, those results should be viewed with caution, especially where there are only two trials.<sup>4</sup>

<sup>3</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>4</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

Table 2: Comparative performance of mid-maturing varieties of canola, based on predicted yields from an analysis across all sites (NVT, 2010–14)

Number of trials in parentheses. Oil content, adjusted to 6% moisture content, is expressed as a region-wide average for the maturity trial grouping and is for 2014 only. Blackleg ratings are the published ratings for spring 2014

Variety	North West 2010–2014	North East 2010–2014	South West 2010–2014	South East 2010–2014	Oil % 2014	Blackleg rating 2014
<b>Mid-maturing conventional trials– mean seed yield expressed as a % of AV-Garnet</b>						
AV-Garnet	100 (3)	100 (4)	100 (3)	100 (6)	41.9 (4)	MR
AV-Zircon	101 (3)	102 (3)	100 (3)	96 (4)	41.4 (4)	MR
Hyola® 50	111 (3)	111 (4)	113 (3)	105 (6)	42.7 (4)	R
Nuseed® Diamond	115 (2)	n.d.	119 (2)	115 (3)	42.7 (4)	R–MR
Victory® V3002	105 (3)	103 (2)	106 (3)	104 (2)	42.1 (4)	R–MR
AV-Garnet t/ha	2.13	2.01	2.33	2.63		
<b>Mid-maturing Triazine Tolerant (TT) trials – mean seed yield expressed as a % of ATR-Gem</b>						
ATR-Bonito	103 (4)	104 (5)	104 (3)	104 (16)	44.3 (12)	MR
ATR-Gem	100 (5)	100 (5)	100 (4)	100 (20)	43.5 (12)	MR
ATR-Stingray	96 (7)	96 (7)	99 (4)	98 (22)	43.2 (12)	MR
ATR-Wahoo	101 (4)	100 (4)	n.d.	102 (15)	43.8 (10)	MR
Hyola® 450TT	103 (3)	106 (4)	106 (3)	102 (8)	43.7 (8)	R
Hyola® 559TT	108 (4)	111 (5)	111 (3)	108 (17)	43.4 (12)	R
Hyola® 650TT	107 (2)	109 (4)	110 (2)	111 (9)	42.9 (12)	R
Hyola® 525RT	101 (2)	n.d.	103 (3)	103 (7)	44.5 (8)	R–MR
Hyola® 725RT	n.d.	n.d.	n.d.	101 (3)	44.4 (4)	n.d.
Monola® 314TT	92 (2)	93 (2)	89 (3)	84 (7)	41.5 (9)	MR
Monola® 515TT	92 (2)	n.d.	90 (2)	87 (4)	42.4 (9)	n.d.
Pioneer® Atomic TT	106 (4)	109 (5)	106 (3)	101 (13)	41.1 (8)	MS
ATR-Gem t/ha	2.03	2.06	1.95	2.28		
<b>Mid-maturing CLEARFIELD® trials– mean seed yield expressed as a % of Hyola® 575CL</b>						
Archer	104 (4)	105 (5)	101 (3)	100 (18)	42.4 (12)	MR–MS
Hyola® 474CL	100 (6)	100 (7)	100 (6)	98 (18)	42.8 (8)	R
Hyola® 575CL	100 (7)	100 (8)	100 (6)	100 (29)	43.5 (12)	R
Hyola® 577CL	100 (3)	99 (4)	100 (2)	100 (11)	43.6 (12)	R
Pioneer® 44Y87(CL)	103 (3)	104 (3)	101 (3)	100 (10)	41.6 (12)	MR
Pioneer® 44Y89(CL)	103 (2)	104 (2)	103 (3)	100 (5)	42.8 (12)	R–MR
Pioneer® 45Y86(CL)	105 (6)	107 (7)	102 (6)	100 (29)	43.7 (12)	MR–MS
Pioneer® 45Y88(CL)	104 (4)	105 (5)	103 (4)	103 (16)	41.7 (12)	R–MR
Hyola® 575CL t/ha	2.18	2.16	2.02	2.50		
<b>Mid-maturing Roundup Ready trials – mean seed yield expressed as a % of Hyola® 500RR</b>						
DG550 RR	96 (6)	n.d.	96 (2)	96 (6)	43.4 (7)	R–MR
Hyola® 400RR	100 (3)	n.d.	98 (3)	100 (3)	45.2 (4)	R
Hyola® 404RR	102 (19)	n.d.	99 (5)	102 (19)	45.9 (7)	R–MR
Hyola® 500RR	100 (8)	n.d.	100 (3)	100 (8)	45.0 (7)	R
Hyola® 600RR	103 (3)	n.d.	n.d.	103 (3)	46.9 (4)	n.d.
IH51 RR	93 (3)	n.d.	91 (2)	93 (6)	42.5 (7)	n.d.
IH52 RR	99 (6)	n.d.	96 (2)	99 (6)	42.6 (7)	R–MR
Monola® 513GT	92 (8)	n.d.	88 (3)	92 (8)	45.5 (4)	MR
Monola® G11	96 (5)	n.d.	95 (2)	96 (5)	45.3 (6)	R–MR
Nuseed GT-41	99 (7)	n.d.	95 (4)	99 (7)	43.2 (4)	R–MR
Nuseed GT-50	106 (14)	n.d.	101 (5)	106 (14)	44.2 (7)	R–MR
Pioneer® 43Y23(RR)	105 (10)	n.d.	103 (4)	105 (10)	42.2 (5)	R–MR
Pioneer® 44Y24(RR)	106 (15)	n.d.	101 (5)	106 (15)	42.9 (7)	R–MR
Pioneer® 44Y26(RR)	n.d.	n.d.	95 (2)	99 (3)	44.1 (7)	R–MR
Pioneer® 45Y25(RR)	109 (6)	n.d.	105 (2)	103 (16)	44.1 (7)	R–MR
Hyola® 500RR t/ha	2.40		1.84	2.63		

Table 3: Comparative performance of early-maturing varieties of canola, based on predicted yields from an analysis across all sites (NVT, 2010–14)

Number of trials in parentheses. Oil content, adjusted to 6% moisture content, is expressed as a region-wide average for the maturity trial grouping and is for 2014 only. Blackleg ratings are the published ratings for spring 2014

Variety	North West 2010–2014	North East 2010–2014	South West 2010–2014	South East 2010–2014	Oil % 2014	Blackleg rating 2014
<b>Early maturing conventional trials– mean seed yield expressed as a % of Hyola® 50</b>						
AV-Garnet	88 (9)	94 (2)	94 (5)	n.d.	37.8 (3)	MR
Hyola® 50	100 (9)	100 (2)	100 (5)	n.d.	39.5 (3)	R
Nuseed® Diamond	91 (3)	n.d.	101 (2)	n.d.	38.8 (3)	R–MR
Victory V3002	90 (5)	97 (2)	94 (2)	n.d.	38.6 (1)	R–MR
Hyola® 50 t/ha	1.82	1.23	1.34			
<b>Early maturing Triazine tolerant (TT) trials – mean seed yield expressed as a % of ATR-Stingray</b>						
ATR-Bonito	108 (3)	105 (2)	106(3)	n.d.	39.8 (3)	MR
ATR-Gem	107 (3)	n.d.	104 (3)	n.d.	40.1 (2)	MR
ATR-Stingray	100 (8)	100 (2)	100 (4)	n.d.	40.2 (3)	MR
Hyola® 450TT	n.d.	n.d.	106 (2)	n.d.	40.7 (3)	R
Hyola® 559TT	122 (5)	112 (2)	116 (2)	n.d.	39.6 (3)	R
Monola® 314TT	n.d.	n.d.	89 (2)	n.d.	39.1 (2)	MR
Pioneer® Atomic TT	123 (2)	n.d.	n.d.	n.d.	39.0 (2)	MS
Pioneer® Sturt TT	106 (5)	n.d.	106 (3)	n.d.	38.0 (3)	MS
ATR-Stingray t/ha	1.74	0.91	1.37			
<b>Early maturing Clearfield trials – mean seed yield expressed as a % of Hyola® 474CL</b>						
Hyola® 474CL	100 (7)	100 (2)	100 (4)	n.d.	39.4 (3)	R
Hyola® 575CL	102 (7)	102 (2)	101 (4)	n.d.	39.2 (3)	R
Pioneer® 43Y85(CL)	91 (7)	92 (2)	98 (4)	n.d.	37.6 (3)	MR
Pioneer® 44Y87(CL)	99 (4)	100 (2)	105 (3)	n.d.	37.2 (3)	MR
Pioneer® 44Y89(CL)	n.d.	n.d.	n.d.	n.d.	38.7 (3)	R–MR
Hyola® 474CL t/ha	1.75	1.12	1.19			
<b>Early maturing Roundup Ready trials – mean seed yield expressed as a % of Hyola® 404RR</b>						
Hyola® 400RR	97 (2)	n.d.	96 (3)	n.d.	41.5 (2)	R
Hyola® 404RR	100 (4)	n.d.	100 (4)	n.d.	42.0 (2)	R–MR
Hyola® 500RR	94 (2)	n.d.	n.d.	n.d.	40.0 (2)	R
IH30 RR	97 (3)	n.d.	100 (3)	n.d.	39.6 (2)	R–MR
Nuseed GT-41	99 (3)	n.d.	96 (3)	n.d.	40.0 (2)	R–MR
Pioneer® 43Y23(RR)	100 (4)	n.d.	100 (4)	n.d.	38.5 (2)	R–MR
Pioneer® 44Y24(RR)	100 (3)	n.d.	98 (3)	n.d.	38.5 (2)	R–MR
Pioneer® 44Y26(RR)	97 (2)	n.d.	n.d.	n.d.	38.9 (2)	R–MR
Hyola® 404RR t/ha	1.72		1.35			

**Blackleg rating disclaimer.** The blackleg ratings above, published by NSW Department of Primary Industries, are based on best information available at the time of publication. However, nursery and grower experience has shown that disease severity may vary between locations and years, depending on seasonal conditions and possible changes in the fungus for reasons not currently understood. Therefore, growers may sometimes experience significant variation from the averages shown in these ratings.

### More information

[GRDC Update paper: Australian canola oil quality](#)

[Variety and agronomy trials](#)

### 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.<sup>5</sup>

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
- 59–62% oleic acid
- 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.<sup>6</sup>

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

The minimum protein content of seed meal, as determined by the AOF (Australian Oilseeds Federation) is 36%, measured at 12% moisture.<sup>7</sup>

## 2.2 Varieties for NSW

### 2.2.1 Conventional varieties

**AV-Garnet:** a mid-maturing to mid-early-maturing variety. Medium height. Moderate–high 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.

<sup>5</sup> R Mailer (2009) Grain quality. In Canola best practice management guide for eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>6</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

<sup>7</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

## More information

[Pacific Seeds Hyola hybrid agronomy](#)

**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.<sup>8</sup>

### 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.

**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.

<sup>8</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

**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 and resistance group. Tested in NVT trials 2013 and 2014. Bred and marketed by Nuseed Pty Ltd.

**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.<sup>9</sup>

### 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.

<sup>9</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

**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. Medium–tall 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.

**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.

## 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. 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.<sup>10</sup>

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

### 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. High–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 for 2014. Tested in NVT trials for the first time in 2014. Bred and marketed by Pacific Seeds.

#### More information

[What is Roundup Ready canola?](#)

[Queensland hope for short season canola](#)

[Crop Guide- Canola: Juncea Canola in low rainfall SW NSW](#)

### 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.<sup>11</sup>

## 2.3 Planting seed quality

### 2.3.1 Seed size

Canola seeds weigh only approximately 3 mg each, with the 1000-seed weight of canola 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 (Table 4). There is also an interaction with sowing depth. Larger seeds establish more plants, particularly if sown at depth of  $\geq 3$  cm.<sup>12</sup>

<sup>11</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>12</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)



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)

Table 4: Plant establishment, days to emergence and 100 plant weights (15 days after emergence) for three hybrids (Pioneer 44Y84 (CL), Hyola 50 and Hyola 555TT) and three open pollinated (Pioneer 43C80 (CL), AV-Garnet and ATR-Gem) canola varieties segregated into large and small seed sown at three planting depths.<sup>13</sup>

Planting depth	Hybrid		Open-pollinated	
	Large seed	Small seed	Large seed	Small seed
<b>Establishment</b>				
2.5 cm	19.4a	19.8a	19.4a	16.3b
5.0 cm	18.8ab	12.8c	17.4b	8.8d
7.5 cm	15.9b	3.8e	8.7d	1.0f
<b>Days to emergence</b>				
2.5 cm	5.0a	5.1a	5.1a	5.2a
5.0 cm	5.9ab	6.7b	6.8b	7.2b
7.5 cm	7.4b	11.3e	8.7c	10.0d
<b>100 Plant weight 15 days after emergence</b>				
2.5 cm	56.9a	31.5d	45.7c	29.7d
5.0 cm	51.8b	24.5e	44.9c	23.5e
7.5 cm	49.5b	10.3g	45.8c	13.0f

\*\*Numbers within each section (e.g. Establishment) designated with a different letter are significantly (P=0.05) different.

<sup>13</sup> R Brill, L Jenkins, M Gardner (2014) Canola establishment; does size matter. GRDC Update Papers, 5 February 2014, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Canola-establishment-does-size-matter>

Sowing-depth trials were conducted at Coonamble, Nyngan and Trangie in 2012 and at Nyngan and Trangie in 2013. Each trial used six common varieties with a range of seed sizes (Table 5). Target seeding depths were 2.5, 5 and 7.5 cm.

Table 5: Seed size (1000-seed weight, g) and number of seeds sown in three canola variety-sowing depth trials in 2012

Variety	Seed weight		No. of seeds sown per m
	2012	2013	
AV-Garnet	3.78	3.27	60
ATR-Stingray	3.06	2.97	60
Pioneer® 43C80(CL)	3.68	4.11	60
Pioneer® 43Y85(CL)	5.03	4.77	60
Pioneer® 44Y84(CL)	5.34	5.20	60
Hyola® 555TT	4.26	4.00	60

### More information

[Canola establishment: does size matter?](#)

Sowing large seed (> 5 g/1000 seeds) increases the likelihood of achieving an adequate establishment. For growers who wish to purchase seed, hybrid seed is generally larger than open-pollinated seed. For growers who retain open-pollinated seed on farm for their own use, aim to clean seed with a 2-mm screen.<sup>14</sup>

For full results, see [GrowNotes Canola. Section 3. Planting](#)

## 2.3.2 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.<sup>15</sup>

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.

<sup>14</sup> R Brill, L Jenkins, M Gardner (2014) Canola establishment; does size matter. GRDC Update Papers, 5 February 2014, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Canola-establishment-does-size-matter>

<sup>15</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

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.<sup>16</sup>

### *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.<sup>17</sup>

## 2.3.3 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:

- aeration
- 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).

<sup>16</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

<sup>17</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

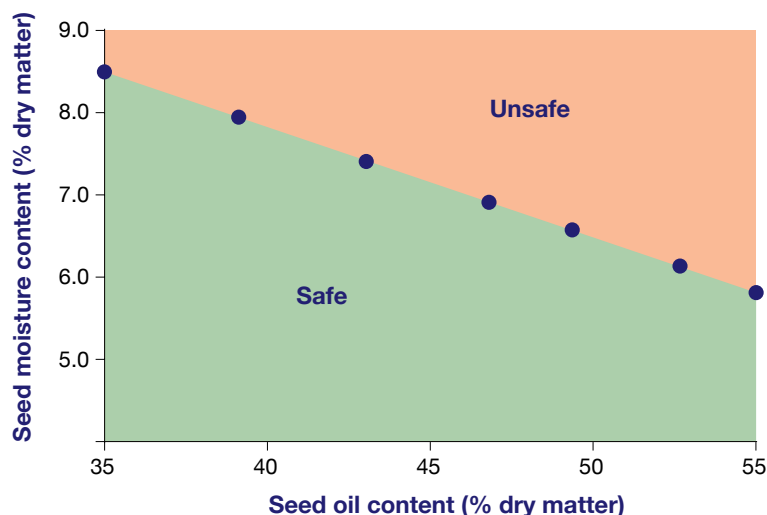


Figure 2: Potential unsafe storage limits for Australian canola varieties at 60% equilibrium relative humidity and 25°C. (Source: [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0006/4110/Oilseeds\\_Flyer.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0006/4110/Oilseeds_Flyer.pdf))

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  $< 25^\circ\text{C}$  (but preferably  $< 20^\circ\text{C}$ ).

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.<sup>18</sup>

### More information

[GRDC Fact sheet:](#)

[Fertiliser toxicity](#)

### 2.3.4 Safe rates of fertiliser sown with the seed

Nitrogen (N) and starter (N and phosphorus, P) fertilisers can affect germination and reduce establishment if sown in contact with canola seed. Seed can be affected in a number of ways:

- Toxic chemical effects from ammonium vapour, most likely from urea and ammonium phosphates (e.g. mono- and di-ammonium phosphate, MAP and DAP)
- osmotic or salt effect due to high concentrations of salts produced from soluble fertiliser dissolving in water (both N and P)
- seed desiccation from direct moisture absorption by fertiliser in very dry soil

<sup>18</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

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 (Table 6)
- in more sandy soils
- in dry soils

Table 6: Amounts of nitrogen (kg N/ha) that can be sown with canola seed, as determined by calculations of seedbed utilisation

Source: Jim Laycock, Incitec Pivot, adapted from 'Fertiliser management in direct seeding systems'. Better Crops 81(2), 1997

	25-mm seed spread (e.g. discs, knife-point)			50-mm seed spread		
	15 cm	22.5 cm	30 cm	15 cm	22.5 cm	30 cm
<b>Row spacing:</b>						
<b>Seed bed utilisation:</b>	17%	11%	8%	33%	22%	17%
Light (sandy loam)	10	5	0	20	15	10
Medium-heavy (loam-clay)	15	10	5	30	20	15

## More information

[Canola best practice management guide for south-eastern Australia](#)

[Canola irrigated: GM—SQ](#)

## SECTION 3

# Planting

## 3.1 Seed treatments

### 3.1.1 Insecticide treatments

Insecticide treatments are important for the proactive control of insect pests in canola.

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.<sup>1</sup>

[APVMA Pubcris](#)

[Winter crop variety sowing guide](#)

### 3.1.2 Fungicide treatments

Fungicide treatments can be used in high disease risk situations, however depending on level of risk may not be required.

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

<sup>1</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



## More information

[Assessment of fungicide efficacy against blackleg disease](#)

[Evaluation of fungicides for the control of downy mildew](#)

GRDC Update papers:  
[Turning sowing times on their head with winter habit canola and wheat](#)

[Early sowing of canola in southern NSW](#)

*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.<sup>2</sup>

### 3.2 Time of sowing

Early sowings maximise yield potential and oil content. Traditionally ANZAC day (25 April) has been a commonly accepted ideal sowing date but growers can make adjustments from this date in response to the maturity rating of the variety grown, the respective frost risk of that paddock or climate of that location. For example, longer season varieties could be planted earlier than this date, shorter ones after. Warmer locations with less frost risk or greater chance of shorter springs might see midseason maturities sown earlier than this date, or cold frosty climates may see mid seasons sown later than this. Growers should seek local advice on variety choice and sowing date. One thing for sure, delayed or late sowing of canola will have severe yield penalties.

Frosting can occur in canola and can be quite severe in many cases but frosting in canola is different to that experienced in wheat. Frost can destroy/damage canola flowers but canola flowers over extended periods of up to 6 weeks or more so any lost flowers from single frost events are easily replaced. Missing podding sites in many cases will not have equated to much, if any, yield loss. Very little energy has been spent to get to this stage and the future requirement is just redirected to newer or remaining pods.

This is in contrast to wheat which flowers over 1-5 days across a paddock. One or 2 severe frosts can destroy up to 20-30% of kernels and this damage cannot be compensated by remaining grains. Manipulating the sowing date of canola to avoid flower frosts is not worthwhile unlike wheat. However canola is most sensitive to frost during early pod fill. Heavy frosts at this stage can freeze the entire pod destroying all the seed embryos. At this crop stage flowering is either finished or very close to finishing and as such there is little chance for the crop to compensate for this loss. Because this sensitive stage of the crop is later in the season the risk of such frosts is reduced.

Frost damage in canola is often very severe and growers can have little direct influence over their crops' frost susceptibility because moisture availability (weeds, fallow management, time of sowing), row spacing, stubble cover can all play a part.

<sup>2</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



Figure 1: Early-stage canola in Central West NSW. (Photo: Penny Heuston)

In paddocks known to have high frost risk, sowing should be delayed further. Seek guidance from experienced agronomists in your district, but in general, finish sowings by about 1 June around Moree and 15 June south of Gunnedah at the very latest. Within these guidelines, consider sowing several varieties with different maturities and even several sowing times to spread the risks of unforeseen seasonal factors such as moisture stress or frost.

Canola usually flowers for 3–5 weeks, and frost damage is greatest if it occurs towards the end of flowering and through pod filling. 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.

NSW DPI have done heaps on time of sowing trials in the CW for canola. This has been done in the VSAP program.

The small seeds of canola need to be sown ideally no more than 5 cm deep in self-mulching 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.

Aim to establish 30–50 plants/m in northern New South Wales (NSW) (Figure 1). This can be achieved with 2–4 kg/ha of seed (provided it is good-quality seed).<sup>3</sup> Recent work by DPI has seen them review this number back to 20 plants, but stands down to 10 plants have shown little negative yield impact.

Table 1: Recommended sowing times for canola in New South Wales (source: Winter crop variety guide NSW DPI 2011)

1–4 are weeks of the month. ■ Best sowing time; ■, earlier or later than desirable (earlier—too vegetative, lodging, disease and/or frost risk; later—spring moisture and heat stress); ■, too late for good yields unless favourable spring

Region	Week	April				May				June			
		1	2	3	4	1	2	3	4	1	2	3	4
Northern	West			■	■	■	■	■	■	■	■	■	■
	East			■	■	■	■	■	■	■	■	■	■
Central	West		■	■	■	■	■	■	■	■	■	■	■
	East			■	■	■	■	■	■	■	■	■	■
Southern	West			■	■	■	■	■	■	■	■	■	■
	East			■	■	■	■	■	■	■	■	■	■
	Irrigation			■	■	■	■	■	■	■	■	■	■



Figure 2: Cropping regions of NSW. Canola needs to be planted early to maximise grain potential. See Table 1 for regional planting time recommendations.

<sup>3</sup> L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

### 3.2.1 Northern NSW

In the western zone, commence sowing mid-maturing varieties in late April. Sow early-maturing varieties about 2 weeks later than mid-maturing varieties to minimise the risk of frost damage. In the eastern zone, commence from the first week of May and finish by the end of May.

### 3.2.2 Central and southern NSW

Have paddocks ready to sow by mid-late April. An early break, allowing sowing to occur mid-late April maximises yield potential and oil content. Sowing before mid-April may lead to crops becoming too vegetative, increasing their susceptibility to lodging, disease and moisture stress during podfill. They can also be at greater risk of frost damage. For these reasons, longer season varieties should be chosen for early sowings so that flowering and pod filling occur in a period of lower frost risk and lower risk of spring moisture and heat stress.

Where there is a low risk of frost damage at early podfill, early-maturing varieties can be planted from the second week of April in the western zone. In the eastern zone of central and southern NSW, sow mid-late-maturing varieties at the start of the sowing window and early-maturing varieties towards the end of the sowing window. Aim to finish sowing by mid-May in the better rainfall areas. Yields can fall by 10% per week after this period.

### 3.2.3 Southern NSW irrigation areas

Sowing time is often determined by the close to the irrigation season. The risk of winter waterlogging, spring water availability and high spring temperatures are other considerations. These factors need to be taken into account when choosing a variety with suitable maturity. For most situations, mid-maturing to early-mid-maturing varieties are preferred.<sup>4</sup>

To maximise grain yield potential, canola needs to be planted early. This requires careful attention to detail in relation to crop establishment. Because the soil surface dries out more rapidly in early-mid April than mid-May, seed may need to be planted slightly deeper than optimal (up to 5–6 cm deep). In this early-planting situation, pay strict attention to seed quality.

Research in the southern region has almost universally shown a negative correlation between canola later sowing date and grain yield. The challenge is that earlier sowing of canola is generally (but not always) more risky for successful crop establishment.

Recent GRDC-funded NSW Department of Primary Industries (DPI) research aimed not to improve canola establishment *per se*, but rather to increase the likelihood of achieving an adequate plant stand from sowing canola on time or early. The results

<sup>4</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

## More information

[Canola establishment; does size matter?](#)

[Canola time of sowing](#)

[Cowra](#)

have greatest relevance for an early planting opportunity and a lesser relevance for canola that is dry-sown or planted into moisture in May.<sup>5</sup>

## in focus

### 3.3 NSW DPI research. Improving canola profit in central NSW: effect of time of sowing and variety choice

- In western NSW, the practice of moisture seeking (sowing seed deeper than 3 cm) of canola in early–mid April into marginal moisture conditions may result in lower plant establishment rates than sowing just prior to or just after a rainfall event.
- Waiting until there was adequate moisture for sowing (early May), or dry sowing (late April) with a reliable forecast of follow-up rain, achieved higher yields than sowing in mid-April in 2012. However, the yield loss from early sowing in 2012 was assumed to be due to factors in addition to lower establishment rates.
- A high number of frost events contributed to the reduced yield potential of early-planted (mid-April) canola in 2012 in this trial in western NSW.<sup>6</sup>

#### 3.3.1 Background

Canola is an important winter crop-rotation option in western NSW. The advent of new varieties in all four herbicide groups has enabled widespread adoption over recent years. As in all areas where canola is produced, timely and uniform establishment is critical to the success of the crop. Sowing date is known to be an important management strategy to optimise yield of canola in all canola-growing regions.

Time of sowing is a balance between ideal sowing conditions and the appropriate maturity cultivar. Early sowing maximises vegetative growth (biomass) and the length of the flowering period but can predispose the crop to yield-damaging frosts at flowering and early grainfill. Later sowing may reduce frost risk but can result in poor vigour due to cold and/or wet soils at planting time, and an inability to complete seed maturity before the onset of high temperatures and moisture stress, reducing both yield and oil content.

NSW DPI recommends sowing canola from early-mid April to early May in the central-west zone (Condobolin–Nyngan), regardless of soil type (Figure 3). For western NSW regions, warm soil conditions in April, which can enable more vigorous establishment of current varieties, are often offset by lack of soil moisture in the seedbed at planting time. A trial was conducted in 2012 to investigate the effect of three times of sowing

<sup>5</sup> R Brill, L Jenkins, M Gardner (2014) Canola establishment; does size matter? GRDC Update Papers, 5 February 2014, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Canola-establishment-does-size-matter>

<sup>6</sup> 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, <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>

on yield and oil content of seven canola varieties (hybrid and open-pollinated) and evaluate the impact on length of flowering. For two varieties, a seeding-rate component was also included to determine interactions between sowing time and plant population, especially to investigate whether early-sown, low-density crops (<15 plants/m) show yield comparable to early-sown, higher density crops (>20 plants/m).<sup>7</sup>



Figure 3: NSW DPI recommends sowing canola from early-mid April to early May in the central-west zone. (Photo: Penny Heuston)

### 3.3.2 2012 trial details

The 2012 canola time-of-sowing trial was conducted at Trangie Agricultural Research Centre on a Grey Vertosol (cracking clay) soil (Colwell phosphorus (P), 22 µg/g, 0–10 cm). The trial was sown with 80 kg/ha of Granulock Supreme Z (11% nitrogen (N), 22% P, 4% sulfur (S) and 1% zinc (Zn)), by using a Morris Contour drill planter with the fertiliser placed directly with the seed. The trial was topdressed with 100 kg/ha of GranAm (21% N, 24% S) on 1 June, ahead of 9 mm rain on 2 June.

Table 2 indicates the dates and respective conditions at each time of sowing. Dates and conditions were chosen to reflect typical risk scenarios experienced by growers across the region. Table 3 shows the variety treatments. The seven varieties were chosen to compare a range of canola types, including early and midseason maturity, hybrid and open-pollinated, and herbicide tolerance type: conventional, TT and imidazolinone-tolerant (CLF). All seed was sourced from seed suppliers for this trial.

<sup>7</sup> 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, <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>

Table 2: Sowing dates, sowing depth and conditions for canola time-of-sowing trial, Trangie, 2012

Time of sowing	Sowing depth and conditions	Prior and/or follow-up rainfall
1. 13 April	Moisture seeking into marginal moisture, sown 5 cm deep	119 mm, March 2012 (pre-sow)
2. 26 April	Dry-sown, sown 2 cm deep	14 mm, 2 May (post-sow)
3. 14 May	Moderately moist soil, sown 3–4 cm deep	14 mm, 2 May (pre-sow); plus 21 mm, 24 May (post-sow)

Table 3: Variety characteristics, target plant population, number of seeds planted, seed size and actual sowing rate for canola time-of-sowing trial, Trangie, 2012

Variety	Characteristics	Target plant population (plants/m)	No. of seeds planted per m	Seed weight (g/1000 seeds)	Actual sowing rate (kg/ha)
43C80 (CL)	Open-pollinated, Clearfield®, early maturity	40	80	3.68	2.94
43Y85 (CL)	Hybrid, Clearfield®, early maturity	40	80	5.03	4.02
44Y84 (CL)	Hybrid, Clearfield®, early to early–mid maturity	40	80	5.38	4.30
AV-Garnet	Open-pollinated, conventional, mid to mid–early maturity	40	80	3.47	2.78
Hyola 555TT	Hybrid, triazine-tolerant, mid–early maturity	40	80	4.26	3.41
Jackpot TT	Open-pollinated, triazine-tolerant, mid–early maturity	40	80	3.76	3.01
ATR-Stingray	Open-pollinated, triazine-tolerant, early maturity	40	80	3.44	2.75
44Y84 (CL)_Low	As per 44Y84 (CL), low seed rate	15	30	5.38	1.61
AV-Garnet_Low	As per AV-Garnet, low seed rate	15	30	3.47	1.04

Total establishment was assumed to be 48% (rounded up to 50%) based on germination of 80% and field establishment of 60% (industry standard figures). Hence, where 40 plants/m was the target density, sowing rate was 80 seeds/m, and for 15 plants/m, sowing rate was 30 seeds/m.

The canola varieties used in this trial were chosen as representative of particular herbicide, plant-type and maturity groups; seed companies may market other varieties with potential similar to or better than the varieties used in this trial.<sup>8</sup>

<sup>8</sup> 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, <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>

### 3.3.3 2012 trial results

#### *Effect of time of sowing on establishment*

Date and days to emergence (as an average for all varieties) were recorded for the three times of sowing (TOS): 1 (24 April), 11 days; 2 (4 May), 8 days; 3 (28 May), 14 days. Plant counts (Figure 4) were conducted progressively for each time of sowing once there was no recorded change in emergence scores (conducted three times per week).

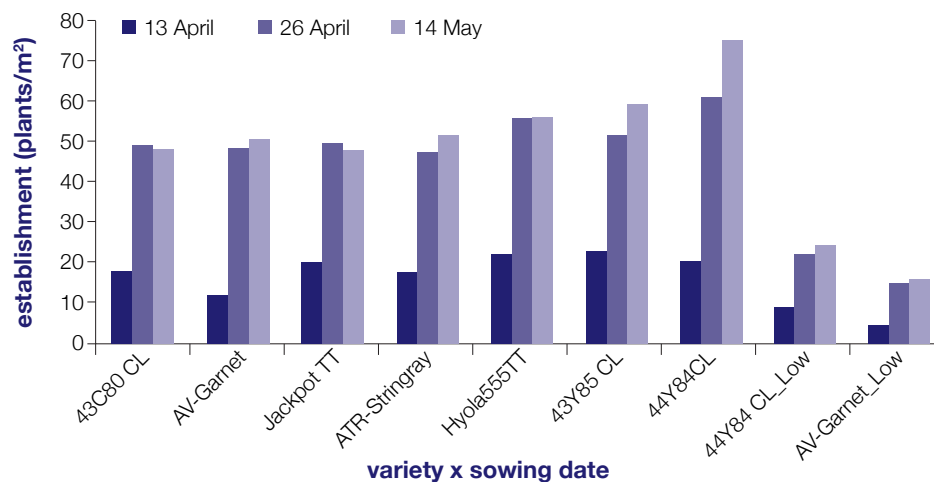


Figure 4: Establishment of seven canola varieties with two target plant populations (40 or 15 plants/m) at three sowing dates (13 April, 26 April, 14 May), Trangie, 2012.

All varieties had reduced establishment from TOS 1, regardless of type (open-pollinated or hybrid) or seed size. For TOS 1, moisture seeking was used to a depth of 5 cm into marginal moisture because there was no rainfall event in early April to plant on. Depth of sowing at TOS 1 may have had a greater effect on establishment than lack of moisture at sowing. For the standard target plant population (40 plants/m), the average of all varieties was 16 plants/m, with only two hybrids (Hyola 555TT and 43Y85 (CL)) achieving >25% establishment (i.e. plant count >20 plants/m from 80 seeds/m planted). For the low seeding rate (target 15 plants/m), the average was <7 plants/m (i.e. <25% target establishment from 30 seeds/m planted). AV-Garnet had the lowest plant count at both seeding rates.

Establishment for all varieties at TOS 2 and TOS 3 exceeded the target plant population, because plant establishment was greater than the assumed 50% on which seed rates were calculated. This could be due to either the shallower sowing depth and/or the follow-up rainfall received post-sowing. TOS 2, with dry sowing at 2 cm depth, showed quicker emergence than either TOS 1 or TOS 3, once follow-up rain was received. The average plant counts for the standard sowing rate (target 40 plants/m) was 48 plants/m (60%) for both TOS 2 and TOS 3, whereas for the low sowing rate (target 15 plants/m), TOS 2 achieved 18 plants/m (60%) and TOS 3 achieved 20 plants/m (67%).

In terms of variety effect, the three hybrids, with seed size >4 g/1000 seeds (Hyola 555TT, 43Y85 (CL) and 44Y84 (CL)), averaged 74% establishment, compared with the



four open-pollinated varieties, with seed size <4 g/1000 seeds, which averaged 61% establishment.<sup>9</sup>

### Effect of time of sowing on length of flowering

Previous time-of-sowing trials with canola have suggested that late sowing shortens both the vegetative and reproductive phases through temperature and photoperiodic effects, as well as increased water stress during the grain-filling period. Weekly observations of flowering were conducted to assess the impact of time of sowing on length of flowering. The summary in Figure 5 highlights 10% start flower, 100% full flower and 10% end flower, defined as follows:

- 10% start flower: the date when 10% of plants in the crop (plot) have commenced flowering.
- 100% full flower: the date when 100% of plants in the crop (plot) are in full (maximum) flower. The crop is bright yellow with all branches flowering. Some early pods may be visible in the lower section of branches.
- 10% end flower: the date when 10% of plants in the crop (plot) have flowers remaining at the top of the branch. The lower 90% of the branch will have pods formed or forming.

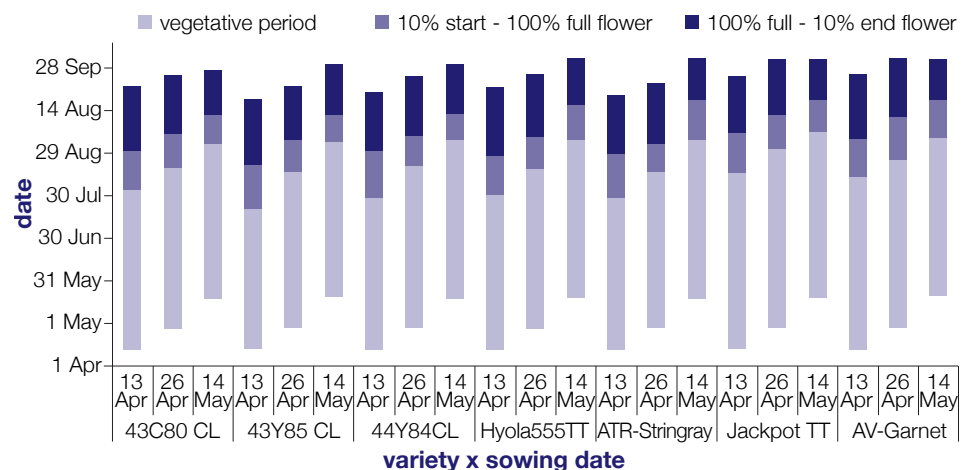


Figure 5: Length of flowering of seven canola varieties with three sowing dates, Trangie, 2012.

The observations presented below are based on calendar days, which do not take into account the difference in thermal time (accumulated day-degrees) between each TOS treatment. Temperature effects are a major driver of plant growth and development in canola. As an example, TOS 1 would have accumulated more day-degrees in May than TOS 3. In addition, these data have not been statistically analysed.

For each canola variety, the length (calendar days) of the vegetative period was reasonably consistent regardless of time of sowing, within a range of ~10 days of variation between TOS treatments. There were differences between varieties for average length of vegetative period. Longer season varieties Jackpot TT and AV-Garnet averaged >100 days. Short-season varieties 43Y85 CL and ATR-Stringray

<sup>9</sup> 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, <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>

averaged 90 and 92 days, respectively. The lower seeding rate lengthened the vegetative period of 44Y84 (CL) for TOS 1 only (by 4 days). The lower seeding rate shortened the vegetative period of AV-Garnet by 4 days for TOS 1 and lengthened it by 5 days for TOS 2.

There were differences in the total length (calendar days) of flowering period as a time-of-sowing effect. For each canola variety (including those planted at lower seeding rates), total length of the flowering period was shortened as sowing was delayed. Lengths of flowering period averaged for all varieties were 62 days (TOS 1), 55 days (TOS 2) and 47 days (TOS 3). Some varieties showed a greater difference between TOS 1 and TOS 2 (e.g. 43Y85 (CL), 13 days; 44Y84 (CL), 11 days), whereas other varieties were more affected by the delay from TOS 2 to TOS 3 (e.g. AV-Garnet, 12 days; Jackpot TT, 10 days). The Pioneer Clearfield® varieties appeared more affected than the TT varieties (shorter flowering period by up to 20 days). The lower seeding rate had opposite effects on the two varieties tested. In 44Y84 (CL)\_Low, flowering period was 1.5 days shorter for TOS 1 but 2–3 days longer for TOS 2 and TOS 3 than in 44Y84 (CL). In AV-Garnet\_Low, flowering period was 4 days longer for TOS 1 but up to 5 days shorter for TOS 2 and TOS 3 than in AV-Garnet.<sup>10</sup>

### Effect of time of sowing on yield

There were significant differences in yield (Figure 6) with regard to both variety and time of sowing. However, there was no significant variety x sowing time interaction, meaning that varieties performed relatively consistently regardless of when they were planted.

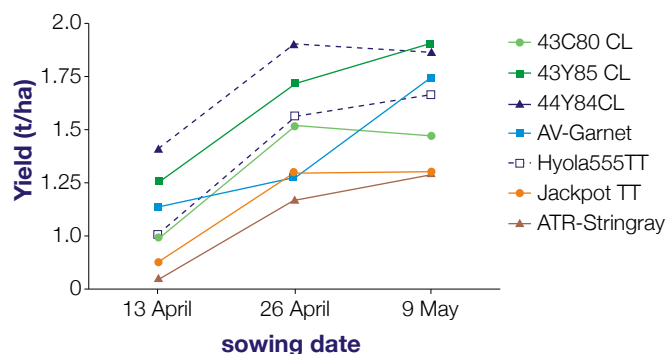


Figure 6: Grain yield (t/ha) of seven canola varieties sown with three sowing dates, Trangie, 2012. For statistical comparisons, l.s.d. ( $P = 0.05$ ) is 0.16 t/ha for varieties and 0.1 t/ha for sowing dates.

Analysis of the effect of time of sowing, averaged for all varieties, showed that yield for TOS 3 was significantly higher than for TOS 2 (by 0.11 t/ha) and, in turn, yield for TOS 2 was significantly higher than for TOS 1 (by 0.43 t/ha). The lower yield of TOS 1 was likely due to a combination of factors including reduced plant establishment, frost damage from early flowering, and potentially higher rates of vegetative water use.

The hybrids 44Y84 (CL) and 43Y85 (CL) were the highest yielding varieties in the trial, with an average yield across all sowing times of 1.72 and 1.62 t/ha, respectively.

<sup>10</sup> 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, <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>

Jackpot TT and ATR-Stingray were the lowest yielding varieties, with an average yield across all sowing times of 1.15 and 1.07 t/ha, respectively.

Seeding-rate treatment had a significant effect on yield ( $P = 0.002$ ). Averaged over the two varieties (44Y84 (CL) and AV-Garnet), the high seeding rate targeting 40 plants/m yielded 0.24 t/ha more than the low seeding rate targeting 15 plants/m (l.s.d. ( $P = 0.05$ ), 0.14 t/ha). There was no seeding rate x sowing time interaction, meaning that the advantage of the higher seeding rate was observed for all sowing times.<sup>11</sup>

### Effect of time of sowing on oil content

There were significant differences in oil content between varieties (Figure 7), but no significant difference due to time of sowing. Jackpot TT had the highest average oil content (43.2%), followed by 44Y84 (CL) (42.1%). All other varieties averaged less than the minimum base oil content of 42%, meaning that discounts would apply at delivery. The lowest of these were 43Y85 (CL) (40.8%) and Hyola 555TT (40.6%)

There was no significant effect of seeding-rate treatment on oil content.<sup>12</sup>

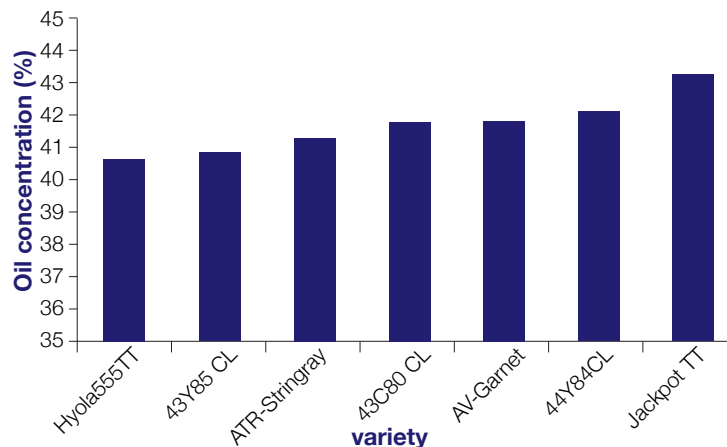


Figure 7: Oil concentration at 6% moisture of seven canola varieties averaged across three sowing dates, Trangie, 2012. For statistical comparison between varieties, l.s.d. ( $P = 0.05$ ) is 0.6%.

### 3.3.4 Discussion

Previously published time-of-sowing trial data suggest that, generally, early sowing (early–mid April) predisposes the crop to greater frost risk during flowering, whereas delayed sowing (late May–late June in southern grain zones) can result in reduced yield potential. This reduced potential is due to a combination of factors, including a shortened vegetative period (reduced crop biomass), reduced length of flowering period, and moisture and high temperature stress at grainfill.

<sup>11</sup> 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, <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>

<sup>12</sup> 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, <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>

The present trial was focused on the early sowing period for western NSW, from mid-April to early May. TOS 1 (13 April) involved moisture seeking into marginal moisture at 5 cm depth, resulting in an average of <25% establishment of target plant densities. TOS 2 (26 April) showed that dry sowing can be a viable option for canola if there is a reliable forecast of follow-up rain (15–20 mm). TOS 2 received 14 mm rain on 2 May and the crop had begun emerging by 4 May. TOS 3 (14 May) was sown into good moisture and received 21 mm follow-up rainfall. Both TOS 2 and TOS 3 achieved plant densities higher than the target because the field establishment percentage was greater than the assumed 50%.

The 2012 Trangie trial confirmed previous studies that the length of the flowering period is reduced as time of sowing is delayed, regardless of variety maturity. However, the shorter flowering period for TOS 2 and TOS 3 compared with TOS 1 did not translate into reduced yield or oil content. Both TOS 2 and TOS 3 resulted in significantly higher yields (as an average for all varieties) than TOS 1, and there was no significant difference in oil content.

The most likely contributing factor to the reduced yields for TOS 1 was greater frost damage. Frost-impact data (number of aborted pods) were collected at the end of flowering but the data are not yet analysed. Meteorological data from Trangie Agricultural Research Centre weather station support grower observations that 2012 had an unusually high number of frosts during late winter–early spring. There were 59 frosts (defined as <math><2^{\circ}\text{C}</math> recorded in Stevenson screen) from 1 May to 30 September in 2012. Several periods of consecutive frosts occurred from late July to early September. Some of these frost events were severe, e.g. 3 days below  $-3.0^{\circ}\text{C}$  recorded 31 July–2 August. Because TOS 1 commenced flowering earlier (average for all varieties 17 July) and flowered for a longer period than TOS 2 or TOS 3, which commenced flowering on average 2 August and 16 August, respectively, it is assumed that TOS 1 was more affected by frosts during flowering.

Further research is required to investigate the effect of early sowing on vegetative water use. The early sowing date resulted in plants growing in May, in relatively warm temperatures; therefore, water use may also have been higher, leaving less water available for grainfill. <sup>13</sup>

### 3.3.5 Conclusion

Conditions at sowing can affect crop establishment rates. Moisture seeking early (mid-April) into marginal moisture conditions may reduce establishment. Delaying sowing until moisture conditions are better after an autumn break (early May), and even dry sowing (at a shallow depth) prior to the autumn break, can be acceptable for canola, provided adequate rainfall (15–20 mm) is received soon after sowing. In this 2012 trial, if May had remained dry, the early deep-sown treatment may still have had a better outcome than not planting canola at all. Seeding rates that target a lower plant population may reduce yield potential. However, the greatest risk associated with early sowing is the impact of frost, which may significantly reduce the yield potential of early-planted (mid-April) canola in western NSW. <sup>14</sup>

#### More information

[Canola agronomy research in central west NSW](#)

<sup>13</sup> 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, <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>

<sup>14</sup> 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, <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>

### 3.4 Targeted plant population

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

Crops with low plant densities tend to yield poorly. 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.

Aim for 40–60 plants/m (20–40 plants/m in northern and western NSW) which can normally be achieved with 2–4 kg/ha of seed. Plant densities as low as 15 plants/m, 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 per square metre to be sown (see NSW DPI *Winter crop variety sowing guide*).<sup>15</sup>

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.

#### More information

[Over the bar with better canola agronomy](#)

#### 3.4.1 Calculating seed requirements

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

Suppliers usually supply canola seed by number of seeds per kg, e.g. 200,000 seeds/kg. To determine the seeding rate based on this, the formula below 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

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

Thus, the seeding rate =  $(40 \times 1,000,000)/(211,400 \times 85)$   
 $= 40,000,000/17,969,000$   
 $= 2.23 \text{ kg/ha}$ <sup>16</sup>

<sup>15</sup> P.Matthews, D. McCaffery and L. Jenkins (2015) Winter crop variety sowing guide 2015. [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>16</sup> BCG (2015) Calculating canola seeding rates. News article. Birchip Cropping Group, [http://www.bcg.org.au/cb\\_pages/news/The\\_time\\_for\\_sowing\\_canola\\_is\\_upon\\_us\\_making\\_it\\_important\\_to\\_revisit\\_our\\_understanding\\_of\\_seeding\\_rates.Getting\\_this\\_right.php](http://www.bcg.org.au/cb_pages/news/The_time_for_sowing_canola_is_upon_us_making_it_important_to_revisit_our_understanding_of_seeding_rates.Getting_this_right.php)

## Seeding rate calculators

[Pacific Seeds: canola seed planting rate calculators](#)

[Pioneer canola seed rate calculator](#)

### 3.4.2 Row spacing

Canola has traditionally been sown at 15 cm row spacing, but the adoption of stubble retention and no-till farming systems has resulted in a trend to wider row spacing and the possibility of inter-row sowing using GPS guidance systems.

Experiments in southern NSW have shown that widening row spacing in canola does appear to reduce yield when the row space is increased to 35 cm.<sup>17</sup> Aim for 40–60 plants/m (20–40 plants/m in northern and western NSW), which can normally be achieved with 2–4 kg/ha of seed. Plant densities as low as 15 plants/m, 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 m.

Establishment can be significantly reduced by sowing too deep, sowing late into cold, wet soils, and no-till sowing into dense stubble. Use the 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.<sup>18</sup>

## 3.5 Sowing depth

Where conditions allow, aim to drill seed through the main seed box to 1.5–3 cm deep and up 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.<sup>19</sup>

<sup>17</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

<sup>18</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>19</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

Sowing depth has a major influence on seedling vigour, which subsequently affects seedling establishment and crop performance. A sowing depth of 1.2–2.5 cm is ideal.

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, less 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.<sup>20</sup>

This effect can contribute to slower growth of plants in surface-mulch treatments, and the slower growth can be compounded by low temperatures.

### More information

[Over the bar with better canola agronomy](#)

## in focus

### 3.5.1 Canola establishment research

Sowing depth trials were conducted at Coonamble, Nyngan and Trangie in 2012 and at Nyngan and Trangie in 2013. Each trial had six common varieties with a range in seed size (Table 4). Target seeding depths were 2.5, 5 and 7.5 cm.

Table 4: Seed size and number of seeds sown in three canola variety–sowing depth trials in 2012

Variety	Seed weight (g/1000 seeds)		No. of seeds sown per m
	2012	2013	
AV-Garnet	3.78	3.27	60
ATR-Stingray	3.06	2.97	60
Pioneer 43C80 (CL)	3.68	4.11	60
Pioneer 43Y85 (CL)	5.03	4.77	60
Pioneer 44Y84 (CL)	5.34	5.20	60
Hyola 555TT	4.26	4.00	60

In 2012, averaged across all trials and varieties, establishment (as a percentage of seeds sown) at the target depth of 2.5 cm was ~66%, with no difference between varieties. All varieties had reduced establishment at 5 cm sowing depth relative to 2.5 cm sowing depth, with the exception of Pioneer 44Y84 (CL), which had the largest seed (Figure 8). At 7.5 cm sowing depth, the differences between varieties, and seed size, became more marked, with the largest seeded variety achieving 50% establishment compared with 20% for the smallest seeded variety.

<sup>20</sup> 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, <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>

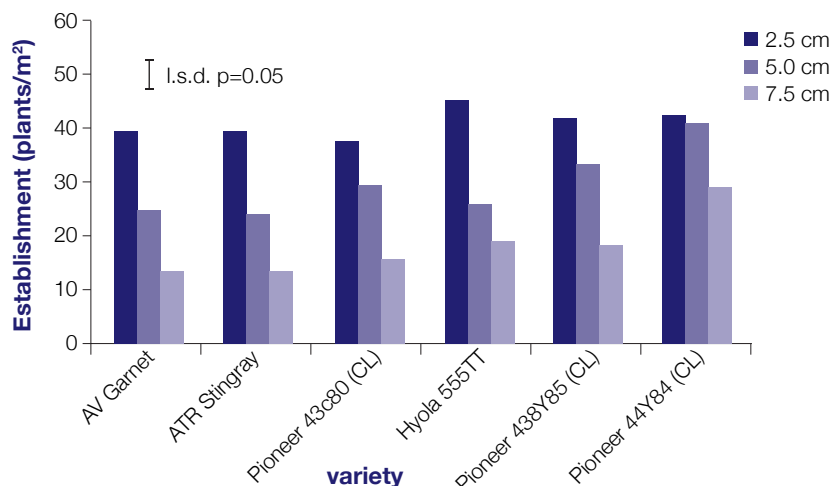


Figure 8: Establishment of six canola varieties at three sowing depths, averaged across three trials at Coonamble, Nyngan and Trangie in 2012.

The effect of sowing depth on grain yield in 2012 was less marked than the effect on establishment. At Nyngan and Coonamble, the target depth of 7.5 cm yielded ~250 kg/ha less grain than the target depths of 2.5 and 5 cm. At Nyngan, Pioneer 44Y84 (CL) showed no grain-yield reduction at 7.5 cm sowing depth compared with the shallower sowing depths; however, all other varieties showed a significant grain-yield reduction as a result of deep sowing. There was no effect of sowing depth on grain yield at Trangie.

In 2013, the overall establishment achieved was less than in 2012. At 2.5 cm sowing depth, establishment was approximately 50%, with no significant difference between varieties (Figure 9). All varieties showed reduced establishment at 5 cm sowing depth compared with 2.5 cm; however, the reduction was less severe for the hybrids than for the open-pollinated varieties. Establishment was further reduced at 7.5 cm sowing depth, with a hybrid advantage similar to that at 5 cm sowing depth.

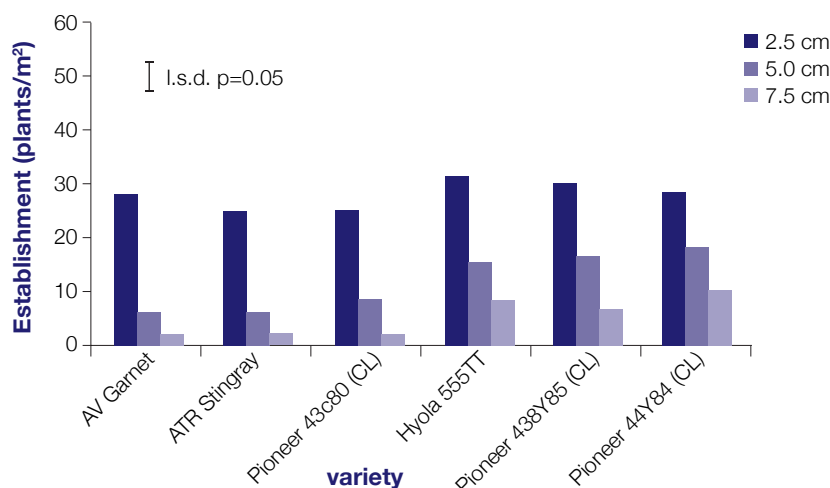


Figure 9: Establishment of six canola varieties at three sowing depths, averaged across two trials at Nyngan and Trangie in 2013.



The effect of sowing depth on grain yield was greater in 2013 than in 2012 but was still of a lesser magnitude than the effect of sowing depth on establishment. At Nyngan, the grain yields of Pioneer 44Y84 (CL), AV-Garnet and Hyola 555TT were similar for 2.5 cm sowing depth. However, AV-Garnet and Hyola 555TT both had a significant grain-yield reduction at 5 and 7.5 cm sowing depths, whereas Pioneer 44Y84 (CL) did not suffer a yield penalty from deeper sowing. At Trangie, all varieties suffered a grain-yield penalty with increasing sowing depth, but this reduction in grain yield was less severe for the larger seeded varieties.

At each trial site in 2012, a P rate trial was also sown. The P product used was triple superphosphate, which does not supply any N with the P. The P rates applied were 0, 5, 10 and 20 kg/ha, the fertiliser being placed directly with the seed.

There was no effect of P rate on canola establishment on the cracking clay (Grey Vertosol) soil at Trangie. By contrast, increasing P rate significantly reduced the establishment of all varieties on the lighter textured soils at Nyngan (Red Chromosol) and Coonamble (Brown Chromosol) (Figure 10). All varieties experienced a similar reduction in establishment, regardless of seed size or plant type.

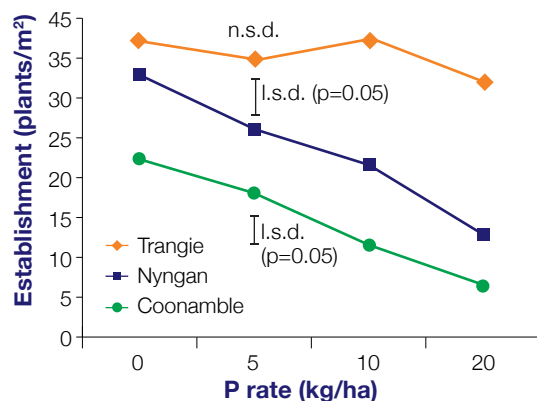


Figure 10: Average establishment of four canola varieties sown with four rates of phosphorus at Trangie, Nyngan and Coonamble in 2012.

Grain yield responded positively to P application at Trangie and Nyngan, which highlighted that the complete exclusion of P in order to improve crop establishment is not reasonable.

Two further P trials were conducted in 2013, with the Trangie trial planted on a lighter textured soil (Red Chromosol) rather than the heavy (Grey Vertosol) soil used in 2012. There was a significant establishment reduction at both sites as P rate (applied as triple superphosphate) increased (Figure 11). Further product comparisons at a common P rate showed that all major phosphate fertilisers (mono- and di-ammonium phosphate, single and triple superphosphate, Supreme Z) affected establishment to a similar degree. Despite the effect on establishment, grain yield still responded positively to P at Nyngan, with the 5 kg P/ha rate yielding 0.25 t/ha more than the nil P treatment but with no further yield increase beyond this rate.

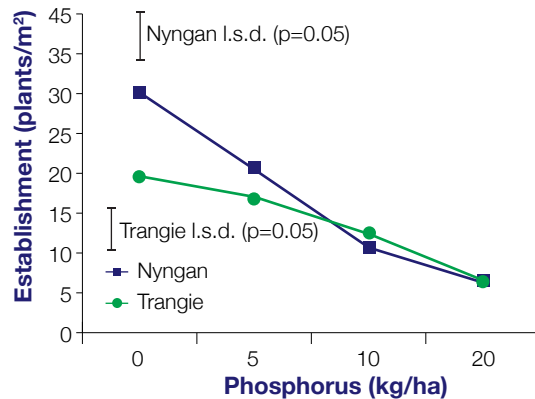


Figure 11: Average establishment of two canola varieties sown with four rates of phosphorus at Trangie and Nyngan in 2013.

For growers using a tine seeder, it is generally possible (and recommended) to separate seed and fertiliser to avoid the negative effects of starter fertiliser. For growers with a disc seeder (or considering a disc seeder), several management options are available, such as:

- Plant on relatively narrow crop rows to reduce fertiliser concentration in the furrow.
- Plant canola early to allow greater root exploration, with potentially less P application required.
- Pay strict attention to closing devices; the firmer or heavier the closing device, the greater the negative effects of P fertiliser.<sup>21</sup>

### Conclusion

To maximise grain-yield potential, canola needs to be planted early. This requires careful attention to the details of crop establishment. Because the soil surface dries out more rapidly in early-mid April than mid-May, seed may need to be planted slightly deeper than optimal (up to 5–6 cm deep). In this early planting situation, pay attention to seed quality. Sowing large seeds (> 5 g/1000 seeds) increases the likelihood of achieving an adequate establishment. For growers who wish to purchase seed, hybrid seed is generally larger than open-pollinated seed. For growers who retain open-pollinated seed on farm for their own use, aim to clean seed with a 2-mm screen.

Phosphorus is essential for canola growth, but starter fertiliser may have an effect on crop establishment. Avoid high rates of P in direct contact with canola seed at sowing. Further research is required on P nutrition of canola, especially on the interactions between P application and sowing time and the effect that liquid P products may have on canola establishment.<sup>22</sup>

### More information

[Canola establishment: does size matter?](#)

<sup>21</sup> R Brill, L Jenkins, M Gardner (2014) Canola establishment; does size matter? GRDC Update Papers, 5 February 2014, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Canola-establishment-does-size-matter>

<sup>22</sup> R Brill, L Jenkins, M Gardner (2014) Canola establishment; does size matter? GRDC Update Papers, 5 February 2014, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Canola-establishment-does-size-matter>

### 3.6 Sowing equipment

Canola can be sown by using no-till techniques or sown into a well-prepared, cultivated seedbed. 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.<sup>23</sup>

Sow seed through the main seed box or small seed 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 ground speed 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 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 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 result in front-tine seed being sown too deep.
- 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 N (see above).<sup>24</sup>

<sup>23</sup> 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

<sup>24</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

### 3.6.1 Alternate 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.<sup>25</sup>

<sup>25</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## SECTION 4

# Plant growth and physiology

## 4.1 Canola types

### 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 swing to breeding *B. napus* varieties.

*Brassica napus* is thought to have formed originally 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.<sup>1</sup>

### 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 triazine-tolerant trait is associated with reduced conversion of sunlight into biomass (i.e. reduced radiation-use efficiency). Triazine-tolerant varieties are therefore generally less vigorous as seedlings and produce less biomass than conventional varieties. This results in 10% to 15% lower yields and 1% to 3% lower oil contents than in conventional varieties. However the effective weed control available in these

<sup>1</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

varieties means actual yield is often higher than conventional varieties competing with weeds. Another effect of the triazine-tolerant trait is a delay in plant development.<sup>2</sup>

### 4.1.3 Hybrids

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

### 4.1.4 Specialty canola – high oleic/low linolenic (HOLL)

Specialty canolas 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. This type of oil is more stable at higher temperatures and more suited for deep frying. This gave a high oleic/low linolenic (HOLL) canola.<sup>4</sup>

### 4.1.5 IMI-tolerant canola

IMI-tolerant varieties are tolerant to imidazolinones (IMIs), the active ingredients 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.<sup>5</sup>

### 4.1.6 Condiment (Indian) mustard

Condiment mustards are varieties of *Brassica juncea* grown for their hot, peppery taste. Although related to juncea canola, 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. The oil has a distinct 'nutty' flavour, but the erucic acid level is sufficiently low to make it suitable for human consumption. 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.<sup>6</sup>

<sup>2</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>3</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>4</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>5</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>6</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

### 4.1.7 Juncea canola – *Brassica juncea*

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

### 4.1.8 Roundup Ready®

Roundup Ready® (RR) 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 a number of 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.<sup>7</sup>

Table 1: Typical seed quality characteristics for canola, juncea canola and condiment mustard when grown in the low rainfall zone.

Characteristic	Canola	Juncea canola	Condiment mustard
Oil %	36–42	34–40	34–40
Oleic acid %	57–63	57–63	variable
Linoleic acid %	18–25	18–25	variable
Linolenic acid %	8–13	8–13	variable
Erucic acid %	<1	< 1	1–20
Glucosinolate in meal (µmol/g – 10% MC)	< 30	< 30	110–160
Allyl glucosinolate in meal (µmol/g – 10% MC)	0	< 1	NA

Source: NSW DPI

<sup>7</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

All canola grown commercially in Australia is the Swede rape type *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.

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.)<sup>8</sup>

**i More information**

[Revisiting canola management can lift returns](#)

[Canola growth and development—impact of time of sowing \(TOS\) and seasonal conditions](#)

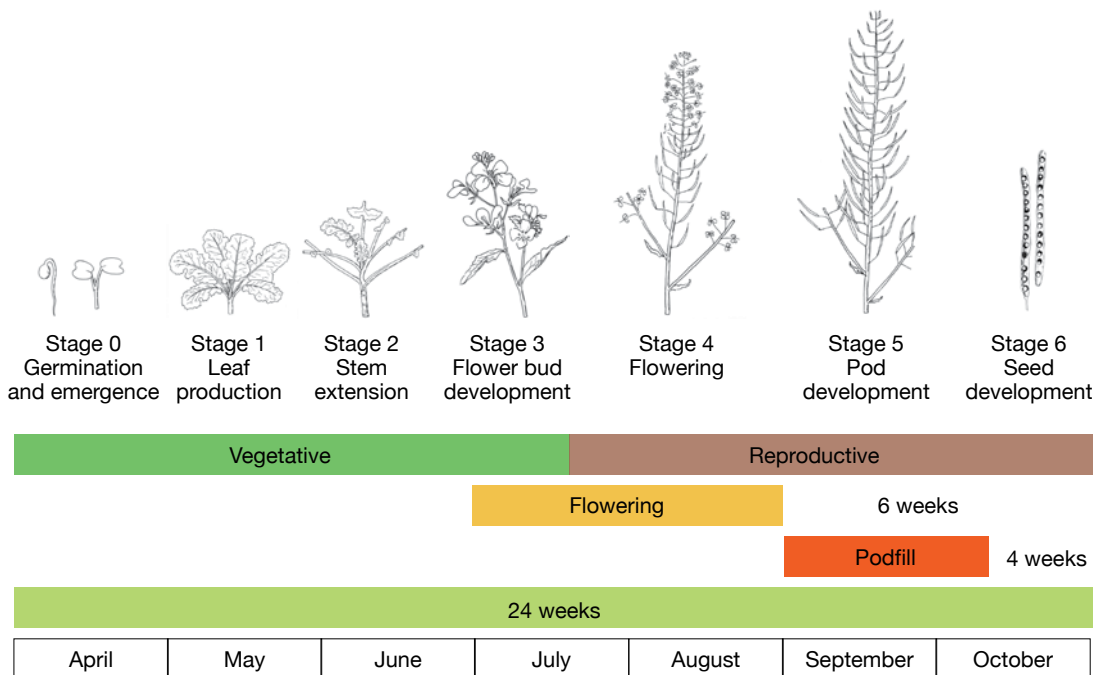


Figure 1: Canola growth stages

<sup>8</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



## infocus

### 4.2 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 x E x 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.
3. Manage the trajectory of biomass accumulation (of specific varieties) to maximise water-use efficiency, optimise N-use efficiency and minimise the risk of high-input 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

## **i** More information

[Canola growth and development—impact of time of sowing \(TOS\) and seasonal conditions](#)

[Improved understanding of thresholds of armyworm in barley and aphids in canola](#)

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.<sup>9</sup>

## 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.<sup>10</sup>



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.<sup>11</sup>

<sup>9</sup> A Ware *et al.* (2015) Canola growth and development—impact of time of sowing (TOS) and seasonal conditions. GRDC Update Papers, 10 February 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Canola-growth-and-development-impact-of-time-of-sowing-TOS-and-seasonal-conditions>

<sup>10</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>11</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



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 about 15 internodes.<sup>12</sup>



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.<sup>13</sup>

<sup>12</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>13</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



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).<sup>14</sup>



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).<sup>15</sup>

<sup>14</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>15</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



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
- 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 triazine-tolerant (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, 50–70% 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%.<sup>16</sup>



Figure 8: Seed development, stage 6.



Figure 9: Seed pods.

<sup>16</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

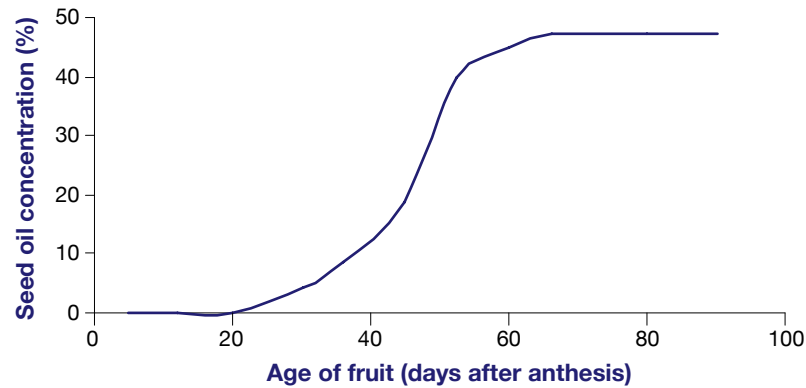


Figure 10: Seed oil concentration in Australian crops increases throughout seed development and reaches a plateau at ~60 days after flowering. (Source: P. Hocking and L. Mason)

### 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 either independently or in combination (Figure 12).<sup>17</sup> Hail damage to pods can also affect seed development (Figure 13).

<sup>17</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



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)



## SECTION 5

# Nutrition and fertiliser

## 5.1 New nutrition thinking for the northern region

Canola best management recommendations from the southern region have been a useful starting point; however, they are now being fine-tuned and adapted for conditions and soil types in the northern region.

Research into optimal fertiliser rates, particularly for [nitrogen \(N\)](#), [phosphorus \(P\)](#) and [sulfur \(S\)](#), has generated useful data. The relationship between crop nutrition and production of consistent oil content is also under investigation (see [Section 5.6 Sulfur](#))

Previous recommendations considered S to be non-negotiable and N applications more seasonally dependent. New research indicates this approach needs to be reversed; S application may not be needed and attention should be refocused and effort redirected to getting N rates right.

Trials over 3 years in the central and northern regions of New South Wales (NSW) indicate that the previous recommendation of 20–25 kg S/ha independent of soil nutritional status is unwarranted, with no trial demonstrating a response.

Sulfur deficiency in canola, if it occurs, can be severe but this is not always the case. The frequency of such deficiency is most likely lower than thought and can be rectified early in-crop without ongoing penalty.

Canola has abundant fine roots with the ability to branch and proliferate in zones of higher nutrient content, such as around fertiliser bands or granules. In addition, canola roots can increase their root hair number and length in response to low P conditions.

Strong responses to N have been observed. Savings in S fertiliser costs may be better used to increase N rates. <sup>1</sup>

## 5.2 Crop removal rates

Canola requires high inputs per tonne of grain for the major (macro-) nutrients N, P and S compared with other crops (Table 1). However, on a per-hectare basis, canola's nutritional requirements are similar to cereals, because yields are usually about 50% of wheat. <sup>2</sup>

<sup>1</sup> GRDC (2014) Canola nutrition in the northern region. GRDC Media Centre, 28 April 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-nutrition-in-the-northern-region>

<sup>2</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

### More information

[Economics and management of P nutrition and multiple nutrient decline](#)

[Nitrogen and sulfur for wheat and canola—protein and oil.](#)

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

	Nitrogen		Phosphorus		Potassium		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

### 5.3 Soil testing

In Australia, canola is not recommended for soils of pH<sub>CaCl</sub> <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, with some 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 is pH is ≤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.<sup>3</sup>

[NSW DPI soil testing](#)

### 5.4 Nitrogen

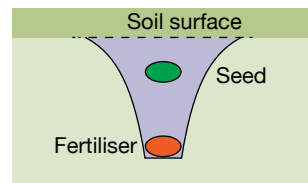
Canola has a high N demand, twice that per ton of wheat. One ton per Ha of canola will remove approximately 40Kg/ha of N but the crop will require at least twice this amount. For a crop with a targeted yield of around 2t/ha the crop will require around 160kg/ha of N. This can be supplied through soil reserves but additional N fertilizer will be needed in many cases. Depending on the amount of soil N available to the crop, ~80–100 kg/ha of fertiliser N would 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.

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. The majority of the N should be either drilled in before

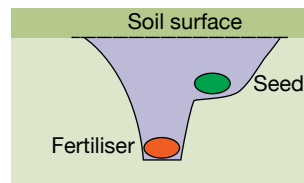
<sup>3</sup> P Hocking, R Norton, A Good (1999) Crop nutrition. 10th International Rapeseed Congress, <http://www.regional.org.au/au/gcirc/canola/p-05.htm>

sowing or banded 2-3cm below and beside the seed at sowing (Figure 1). 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.<sup>4</sup>



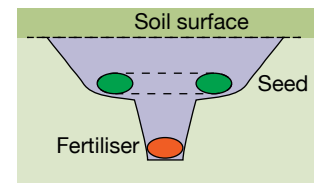
**A. Single outlet with centre banding**

**Pros:** Sub-seed soil disturbance, fertiliser separation banded at depth.  
**Cons:** High draft and breakout force required compared with tillage at seeding depth, seed placement quality variable.



**B. Single outlet with side banding**

**Pros:** Sub-seed soil disturbance, fertiliser separation banded at depth, improved seed placement, good moisture transfer to seed.  
**Cons:** High draft and breakout force required, potentially higher soil and residue disturbance.



**C. Dual outlet paired row and ribbon sowing systems**

**Pros:** Sub-seed soil disturbance, fertiliser separation, good seed placement except over centre section, higher seed-bed utilisation.  
**Cons:** High draft and breakout force required, higher soil and residue disturbance influencing seeding depth uniformity.

Figure 1: Three arrangements of split seed and fertiliser banding with tillage below the seeding point that illustrate the different types of seed and fertiliser separation achieved.

The N content of a canola plant (expressed as a percentage of dry matter) is highest at the full rosette stage, when deficiency symptoms are often visible.

Generally, the older leaves become pale green to yellow, and may develop red, pink or purple colours (Figure 2). 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.

<sup>4</sup> L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)



Figure 2: 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)

Unfortunately, some visual symptoms are similar to other nutrient deficiencies (e.g. P and S), which can result in incorrect diagnosis.<sup>5</sup>

N deficiency affects older leaves first, while sulfur deficiency affects younger leaves first.<sup>6</sup>

Tissue tests combined with a good knowledge of the paddock's history (including past fertiliser use and crop yields) will assist in a more accurate assessment of the most likely deficiency.<sup>7</sup>

#### [Diagnosing nitrogen efficiency in canola](#)

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

Canola removes 40 kg N/t grain, but the crop requires up to three times this amount of N to produce this 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 (HI) of about 33%.

<sup>5</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>6</sup> Diagnosing nitrogen deficiency in canola, <https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-canola>

<sup>7</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

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

As a rough 'rule of thumb', the in-crop mineralisation is calculated as:

$$\text{Growing season rainfall (mm)} \times \text{organic carbon (\%)} \times 0.15$$

$$\begin{aligned} \text{Fertiliser N required for crop} &= \text{total N required} - \text{available soil N (kg N/ha)} \\ &= 200 - 125 \text{ kg N/ha} \\ &= 75 \text{ kg N/ha} \end{aligned}$$

### 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:

$$\begin{aligned} \text{Estimated target yield} &= 2 \text{ t/ha} \\ \text{N removal in grain} &= 2 \times 40 \text{ kg N/t} = 80 \text{ kg N/ha} \\ \text{Total N required} &= 80 \times 2.5 \text{ kg N/ha} \\ &= 200 \text{ kg N/ha}^8 \end{aligned}$$

### Nitrogen fertiliser rates

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

Using the example:

$$\begin{aligned} \text{Available soil N (calculated from deep N test + in-crop mineralisation)} &= 125 \text{ kg/ha} \\ \text{Fertiliser N required for crop} &= 200 - 125 \text{ kg N/ha} \\ &= 75 \text{ kg N/ha (or 163 kg/ha of urea)} \end{aligned}$$

As the above calculations indicate, about 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.<sup>9</sup>

<sup>8</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>9</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## infocus

### 5.4.2 Northern Grower Alliance trials

Recent GRDC-funded Northern Grower Alliance (NGA) research has demonstrated strong yield responses to N in situations with ~25–70 kg N/ha available from soil testing (excluding any mineralised N). Nitrogen removal in grain was ~60–80 kg N/ha at yields of ~1.5–2.0 t/ha. This supports a total crop-available N target of ~120–160 kg N/ha where yield targets are in the range of 1.5–2.0 t/ha. It also corresponds to a total crop-available N target of ~80 kg N/ha for each tonne of grain.<sup>10</sup>

Other key findings included:

- Nitrogen was the key nutrient limiting grain yield, with significant yield responses at all sites and net returns of \$120–200/ha compared with nil N applied.
- Oil content significantly decreased (by 1–3%) with additional N at three of the four sites, but financial impact was more than compensated by yield increases.
- No interaction between N and S was detected at any site.<sup>11</sup>

#### Yield

Key points:

- Significant yield response to N was found at all sites.
- Yield response to N had plateaued at Yallaroi and Bellata but not at Moree and Blackville.
- No yield response to addition of S was detected at any site.
- There was a yield response to P at both Yallaroi and Bellata.

There was no significant N x S interaction for yield at any trial. The results presented in Tables 2 and 3 show the main effects of N or S. The factorial experimental design means that each result for a single rate of N or S is based on 32 individual plots at Moree and Blackville and 12 plots at Yallaroi and Bellata. The results for yield response to P (Table 4) and oil content (Tables 5–7) are based on a smaller subset of treatments at Yallaroi and Bellata with a factorial of two rates of P and three combinations of N and S.<sup>12</sup>

<sup>10</sup> GRDC (2014) Canola nutrition in the northern region. GRDC Media Centre, 28 April 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-nutrition-in-the-northern-region>

<sup>11</sup> R Daniel, M Gardner, A Mitchell, R Norton (2013) Canola nutrition: what were the benefits from N, S and P in 2012? GRDC Update Papers, 5 March 2013, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Canola-nutrition-what-were-the-benefits-from-N-S-and-P-in-2012>

<sup>12</sup> R Daniel, M Gardner, A Mitchell, R Norton (2013) Canola nutrition: what were the benefits from N, S and P in 2012? GRDC Update Papers, 5 March 2013, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Canola-nutrition-what-were-the-benefits-from-N-S-and-P-in-2012>

Table 2: Grain yield response to different rates of nitrogen addition at four sites

CV, Coefficient of variation. Within columns, means followed by the same letter are not significantly different at  $P = 0.05$

Moree		Blackville		Yallaroi		Bellata	
N added (kg N/ha)	Grain yield (t/ha)	N added (kg N/ha)	Grain yield (t/ha)	N added (kg N/ha)	Grain yield (t/ha)	N added (kg N/ha)	Grain yield (t/ha)
0	0.73d	0	0.99c	34	1.58b	34	1.25b
40	1.08c	50	1.51b	84	1.89a	84	1.40a
80	1.31b	100	1.69b	134	1.91a	134	1.45a
120	1.47a	200	1.99a				
l.s.d. (P = 0.05):		0.14		0.19		0.12	
CV		6.4 %		4.8%		14.0%	
						10.7%	

Table 3: Grain yield at different rates of sulfur addition at four sites

There were no significant differences

Moree		Blackville		Yallaroi		Bellata	
S added (kg S/ha)	Grain yield (t/ha)	S added (kg S/ha)	Grain yield (t/ha)	S added (kg S/ha)	Grain yield (t/ha)	S added (kg S/ha)	Grain yield (t/ha)
1	1.16	1	1.53	1	1.75	1	1.32
11	1.14	11	1.52	16	1.77	16	1.40
21	1.12	21	1.56	31	1.85	31	1.38
41	1.16	41	1.54				

Table 4: Grain yield response to different rates of phosphorus addition at two sites

CV, Coefficient of variation. Within columns, means followed by the same letter are not significantly different at  $P = 0.05$

Yallaroi		Bellata	
P added (kg P/ha)	Grain yield (t/ha)	P added (kg P/ha)	Grain yield (t/ha)
0	1.54b	0	1.26b
20	1.83a	20	1.43a
l.s.d. (P = 0.05)		0.19	
CV		12.2%	
		12.0%	

### Oil content

Key points:

- Significant reduction in oil content occurred with increasing N rates at three of the four sites.
- No oil content response was detected to addition of S at any site.
- There was no significant oil content response to addition of P at either site.

Table 5: Oil content response to different rates of nitrogen application at four sites

Within columns, means followed by the same letter are not significantly different at  $P = 0.05$ ; n.s., not significant

Moree		Blackville		Yallaro		Bellata	
N added (kg N/ha)	Oil content (%)	N added (kg N/ha)	Oil content (%)	N added (kg N/ha)	Oil content (%)	N added (kg N/ha)	Oil content (%)
0	43.9a	0	45.5b	34	44.5	34	47.3a
40	44.3a	50	46.2a	84	44.4	84	46.0b
80	43.2b	100	45.8b	134	44.6	134	44.5c
120	42.3c	200	44.7c				
l.s.d. ( $P = 0.05$ )		0.5		0.4		n.s.	

Table 6: Oil content at different rates of sulfur at four sites

There were no significant differences

Moree		Blackville		Yallaro		Bellata	
S added (kg S/ha)	Oil content (%)	S added (kg S/ha)	Oil content (%)	S added (kg S/ha)	Oil content (%)	S added (kg S/ha)	Oil content (%)
1	43.6	1	45.5	1	44.4	1	46.0
11	43.6	11	45.6	16	44.6	16	46.0
21	43.7	21	45.6	31	44.5	31	45.7
41	43.7	41	45.6				

Table 7: Oil content at different rates of phosphorus addition at two sites

There were no significant differences

Yallaro		Bellata	
P added (kg P/ha)	Oil content (%)	P added (kg P/ha)	Oil content (%)
0	44.8	0	45.4
20	44.4	20	46.1

Although the Bellata result in Table 7 was not significant ( $P = 0.11$ ) with respect to P addition, there was an apparent trend to improved oil content, particularly when combined with lower N rates (~0.7–0.9% oil content). This may be experimental noise but appears worthy of further investigation.<sup>13</sup>

For more details about the trial sites and experimental design, read the 2013 Update Paper: [Canola nutrition: what were the benefits from N S and P in 2012?](#)

<http://www.farmtrials.com.au/>

### 5.4.3 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. Hybrid varieties can display leaf purpling with adequate nutrient levels (Figure 3).

<sup>13</sup> R Daniel, M Gardner, A Mitchell, R Norton (2013) Canola nutrition: what were the benefits from N, S and P in 2012? GRDC Update Papers, 5 March 2013, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Canola-nutrition-what-were-the-benefits-from-N-S-and-P-in-2012>





Figure 3: Images of nitrogen deficiency in canola.

### 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 that starts at the end of the leaf and progresses to the base on both sides of the leaf. (See Table 8 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 8: Conditions that result in symptoms similar to nitrogen deficiency

Condition	Similarities	Differences
<a href="#">Beet western yellow virus in canola</a>	Purple-red colours spreading from end of oldest leaves	Affected plants are stunted rather than smaller and thinner
<a href="#">Damping off in canola</a>	Reddened cotyledons and seedling older leaves	Damping off causes stunted plants with pinched roots or hypocotyls. Often plant death occurs
<a href="#">Sulfur deficiency in canola</a>	Purple leaves	Sulfur deficiency affects younger leaves the most
<a href="#">Phosphorus deficiency in canola</a>	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 nitrogen leaching

### Management strategies

- Nitrogen fertiliser or foliar spray can be applied. However only N can be absorbed through the leaf so you will still be reliant on rainfall to move the nitrogen into the root zone, economics of liquid vs 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 new GRDC-funded research shows this may not be as high as traditionally thought.<sup>14</sup>
- 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).
- Unlike cereals, canola does not ‘hay off’ when too much N has been applied, but N reduces oil content, particularly with late application.

#### [Nitrogen volatilisation: Factors affecting how much N is lost and how much is left over time](#)

##### *How can it be monitored?*

###### *Tissue test*

- Use 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.
- Nitrogen soil testing by itself is of little value for most soils.
- 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.<sup>15</sup>

## 5.5 Phosphorus

Research in northern NSW has shown that P application is more critical for canola than for wheat grown under the same conditions. Results have consistently shown greater responses to P in canola than wheat, and responses have occurred in situations where wheat has not responded. Hence, it is critical that P be applied to canola unless soil tests indicate that the soil is well supplied with this nutrient.<sup>16</sup>

With grain removal of ~10 kg P/ha, application of ~15–20 kg P/ha appears warranted from both an agronomic and a financial viewpoint.<sup>17</sup>

For more details about the trial sites and experimental design, read the 2013 Update Paper: [Canola nutrition: what were the benefits from N S and P in 2012?](#)

<sup>14</sup> G. Schwenke, Nitrogen volatilisation: Factors affecting how much N is lost and how much is left over time (2014), <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>

<sup>15</sup> 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>

<sup>16</sup> L. Serafin, J. Holland, R. Bambach, D. McCaffery (2009) Canola: Northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

<sup>17</sup> GRDC (2014) Canola nutrition in the northern region. GRDC Media Centre, 28 April 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-nutrition-in-the-northern-region/Details>



Figure 4: Severe phosphorus deficiency showing plant stunting and delayed maturity. (Photo: R. Colton, NSW DPI)

### 5.5.1 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 4), both of which affect yield potential and seed oil content, particularly in dry spring conditions. Low P levels 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 5). Phosphorus is a very mobile nutrient within the plant, and if a deficiency occurs, it moves rapidly from older leaves to the young leaves or developing pods.



Figure 5: 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 Al 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.

### *Phosphorus requirements*

If a wheat crop responds to P, then a rate at least equivalent should be used when sowing canola at that site. Topdressing is ineffective, so it is important to get the P rate right 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 there are a few laboratory analysis available for P. The Olsen P test (Bicarb) is often recommended on acid soils. The Colwell P test is more useful on alkaline clay soils, however each of these tests only measures a proportion of the P status of a soil. The Phosphorus Buffering Index is also important as it can indicate how available the phosphorus in the soil is to plants, whilst the BSES-P is recommended as a baseline of the pool P status. Using a qualified soil nutrition advisor will help you 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/kg P) a response to P is less likely, unless the soil is acidic (pHCa <4.8) and has a low cation exchange capacity (<5 cmol(+)/kg); in such cases, significant yield responses have been obtained in southern NSW. Soil P tests are less reliable in low-rainfall zones or on alkaline soils, and so 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.<sup>18</sup>

### More information

[Economics and management of P nutrition and multiple nutrient decline](#)

<sup>18</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## 5.6 Sulfur

Traditional thought was that canola requires about 10 kg sulfate-S/t grain. The standard recommendation in southern NSW is to apply 25–30 kg sulfate-S/ha. However, while the standard ‘rule of thumb’ has been commonly extended on northern clay soils as early as 1992, commercial trials indicated a lower requirement on soil types that have naturally occurring gypsum at depth, typically the grey and black clay soils. This was identified in a deep (60–90 cm) soil test.

Under these conditions it was still recommended that 10 kg sulfate-S/ha was required to supply crop requirements until the crop roots accessed deep soil S. Sulfate-S is best applied before or at planting. Sulfur-deficient canola responds well to topdressing and economic responses have been recorded up to the flowering stage in salvage situations.<sup>19</sup>

Unwarranted applications of  $\geq 20$  kg S/ha are reducing the profitability of some canola crops, and rates should be reviewed to maintenance levels of 4 kg S/t grain removed. If soil levels are adequate, this may be reduced even further.<sup>20</sup>

### 5.6.1 The new paradigm in canola nutrition

*NGA and Grain Orana Alliance (GOA) Researchers: ‘Current recommendations consider S to be non-negotiable and N applications more seasonally dependent. This approach needs to be reversed; S application needs to be more prescriptive in its use and refocus our attentions and redirect our expenditure on getting our N rates right.’*

Key points:

- Five years of trials by GOA failed to demonstrate a consistent response to the addition of S for yield or oil content. Numerous recent trials by other organisations have also failed to demonstrate responses to S in canola.
- Sulfur deficiency occurs in canola and can be quite severe, but the frequency of such deficiency is most likely lower than thought and it can be rectified early in the crop without ongoing penalty.
- Unwarranted applications of 20 kg S/ha are reducing the profitability of some canola crops and rates should be reviewed to maintenance levels of 4 kg S/t grain removed. If soil levels are adequate, this may be reduced even further.
- Canola is more frequently responsive to N applications and at least some expenditure on fertiliser may be better redirected from S to N applications.
- Soil-test critical levels for S are uncalibrated, are most likely too high, and should be reviewed.<sup>21</sup>

<sup>19</sup> L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

<sup>20</sup> GRDC (2014) Canola nutrition in the northern region. GRDC Media Centre, 28 April 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-nutrition-in-the-northern-region/Details>

<sup>21</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

### Reducing rates of sulfur fertiliser

When considering fertilising canola, its requirement for S distinguishes it from most other field crops. As such, S is often the first nutrient addressed after starter P fertiliser applications in fertiliser programs, and the requirement for N then follows.

More than 20 trials run over three seasons, mentioned above, have failed to demonstrate responses to added S in either yield or oil percentage. Average crop removal rates do not support the requirement of 20 kg S/ha universally.

Given this scenario, reducing the current recommended practice (CRP) of 20 kg S/ha to rates that more closely match crop yields and subsequent removal rates would be a more economical approach, whilst being sustainable in the longer term.

However, the lack of response to S in recent trials raises the possibility of completely removing intended S applications, as it is done in wheat. Because there is often no yield or oil percentage response, profitability in the short term will only decline with any additions of S.

If growers are to take this approach, soil tests may be still useful to predict potential responsiveness when using removal rates. If soil levels and subsequent calculations of soil-available S outstrip the predicted conservative crop requirements of 4–5 kg S/t crop potential, the likelihood of crop responses or a deficient situation developing is low.

In situations where no S is applied, growers do risk deficiencies developing despite prediction to the contrary. The frequency of such a deficiency based on recent trial work is low but not zero. If deficiency is identified prior to stem elongation and S is applied, research by Hocking *et al.* (1996) has shown that both final yield and oil percentage will not be penalised.<sup>22</sup>

## in focus

### 5.6.2 GRDC Grain Orana Alliance (GOA) research

Canola has been generally accepted as having high requirements for S, much higher than wheat. Sulfur deficiency was first identified in 1988 and 1989, but was only noted as a significant problem in 1990 (Coulton and Sykes 1992). Deficient situations lead to significant yield and oil penalties where it occurred.

In 2010, GOA established four trial sites to investigate the effect of S fertiliser form and timing on canola performance, in particular, on final seed oil percentage. None of the trials demonstrated any response to S fertiliser in terms of yield or oil percentage, regardless of form or timing.

Following this result, GOA questioned why responses were not seen despite prediction that three of the sites would respond. Was it because of changes in our

<sup>22</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

farming systems, a consequence of the trial season being one of the wettest on record, or because our understanding of S nutrition of canola and its occurrence was incorrect?

In 2011 and 2012, GOA established eight and four trials, respectively, to improve our understanding and better identify situations where S deficiency or responses will occur. None of these trials showed any responses to S in yield or oil percentage.

During this period, several other agencies also conducted trials investigating S nutrition in canola. These trials too have failed to realise any responses to S.

The results from these recent trials should challenge our understanding and approach to S nutrition in canola, in particular:

- the frequency and likelihood of deficiencies in the Central West of NSW
- critical soil test levels
- grain removal rates and nutrient budgeting
- new approaches to S nutrition in canola <sup>23</sup>

### Background

Unreliable yields and crop failures of canola in the late 1980s and early 1990s were suspected to be due to S deficiency. Consequently, a series of 14 trials was established in 1992 in collaboration with CSIRO, University of New England, Incitec and NSW Department of Primary Industries (DPI). These trials investigated whether there was an interaction of N and S, and whether higher N rates were exacerbating S deficiency (Sykes 1990).

A report by ACIL Consulting (1998) states that the trials' responses in 1992–93 were 'dramatic', particularly when following pasture. It also states that the trial collaborators reported from the series of trials that 'applying 20–30 kg/ha is sufficient to achieve maximum yields' and is 'the best practice for maximising yield with the least risk versus cost trade off'. Probably, all subsequent recommendations for S application to canola in most industry resources are sourced from this statement.

This recommendation was widely adopted and is still accepted, as quoted in the 2009 [Canola best management practice guide for south-eastern Australia](#):

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

This practice will be referred to as the CRP. The adoption of this recommendation was rapid; it was estimated that even before the completion of the trials, 90% of canola was receiving the additional levels of S recommended. A key factor supporting this rate of adoption was that the relatively low cost of S fertilisers at the time was outweighed by the risk of penalty in deficient situations (ACIL Consulting 1998).

<sup>23</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>



During the same period in the early 1990s, the KCI-40 soil test for S was introduced and was adopted as a more appropriate test method than the existing MCP (mono-calcium phosphate) method; however, this superiority was demonstrated primarily on pasture sites (ACIL Consulting 1998)

The KCI-40 test was then widely used for estimating soil S levels, particularly for canola. Very little literature was available for NSW until Anderson *et al.* (2013) reviewed past trial yield performance against soil tests. Presumably, soil critical levels were based upon values extrapolated from critical levels for pasture situations and/or simply on the base blanket recommendations of 20–30 kg S/ha.

Trials conducted by CL Mullen and SJ Druce between 1993 and 1998 demonstrated that responses to S were not common on heavy grey soils of upper central NSW, owing to S contained in the subsoil. Because of this work, S fertiliser is not commonly applied on these soil types, but all other soils in the GOA region commonly still receive the standard 20 kg S/ha.

More recently, research by Khan *et al.* (2011) has questioned the suitability of gypsum as a source of S for growing of canola compared with sulfate of ammonia (SOA). Gypsum is a commonly used fertiliser in the GOA region, and perhaps this was contributing to lower oil percentages in the region's crops and/or suppressing yields because of S deficiencies.

This was the basis of four trials run by GOA in 2010 investigating sources of S and timing of applications. None of the trials showed response to S in any form or with any timing despite predictions by soil analysis and experience to the contrary. This work is briefed in [Sulfur nutrition in canola—gypsum vs. sulphate of ammonia and application timings](#) (Street 2011).

Following this outcome and other questions raised in above-mentioned paper, GOA continued the research. Trial design was revised to replicate better the earlier trials, with the simple aims of quantifying a response and helping to build on the predictability of response.<sup>24</sup>

<sup>24</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

### Recent findings

Tables 9–15 summarise the findings from recent trials investigating S responses in canola.<sup>25</sup>

#### GOA trials

##### 2010

Four sites were selected in winter 2010 across the GOA region. Three sites were identified through recent KCl-40 soil tests as being low–moderate in S. The fourth site was deemed adequate in S by way of KCl-40 soil tests.

Table 9: Canola yield and oil percentage in response to applied sulfur fertiliser, GOA 2010  
Calculated S total = (KCl-40 x bulk density x depth). Statistical analyses are reported at P = 0.05; n.s., not significant

Site	Total S 0–60 cm (kg/ha)	Site av. yield (t/ha)	Yield response to S	Oil % response to S
Nyngan	1.4 kg	2.5	n.s.	n.s.
Narromine	85 kg	2.2	n.s.	n.s.
Curban	39 kg	2.8	n.s.	n.s.
Wellington	23 kg	2.2	n.s.	n.s.

Treatments addressed three rates of S applied: 0, 15 or 30 kg/ha, in two forms (gypsum or SOA), applied at five different timings from pre-seeding to early flowering.

There was no significant difference between any treatment and the untreated control for yield or oil percentage as assessed by ANOVA (Table 9).

##### 2011

Four plot-sown sites and four farmer-sown replicated trials were established in 2011. All sites were selected for low soil S.

The small-plot trial protocol was changed in 2011 to a full factorial trial design with two N rates (50 and 100 kg N/ha) and five S rates (0, 5, 10, 20 and 30 kg S/ha). All fertiliser treatments were predrilled immediately prior to sowing. The S was supplied in the form of granular SOA (20% N, 24% S) and the N rates adjusted using urea (46% N).

Oil percentage was not available for this set of trials. Yield results were analysed by factorial analysis (Table 10).

<sup>25</sup> M Street (2013) Sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 26 February 2013, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Sulfur-strategy-to-improve-profitability-in-canola-in-the-central-west-of-NSW>

Table 10: Canola yield response to increasing applied sulfur or nitrogen fertiliser, GOA 2011

Calculated N or S total = (soil test value x bulk density x depth). Statistical analyses are reported at P = 0.05; n.s., not significant

Site	Total N 0–70 cm (kg/ha)	Total S 0–70 cm (kg/ha)	Trial av. yield	Yield response	
				N	S
Geurie	62	35	1.68	+0.28 t/ha	n.s.
Curban	37	40.4	0.84	+0.3t/Ha	n.s.
Warren	39	30.1	0.97	+0.26 t/ha	n.s.
Narromine	44	42	2.03		n.s.

There was no response to added S in yield or oil percentage. Three of the sites demonstrated strong positive, statistically significant responses to increased N rates from 50 to 100 kg/ha. Yield responses were an increase of 18% at Geurie, 32% at Warren and 42% at Curban.

The four farmer-sown trials were small-plot replicated trials. The trials were established on farmer-sown paddocks on soils of low S background. These trials were designed only to provide further support to the more comprehensive, plot-sown trials, and treatments were reduced to plus and minus S.

The treatments were broadcast ahead of rain during the vegetative stage and comprised: no N or S added (control); S added in the form of SOA at 100 kg/ha (21 kg N and 24 kg S/ha); N added as urea at 45 kg/ha (21 kg N/ha) to supply the equivalent amount of N contained in the SOA treatment. The outcomes analysed by ANOVA are presented in Table 11.

Table 11: Canola yield and oil percentage in response to applied sulfur or nitrogen fertiliser, GOA 2011

Calculated S total = (soil test value x bulk density x depth). SOA, Sulfate of ammonia. Statistical analyses are reported at P = 0.05; n.s., not significant

Site	Total soil S (kg/ha)	Trial average yield (t/ha)	Yield effect	Oil effect
Wongarbon	No S applied in 14 years	1.7	n.s.	n.s.
Coolah Black	33	0.9	Urea or SOA suppressed yield over control	n.s.
Coolah Red	31	1.06	n.s.	n.s.
Arthurville	24	2.3	n.s.	n.s.

The only interaction achieved in these trials was a reduction in yield to applied S at Coolah Black. This reduction, however, was achieved with both urea and SOA, so it may have been primarily due to the added N in both treatments, not the S. The resulting reduction in yield could be attributed to the dry conditions in late winter and spring experienced in 2011 at this site and over-fertilisation with N, supported by the low average trial yield.

2012

GOA repeated the same plot-sown protocol employed in 2011 on a further four sites in 2012. Yield and oil percentage results were analysed by factorial analysis (ANOVA) with the outcome listed in Table 12.

Table 12: Yield and oil percentage in response to increasing applied sulfur or nitrogen fertiliser, GOA 2012

Calculated N or S total = (soil test value x bulk density x depth). Statistical analyses are reported at  $P = 0.05$ ; n.s., not significant

Site	Total N 0–70 cm (kg/ha)	Total S 0–70cm (kg/ha)	Trial average yield (t/ha)	Yield response		Oil % response	
				N	S	N	S
Narromine	75	18.3	2.79	n.s.		n.s.	
Curban	88	33.8	1.27	n.s.		n.s.	
Wellington N	32	37	0.61	+ 0.13 t/ha	n.s.	n.s.	
Wellington S	71	50	1.4	+ 0.1 t/ha	n.s.	n.s.	

In 2012, there was no response to added S in yield or oil percentage. In two of the trials there was a significant yield response to increasing the N from 50 to 100 kg/ha. At the Wellington N site, yield was increased by 24% with the increased N rate, and at Wellington S, by 7%.<sup>26</sup>

#### DPI collaborative trials 2012

In 2012, in collaboration with the NSW DPI, two trials were undertaken at Trangie and Coonamble. The trials were a factorial design with four N rates (0, 25, 50 and 100 kg/ha) and four S rates (0, 10, 20 and 30 kg/ha) and two canola varieties, Pioneer 43C80 and Pioneer 44Y84, sown at the Trangie site, but only Pioneer 44Y84 sown at the Coonamble site. Yield and oil percentage results were analysed by factorial analysis (ANOVA) with the outcome listed in Table 13.

Table 13: Canola yield and oil percentage in response to increasing applied sulfur or nitrogen fertiliser, NSW DPI/GOA 2012

Calculated N or S total = (soil test value x bulk density x depth). Statistical analyses are reported at  $P = 0.05$ ; n.s., not significant

Site	Total N 0–90 cm (kg/ha)	Total S 0–90 cm (kg/ha)	Trial average yield (t/ha)	Yield response		Oil % response	
				N	S	N	S
Coonamble	73	20	2.56	n.s.		n.s.	
Trangie	113	141	1.81	+ 0.35 t/ha	n.s.	-1.60%	n.s.

At the Coonamble site there was no response to the addition of N or S in either yield or oil percentage. The Trangie site showed no significant response to S in yield or oil percentage, but that would not be expected given the soil S levels. There were significant responses to N in yield and oil percentage. Increasing N rates increased

<sup>26</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

yields but decreased oil percentage. There was a significant variety response, with 44Y84 outperforming 43C80 in both yield and oil percentage (data not presented).<sup>27</sup>

#### DPI northern region trials 2012

NSW DPI established two trials in northern NSW investigating N and S interactions. The trials were a factorial design with four N rates of 0, 40, 80 and 120 kg/ha at Moree and 0, 50, 100 and 200 kg/ha at Blackville, both with four S rates of 0, 11, 21 and 41 kg/ha and two canola varieties. Nitrogen was applied as urea with S applied as granulated gypsum applied pre-sowing.

Yield and oil percentage results were analysed by factorial analysis (ANOVA) with the outcome listed in Table 14.

Table 14: Canola yield and oil percentage in response to increasing applied sulfur or nitrogen fertiliser, DPI 2012

Calculated N or S total = (soil test value x bulk density x depth). Statistical analyses are reported at P = 0.05; n.s., not significant

Site	Total N 0–90 cm (kg/ha)	Total S 0–90 cm (kg/ha)	Trial av. yield (t/ha)	Yield response		Oil % response	
				N	S	N	S
Blackville	28	130	1.54	+1 t/ha	n.s.	–0.79%	n.s.
Moree	46	94	1.15	+0.74 t/ha	n.s.	–1.60%	n.s.

There was no response to added S at either site in yield or oil percentage, as would be expected with such high levels of soil S. Both sites responded strongly to the addition of N; the yield response was positive and the oil percentage response negative.

#### NGA trials 2012

NGA established two trials in 2012 to investigate nutrition of canola in the northern region. The trials investigated the interaction of N and S as well as P. The trials were a factorial design with three N rates of 34, 84 and 134 kg/ha and three S rates of 1, 16 and 31 kg/ha. Nitrogen was applied as urea with S applied as Gran Am (SOA) pre-sowing.

Yield and oil percentage results were analysed by factorial analysis (ANOVA) with the outcome listed in Table 15.

Table 15: Canola yield and oil percentage in response to increasing applied sulfur or nitrogen fertiliser, NGA 2012

Calculated N or S total = (soil test value x bulk density x depth). Statistical analyses are reported at P = 0.05; n.s., not significant

Site	Total N 0–90 cm (kg/ha)	Total S 0–90 cm (kg/ha)	Trial av. yield (t/ha)	Yield response		Oil % response	
				N	S	N	S
Bellata	69	164	1.37	+0.15 t/ha	n.s.	–2.80%	n.s.
Yallaro	30	NA	1.79	+0.31 t/ha	n.s.	n.s.	

<sup>27</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

There was no response to added S at either site in yield or oil percentage. At both sites, there was a positive yield response to increasing N rates, 13% at Bellata and 20% at Yallaroi. At Bellata, there was a negative response to increased N rates in oil percentage. The Bellata site responded to added P; at the Yallaroi site there was a non-significant trend to increase with added P (data not presented).<sup>28</sup>

### *Central West Farming Systems (CWFS)*

CWFS have undertaken several trials at their regional sites investigating canola S nutrition over a number of seasons. Unfortunately, individual trial data are not yet available, but personal comments by John Small of CWFS regarding the trials over recent seasons are as follows:

*'There has been no clear or statistically significant response to the addition of S in terms of yield or oil performance in canola over a number of trials by CWFS over recent seasons.'*

Readers should seek further clarification and data from CWFS concerning these trials. The outcomes will be valuable to farmers in the Central West because the trials were generally undertaken on red soils of the region, which are more likely to respond than the heavier soils of the northern regions.<sup>29</sup>

<http://cwfs.org.au/regional-sites/>

### *Discussion*

As indicated above, there has been no response to S in terms of yield or oil percentage in recent trial work. This work has been undertaken by several agencies across a range of soil types and three seasons. It should also be noted that all but one of GOA's trial sites were selected specifically for low soil S levels and were predicted to be responsive.

Why have responses not been achieved?

The CRP is that all canola paddocks should receive S fertiliser. However, of the original work that formed this recommendation, only six of the 14 sites showed a yield response to S and only three an oil percentage response (Sykes 1990). Many of these sites did not respond despite prediction by soil tests.

The most commonly reported trial was at the Wellington site, where yields increased from 1 to 4 t/ha with the addition of S. At this site, 75% of the site maximum yield was achieved at an application rate of 10 kg S/ha, and 92% at 20 kg S/ha. A similar result was demonstrated at Baradine, but these could be described as the two most severe documented cases of S deficiency.

<sup>28</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

<sup>29</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

Many of the other responsive sites did not realise such a magnitude of improvement. At the Gollan site at the rate of 40 kg N/ha, increasing S from 0 to 20 kg/ha increased yields by only 590 kg. At 80 kg N/ha, there was a 325 kg/ha improvement by increasing the S rate from 0 to 20 kg/ha. At the Junee Reefs and Tamworth sites, a maximum response was achieved of ~400 kg/ha. These would still be worthy and economic responses at today's fertiliser prices, but the penalties are nowhere near the extent often promoted.

The ACIL Consulting (1998) report also mentions other previous work from 1990, commenting, 'A major field study of canola in NSW reported significant grain yield increases from the addition of N but no significant responses to S (Sykes and Coulton, 1990)'.

The more recent work detailed above shows no response to the addition of S over 3 years and in a range of soils predicted to respond.

In summary, the frequency of response to added S is quite low; considering the trials detailed above, <14% of trial sites were responsive (excluding the field study of 1990 and those of CWFS).

Industry-accepted grain-removal rates used in nutrient budgets may also lend support to the CRP. Current industry references suggest that removal rates are 10 kg S/t grain and that crop requirements of canola are much higher than of wheat (Coulton *et al.* 1992).

Analysis of grain samples from the GOA and NGA trial work has shown that grain removal is much lower than these levels. Janzen and Bettany (1994), Pinkerton *et al.* (1993) and Hocking *et al.* (1996) all measured grain S contents in their range of experiments. Grain S levels no greater than ~0.5% or 5 kg S/t grain were measured, even in treatments with adequate S. In many cases, the S levels were even lower, resulting in them being less than half of the industry benchmarks.

When considering this information for formulating crop requirements and fertiliser programs, there may be little difference in requirements between wheat and canola. For example, an average wheat yield for the GOA region may be 3 t/ha, removing ~1.8 kg S/t or 5.4 kg S/ha. Canola generally performs at 50% of comparable wheat yields, so 1.5 t/ha removing 3.6 kg S/t (critical threshold, Hocking *et al.* 1996) will remove only 5.4 kg S/ha, or similar amounts to the wheat crop.

So, as a possible explanation of the lack of responsiveness in all of these trials, the sites were simply predicted to respond when in fact that was not likely; there was adequate S contained in the soil profile and subsequent mineralisation to satisfy crop demands, a demand much lower than previously understood.

For example, using the highest achieved yield in the GOA trials of ~ 2.8 t/ha, the crop removal rate would be 9.8 kg/ha. If we assumed an arbitrary uptake or transfer efficiency of 50%, the crop would have a growing requirement of only 20 kg/ha. All of the sites detailed in this paper would have satisfied this requirement with starting soil

levels and only a minimal amount of mineralisation; no additional fertiliser would be required.

So, what is the critical soil level to indicate when S addition may be required? To supply this requirement of 20 kg S/ha, a soil KCl-40 test would have a critical level of ~2.3 mg/kg averaged in the top 60 cm of soil. If this were indeed the soil critical level, few cropping soils would be lower.<sup>30</sup>

### *Re-focus investment on nitrogen instead of sulfur*

By contrast, the majority of all trials have demonstrated response to N. Twelve of the 14 trials undertaken in 1992 resulted in significant and economic responses, with an average increase in response to 80 kg N/ha of 600 kg/ha (Sykes 1990). Of the two trials that did not show a response, one was following 5 years of grass-free legume-based pasture, and the other was compromised by frost, resulting in a high coefficient of variation.

Three of four GOA trials in 2011 responded significantly to increasing N application from 50 to 100 kg/ha. The average yield increase over the three sites was 280 kg/ha, returning around 200% on investment. Two of GOA's trials in 2012 also returned a significant yield response to increasing N. Returns were much lower with the dry spring conditions, with the yield increases only breaking even after additional costs.

Trials by NGA in 2012 demonstrated a 13% yield increase or ~150 kg/ha (break-even) by increasing N from 34 to 84 kg/ha in one trial. The second site saw an increase yield of 20% or ~310 kg/ha, resulting in approximately a 200% return on investment.

It should be noted that the GOA and NGA trials did not have nil N treatments, but they were all clearly N-responsive sites.

In the NSW DPI-GOA trials in 2012, treatments of nil N were included, and this allows a response curve to be generated. The Trangie site showed strong responses to N, with yield increasing by 0.35 t/ha or 21% by increasing N from 0 to 100 kg/ha. The economics of such applications are demonstrated in Figure 6.

<sup>30</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>



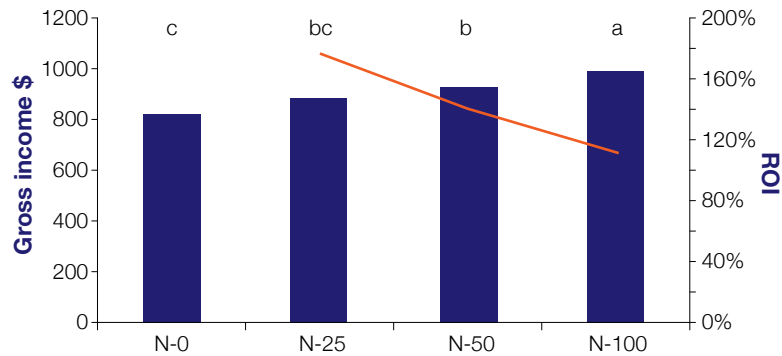


Figure 6: Canola yield performance in relation to applied nitrogen rate and the corresponding return on investment (ROI), Trangie. Columns headed by the same letter are not significantly different. (Source: NSW DPI-GOA 2012)

Although the starting soil N at this site was high at 113 kg/ha, yield and resultant gross income increased almost in a linear response, and the treatments have not demonstrated a clear upper limit. The responsiveness of canola to high rates of N is reinforced at three other sites detailed in Figure 7; again there was no clear indication of a yield plateau even up to 200 kg N/ha.

Therefore, although canola will tend to respond to increasing N, the return on investment declined beyond the 25 kg/N rate but remained positive. This is only one trial in a dry spring, but it demonstrates that the most economical rate is not necessarily the point of yield maximisation. The economically optimum N rates may be different for each situation.

Determining the optimal N rate for canola through deep soil tests coupled with yield forecasting is one approach and probably the most reliable.

It is worth noting that increasing N rates may have the effect of reducing oil percentage, as demonstrated in the Trangie, Bellata, Blackville and the Moree trials (Figure 7). Many of the trials from 1992 also showed statistically significant reductions in oil content from increased N rates. Increased N can lead to increased protein, and the relationship of protein to oil percentage is inverse, which can result in depressed levels of oil. However, in all cases the increased yield more than adequately offset this loss.<sup>31</sup>

<sup>31</sup> M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

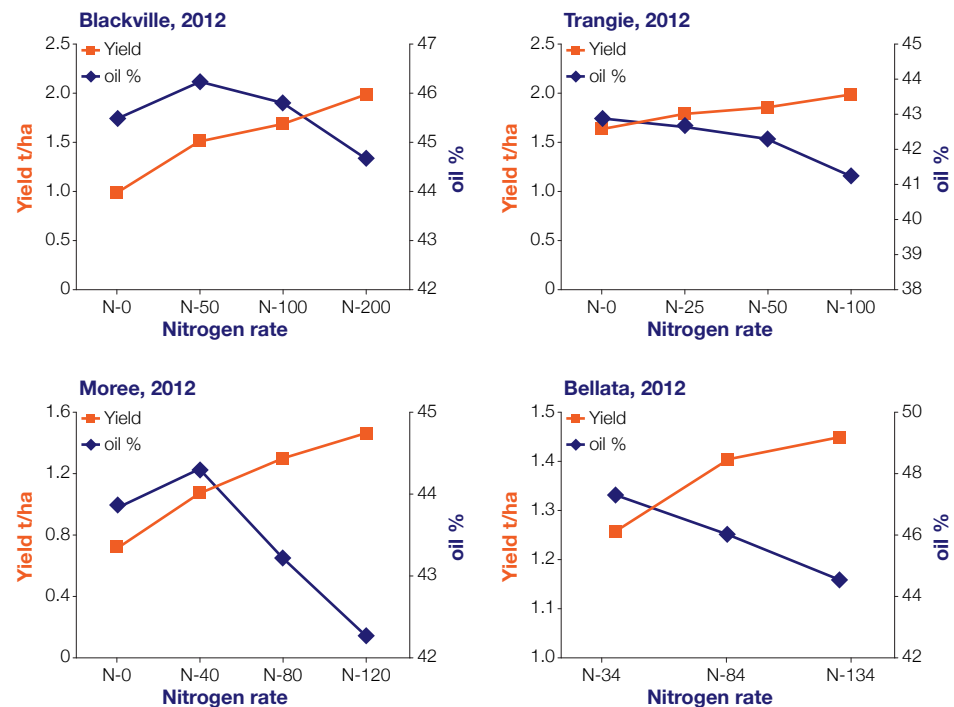


Figure 7: Canola yield and oil percentage performance demonstrating the inverse relationship to applied nitrogen. (Source: NSW DPI/NGA/GOA 2012)

### Summary

Twenty trials have recently been undertaken across several seasons and locations in NSW. None has demonstrated S responses in yield or oil percentage. This does not preclude deficiency and yield penalties from occurring but does highlight that the frequency and the likelihood is not high.

The results from the trial work in 1992 and the ensuing extension message regarding the need for S may have lost their original perspective. Within the original reports, the data suggested that N was paramount to achieving maximum profitability for canola in nearly all cases. The data also suggested that, in only some cases, canola responded to S as well.

The one extension message that persisted was that all canola crops needed 20 kg S/ha, and sometimes more. The then lower cost of S fertiliser and the significant penalties seen in deficient situations meant that this recommendation was adopted rapidly, needed or not. Declining terms of trade over the last 20 years do not allow for such a potentially wasteful approach.

Through the efforts of GOA, several shortcomings in the understanding of canola agronomy have been highlighted. Removal rates are over-estimated and the lack of calibrated soil critical levels is a major problem. Rectification in both of these areas may improve the predictability of S responsiveness.

With the reduced frequency of response and considering the reviewed S demand of canola, the CRP may need revision to match more closely the S removal rates. This will result in increased profitability and sustainability for growers.

## **i** More information

[Canola research insight for Trangie farmer](#)

[Review of sulfur strategy](#)

[Sulfur strategy to improve profitability in-canola in the Central West of NSW](#)

[Sulfur nutrition in canola—gypsum vs sulphate of ammonia and application timing](#)

[Sulphur in northern Vertosols](#)

Removal of S from fertiliser programs may be risky but will prove most profitable in many cases. However, wheat, which has a similar S requirement per hectare and is predominantly fertilised with mono- or di-ammonium phosphate (containing only minimal S), is not noted to suffer yield impacts through S deficiencies. It should also be remembered that deficient situations are easily corrected by in-crop applications.

There is a strong case for the savings in expenditure on S to be redirected to N, where a response is much more common. However, the optimal rate of N may need to be revisited or targeted through soil tests and nutrient budgets to ensure that return on investment is also maximised, not simply the yield.<sup>32</sup>



## 5.7 Potassium

## **i** More information

[Do we need to revisit potassium](#)

[Economics and management of P nutrition and multiple nutrient decline](#)

An adequate supply of potassium (K) is important to provide plants with increased resistance to disease, frost and drought, as well as increased 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 K level, tissue tests are the most reliable method to determine whether K fertiliser is needed. Avoid sowing potassium fertiliser with the seed; it could affect germination.<sup>33</sup>

<sup>32</sup> M Street (2013) Sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 26 February 2013, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Sulphur-strategy-to-improve-profitability-in-canola-in-the-central-west-of-NSW>

<sup>33</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## 5.8 Micronutrients

### 5.8.1 Zinc

Although canola is a non-mycorrhizal crop, it requires zinc (Zn) on alkaline soils. The precise level of response in northern NSW is not known, but in the absence of better information, use wheat guidelines.

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 beside and below the seed at planting. Zinc is highly competitive with soil moisture and the seed at planting so 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. Zinc sulfate is incompatible with most herbicides and insecticides. Zinc seed treatments are not normally applied to canola, because insufficient Zn will be applied with the low seeding rate used.<sup>34</sup>

#### *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 8). Although there are few reports of Zn deficiency in canola, growers should be cautious. Zinc is routinely applied to the clay soils of northern NSW.

Zinc deficiencies can occur in the following situations:

- in strongly alkaline soils, pH<sub>Ca</sub> >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.<sup>35</sup>

#### *Fertiliser strategies*

Where responses to Zn are known to occur, incorporate Zn into the soil before sowing canola. In northern NSW and irrigation areas, broadcast rates of 10–20 kg Zn/ha are common where summer crops such as maize and sorghum are also grown. These rates supply enough Zn for ≥5 years.

On alkaline soils in south-western NSW, Zn is applied at 2–3 kg/ha every 3–5 years, usually as Zn-supplemented fertiliser at sowing.

<sup>34</sup> L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

<sup>35</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

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.<sup>36</sup>



Figure 8: Zinc deficiency appears as bronzing on the upper leaf surface and may occur in neutral to alkaline soils. (Photo: B. Holloway, SARDI)

## 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 when soil acidity falls (pH<sub>Ca</sub> <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. Molybdenum is compatible with pre-emergent herbicides and can be thoroughly incorporated into the soil before sowing.<sup>37</sup>

### *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.

<sup>36</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>37</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

Molybdenum-treated single superphosphate applied during the pasture phase is cost-effective and it should supply enough Mo for the canola crop.<sup>38</sup>

### 5.8.3 Magnesium

In recent years, magnesium (Mg) deficiency has been reported in a number of 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.<sup>39</sup>

### 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 9).

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.<sup>40</sup>



Figure 9: Death of the canola flower head from calcium deficiency. (Photo: D. McCaffery, NSW DPI)

<sup>38</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>39</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>40</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## 5.9 Toxicity

The most effective treatment for Al and Mn toxicity (Figure 10) is liming to raise the soil pH to >5.0. Lime rates 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.

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

There are breeding programs to improve the Al 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.<sup>41</sup>



Figure 10: Symptoms of severe manganese toxicity in young canola on an acid soil.

## 5.10 Nutrition effects on following crop

Canola has provided the opportunity for more reliable responses to N in subsequent cereals by reducing cereal root diseases. However, growers of grain sorghum and cotton on alkaline soils in northern NSW have reported low yields and poor growth following canola, particularly on the Liverpool Plains.<sup>42</sup>

<sup>41</sup> P Hocking, R Norton, A Good (1999) Crop nutrition. 10th International Rapeseed Congress, <http://www.regional.org.au/au/gcirc/canola/p-05.htm>

<sup>42</sup> R Norton, J Kirkegaard, J Angus, T Potter. Canola in rotations. Australian Oilseed Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0014/2705/Chapter\\_5\\_-\\_Canola\\_in\\_Rotations.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0014/2705/Chapter_5_-_Canola_in_Rotations.pdf)

This is due to the depletion of soil microorganisms called arbuscular mycorrhizal fungi (AMF; previously known as VAM fungi). They are beneficial soil fungi that assist 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 fungal population declines to a low level. To avoid this problem, follow canola with a short-fallow crop such as wheat or another cereal crop rather than pulses or long-fallow crops such as sorghum and cotton that depend on AMF.<sup>43</sup>

<sup>43</sup> P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)



## SECTION 6

# Weed control

## More information

[Weed control in winter crops 2015](#)

[Integrated weed management manual](#)

[Soil behaviour of pre-emergent herbicides in Australian farming systems](#)

[What is Roundup Ready® canola? Clearfield Stewardship Best Management Practice 2014](#)

[Herbicide tolerant canola in farming systems: a guide for growers](#)

## 6.1 Key points:

- Choose paddocks relatively free of broadleaf weeds, especially charlock, wild turnip, wild radish and other weeds of the Brassica family, because in-crop herbicide options are limited. Grass weeds can be controlled in canola by using trifluralin or post-emergent herbicides however Group A resistant grasses are still of concern.
- Herbicide Resistant varietal systems such as Triazine Tolerant (TT), Clearfields (CF) and Roundup Ready (RR) can be of use in managing weeds in canola, particularly broad leaf weeds however careful management is needed to avoid the buildup of resistant weed populations.
- When choosing paddocks for canola be careful 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 sulfonyleureas, 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 sulfonyleureas.
- 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 allows the rotation of herbicide groups and broadens the spectrum of weeds controlled.<sup>1</sup>

Weed management is strongly influenced by crop rotation sequence. Careful planning of a five 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 MOA rotation and cultural management techniques.

<sup>1</sup> L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

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 varieties are not a panacea for herbicide resistance management, but they will add significantly to the options available to farmers in respect to resistance management.

### 6.1.1 Weed spectrum and herbicide resistance

While there are inevitably large numbers of weed species that affect canola production, those that feature consistently in Australia are listed in Table 1. Prior to the introduction of herbicide resistant varieties, control of key broadleaf weeds was the most important constraint to production of canola throughout Australia.

Table 1: Common weeds of Australian canola crops

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

\* Weeds species that have been particularly important in restricting canola production prior to the introduction of TT varieties.

The degree to which such weeds have restricted the canola area is reflected in the rapid adoption of the triazine tolerant (TT) varieties across Australia.<sup>2</sup>

<sup>2</sup> S. Sutherland, Canola Weed Management. [http://www.australianoilseeds.com/\\_\\_\\_data/assets/pdf\\_file/0012/2712/Chapter\\_12\\_-\\_Canola\\_Weed\\_Management.pdf](http://www.australianoilseeds.com/___data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf)



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

### 6.1.2 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, while the majority use reduced tillage methods. Significant proportions of the crops are seeded using no-till. Therefore, crop sequences and seeding techniques are highly dependent on herbicides.

Repetitious use of herbicides has selected for herbicide resistant weed biotypes. Herbicide resistance now affects many species of Australian weeds, foremost among them being annual ryegrass. Where canola production was restricted by weeds like wild radish prior to the introduction of TT varieties, it is likely that herbicide resistant weeds will also reimpose restrictions if not carefully managed.

This could be the case with multiple 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 on canola crops from many herbicide groups and the number of groups will increase with the commercial production of additional herbicide resistant varieties in the next few years (Table 2).

Table 2: Common herbicides in use in canola crops in Australia

Herbicide Groups	Herbicides
A	Fluazifop, Haloxyfop, Diclofop-methyl, Sethoxydim, Quizalofop, Clethodim
B	Intervix* (Clearfield varieties)
C	Simazine, Atrazine, (TT varieties)
D	Trifluralin
I	Clopyralid
K	Metolachlor
M	Glyphosate (RR varieties)

[www.apvma.gov.au](http://www.apvma.gov.au)

Many populations of annual ryegrass would now be classified as resistant to diclofop methyl and on some farms the ryegrass is cross-resistant to both Group A and Group B herbicides. There have been confirmed cases where annual ryegrass biotypes are resistant to all selective herbicides that are currently available. For each paddock monitoring and resistance testing is imperative to understand the control options open to the grower.

While the major herbicide resistance problems in Australian weeds are with Groups A and B herbicides, resistance to Groups C, D, F, L and M herbicides have also been discovered.

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.

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. Weed seed contamination of the canola seed in excess of limits will lead to reduced prices. This is especially the case with weeds from the family Brassicaceae, which lead to increased erucic acid and glucosinolates and consequent reduction in canola quality. Weed seed and other debris in the canola seed leads to direct penalties, based on the percentage present. Weed competition can affect nutrient uptake by the canola plants and thus affect yield.<sup>3</sup>

### 6.1.3 Weed management in differing scenarios

#### *Canola in a continuous cropping sequence*

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

<sup>3</sup> S. Sutherland, Canola Weed Management. [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0012/2712/Chapter\\_12\\_-\\_Canola\\_Weed\\_Management.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf)

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.

Weed numbers tend to be higher as farmers do not have the range of non-selective treatments available in the pasture. This increases the risk of resistant biotypes being present in the crops when the herbicides are applied. Due to herbicide resistance, continuous crop programs may include a forage / fodder or green manure crop so that non selective weed control can be achieved.

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. <sup>4</sup>

### *Triazine Tolerant (TT) canola*

In 1999, TT canola accounted for almost 50% of the Australian crop, even though the varieties have a yield penalty relative to non-TT varieties. In the majority of 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 repetitious 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.

Some areas have a long history of triazine herbicide use, particularly in lupins. The widespread production of TT canola and use of triazines will certainly lead to an escalation in resistant populations of weeds, particularly annual ryegrass. There is already evidence of triazine resistance in wild radish. <sup>5</sup>

### *Imidazolinone Tolerant (IT) canola*

IT canola varieties offer some significant benefits but there are important limitations. These varieties are marketed along with an imidazolinone herbicide mix originally called "On Duty" but this has been replaced with a mix called "Intervix". This has a wide spectrum of activity and does not suffer from extended plant back periods on acid soils. Unlike the TT varieties, the IT varieties carry no yield or oil penalties. The introduction of IT varieties has reduced the area of TT canola, which will have herbicide resistance management and environmental benefits.

Of the disadvantages, Group B herbicides are "high risk" in terms of the development of herbicide resistance. Group B herbicides (e.g. chlorsulfuron and triasulfuron) are already used frequently in cropping sequences. Therefore, producers will have to plan carefully on how to fit the IT varieties without increasing the frequency of Group B herbicide use. The company is developing best management packages that will help greatly in this regard. The Group B resistance problem is so severe already in some

<sup>4</sup> S. Sutherland, Canola Weed Management. [http://www.australianoilseeds.com/\\_\\_\\_data/assets/pdf\\_file/0012/2712/Chapter\\_12\\_-\\_Canola\\_Weed\\_Management.pdf](http://www.australianoilseeds.com/___data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf)

<sup>5</sup> S. Sutherland, Canola Weed Management. [http://www.australianoilseeds.com/\\_\\_\\_data/assets/pdf\\_file/0012/2712/Chapter\\_12\\_-\\_Canola\\_Weed\\_Management.pdf](http://www.australianoilseeds.com/___data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf)

areas (particularly in Western Australia) that the IT varieties may have limited, if any, scope for use.<sup>6</sup>

### *Liberty Link® canola*

Liberty Link® varieties are currently being developed for the Australian market. At this time, there are problems with efficacy of glufosinate ammonium during the cool growing season, particularly on wild radish and annual ryegrass. This may limit the widespread application of Liberty Link® canola in some areas of southern Australia.

However, when Liberty Link® is combined into hybrids the additional seedling vigour may enhance competition with weeds.<sup>7</sup>

### *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. Given these factors, Roundup Ready® canola will offer producers a significant alternative to other varieties, herbicide resistant or otherwise. The introduction of Roundup Ready® canola will lead to further reductions in the area of TT canola, which will be good for management of triazine resistant weeds and the environment.

A problem industry has to deal with is glyphosate resistance in annual ryegrass, for which there are an increasing number of documented cases. If glyphosate is the only herbicide used in Roundup Ready® 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. Therefore, best management packages will need to include recommendations for minimising the risk of increased selection for the glyphosate resistant biotypes.<sup>8</sup>



Figure 2: Herbicide tolerant canola, including Roundup Ready varieties, growing at the NVT site at Forbes, NSW. Source: GRDC

<sup>6</sup> S. Sutherland, Canola Weed Management. [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0012/2712/Chapter\\_12\\_-\\_Canola\\_Weed\\_Management.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf)

<sup>7</sup> S. Sutherland, Canola Weed Management. [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0012/2712/Chapter\\_12\\_-\\_Canola\\_Weed\\_Management.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf)

<sup>8</sup> S. Sutherland, Canola Weed Management. [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0012/2712/Chapter\\_12\\_-\\_Canola\\_Weed\\_Management.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf)

### 6.1.4 Future directions

Canola is set to remain a popular crop in Australia providing grain prices remain satisfactory and blackleg is controlled with varietal tolerance. However, herbicide resistance in weeds may force producers into less intensive rotations in order to manage seed banks of resistant weeds.

Weed resistance is likely to restrict the useful life of the IT and TT varieties. This is particularly the case with the IT varieties because the associated herbicides are “high risk” for resistance development, but also because widespread resistance to these herbicides already exists.<sup>9</sup>

## 6.2 Clethodim damage

Clethodim damage in canola is particularly relevant in the northern region. The application of clethodim at rates of product of 500mL/ha (for Select (240 g/L) this is the maximum label rate in canola, but for Select Xtra (360 g/L) the maximum label rate in canola is 330mL/ha) have been reported to cause the following symptoms on canola:

- Delayed flowering
- Distorted flower buds
- Possible yield suppression

Recent research in the central west parts of NSW by the Grain Orana Alliance (GOA) had resulted in variable results. Overall damage seemed to be light and it was difficult to ascertain whether some damage was attributed to frost or other abnormal conditions. Yield effects were negligible for most sites. It was concluded that more field experiments could be completed over several sites and years, or some of this work could be achieved under controlled climate conditions, but loses the realistic conditions of field based research.

Clearly growers need to be aware of the main factor driving such drop damage. There may also be varietal differences, about which little is known, however, farmers can control the timing and rate of herbicide and should be able to avoid such issues. As for controlling the conditions of canola at the time of application, spraying earlier may avoid moisture stress issues particularly in seasons when rainfall is light. Spraying early means 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 weed could still be managed with non-chemical options such a windrow burning.<sup>10</sup>

Clethodim resistance in annual ryegrass is increasing. In the past clethodim resistance was managed by increasing the rate of clethodim. Unfortunately it is no longer

<sup>9</sup> S. Sutherland, Canola Weed Management. [http://www.australianoilseeds.com/\\_\\_\\_data/assets/pdf\\_file/0012/2712/Chapter\\_12\\_-\\_Canola\\_Weed\\_Management.pdf](http://www.australianoilseeds.com/___data/assets/pdf_file/0012/2712/Chapter_12_-_Canola_Weed_Management.pdf)

<sup>10</sup> T. Cook, G. Brooke, M. Widderick, M. Street (2014) , Herbicides and weeds regional issues trials and developments <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Herbicides-and-weeds-regional-issues-trials-and-developments>

possible to do that. There are now populations of annual ryegrass that are resistant to 500 mL ha<sup>-1</sup> clethodim and some will survive when treated with 2 L ha<sup>-1</sup> of clethodim.

As there are no new post-emergent grass herbicides for canola in the pipeline, pre-emergent herbicides will have to take a greater role in managing ryegrass post-emergent. We examined the ability of some currently registered and potential products for controlling annual ryegrass in canola in 2012 (Table 3). None of the pre-emergent herbicides were particularly efficacious against clethodim resistant annual ryegrass and none were better than using clethodim. Currently, the mix of clethodim plus butoxydim (Factor<sup>®</sup>) applied after a pre-emergent herbicide offers the best control; despite continuing to select for clethodim resistance.<sup>11</sup>

## More information

[Maintaining the best options with herbicides](#)

[Options for using more residual herbicides in northern no-till systems](#)

[Herbicides and weeds regional issues trials and developments](#)

[Revisiting canola management can lift returns](#)

For more information on weed management in winter crops, see the Wheat GrowNotes.

Table 3: Control of clethodim-resistant annual ryegrass in canola at Roseworthy in 2012. POST herbicides were applied 8 weeks after sowing.

Herbicide program	Annual ryegrass 8 weeks after sowing (plants m <sup>-2</sup> )	Annual ryegrass spikes at harvest (m <sup>-2</sup> )	Crop yield (T ha <sup>-1</sup> )
1.5 kg ha <sup>-1</sup> Atrazine IBS + 500 mL ha <sup>-1</sup> Select <sup>®</sup> POST	387ab	149cd	1.34a
1.5 kg ha <sup>-1</sup> Atrazine IBS + 250 ml ha <sup>-1</sup> Select <sup>®</sup> POST	262b	306c	1.13a
1.5 kg ha <sup>-1</sup> Atrazine IBS + 500 mL ha <sup>-1</sup> Select <sup>®</sup> + 80 g ha <sup>-1</sup> Factor <sup>®</sup> POST	333b	92d	1.37a
Group K IBS	498a	1105a	0.46d
Group K + 2.0 L ha <sup>-1</sup> Avadex <sup>®</sup> Xtra IBS	298b	775b	0.76c
Group K + 2.0 L ha <sup>-1</sup> Avadex <sup>®</sup> Xtra IBS	235b	260cd	0.88bc
Group K + 250 mL ha <sup>-1</sup> Dual Gold <sup>®</sup> IBS	350ab	802b	0.50cd
Group D IBS	108c	149cd	1.11ab

Abbreviations: IBS, incorporated by sowing; POST, post-emergence; CT, crop-topped

<sup>11</sup> C. Preston, P. Boutsalis, S. Kleeman, R.K. Saini and G. Gill (2013), Maintaining the best options with herbicides <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/08/Maintaining-the-best-options-with-herbicides>



## SECTION 7

# Insect control

## More information

[Insect and mite control in field crops](#)

[Viral diseases in canola and winter pulses](#)

[Emerging insect pests](#)

[‘Serial pests’ wrap-up—lessons from 2014 and 2015 and some research updates](#)

[Canola disease update 2015 \(NSW\)](#)

[Insect pests of canola](#)

Insects that can pose a problem in canola in New South Wales (NSW) include blue oat mites (*Penthaleus* spp.), redlegged earth mites (*Halotydeus destructor*), cutworms, diamondback moth, *Helicoverpa*, aphids, Rutherglen bugs, slugs, European earwigs, Lucerne flea and wire worms.

The seed dressing Gaucho® (imidacloprid) protects emerging seedlings from redlegged earth mite, blue oat mite and aphids for ~3–4 weeks after sowing. Another seed dressing, Cosmos® (fipronil) protects seedlings from redlegged earth mites.

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 virus in the crop.

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

## 7.1 Integrated pest management

Pests are best managed 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. Monitoring may involve techniques and aids such as sweep nets, a beat sheet or visual assessment.

Integrated pest management uses a range of control tactics to keep pest numbers below the level where they cause economic damage. It is primarily based on biological control of pests, by either encouraging natural enemies or release of biocontrols.

Other methods of control support these biological controls and can include:

- cultural methods such as farm hygiene, weed control, strategic cultivation (pupae busting), physical barriers, quarantine areas, different planting times, crop rotations, trap crops, use of attractants for beneficials or repellants for pests, and keeping plants healthy so they resist attack

<sup>1</sup> L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

- host plant resistance such as genetically resistant varieties or physical features that repel pests
- genetic control measures such as release of sterile male insects
- pheromones to confuse mating or aggregation
- use of microbial pesticides such as *Bacillus thuringiensis* (Bt), nuclear polyhedrosis virus (NPV) or *Metarhizium*.
- manipulation of micro-environmental conditions (e.g. planting density, row spacing, row orientation) to make them less suitable for pests or more suitable for beneficials
- use of chemicals as a last resort
- use of 'soft' chemicals or pest-specific chemicals in preference to broad-spectrum pesticides (especially early in the growing season when it is important to preserve beneficials)

Integrated pest management relies on monitoring the crop regularly, having pests and beneficial insects correctly identified and strategic control decisions made according to established damage thresholds.<sup>2</sup>

### 7.1.1 Area-wide management

Area-wide management (AWM) is IPM that operates over a broad region and attacks the pest when and where it is ecologically weakest, without regard to economic thresholds. It is a system currently used in managing resistance in *Helicoverpa armigera* in cotton. AWM coordinates farmers in implementing management strategies on their own farms to control local populations of *H. armigera* and prevent numbers building up later in the season. AWM strategies involve a detailed understanding of the biology and life cycle of the pest and of how the pest moves around in a region. Strategies can include coordinated timing of operations such as pupae busting, sowing and destroying of trap crops, and spraying of certain chemical types including 'soft' or biological insecticides.<sup>3</sup>

### 7.1.2 Biological control

Biological control can be defined as the use of natural enemies to control pest outbreaks. The pest is not usually eradicated, but brought down to levels where it does not cause economic damage. Success with biological control has been varied in many situations. Complete success, where the pests do not exceed the economic thresholds, has occurred in only 19% of cases. Many releases of biocontrol agents have had no significant effect. Success has been more common in long-term agro-ecosystems such as orchards and forests, where pest and natural enemy populations are more stable. In annual cropping systems, maintaining resources that favour the buildup of natural enemies, for example greater biodiversity of plants, retaining

<sup>2</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

<sup>3</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

stubble and groundcover and limiting use of broad-spectrum insecticides, will help to keep pests in check.<sup>4</sup>



Figure 3: Beneficial insects can help bring down insect pest incursions. Photo: Melina Miles, DAF

### *Types of biological control*

- Natural. An existing control agent is encouraged to control pests. This means avoiding the use of chemicals that may destroy these control agents.
- Single release (classical). The control agent is released with the aim of establishing it as a permanent part of the ecosystem. This is usually carried out for introduced pests.
- Multiple release. The control agent is not usually perfectly adapted to the environment (e.g. drought- or frost-intolerant) and so needs to be re-released. This may occur as a 'top-up' after unfavourable conditions, as a regular seasonal release, or as an inundative release where the control agent does not survive well. In this case, the agent is used as a 'living insecticide' that is released in large numbers to reduce pest numbers before it dies.

<sup>4</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

Biological control agents for insect pests can include:

- Predators. These actively capture their prey. Beetles, lacewings, bugs, flies, spiders and vertebrates are predators.
- Parasitoids. These are host-specific and need only one host to complete their life cycle. They lay eggs in their host and emerge after using the host as a food source. The host is nearly always killed. Parasitoids differ from parasites, which will coexist with the host. Parasitoids include wasps—e.g. the parasitic wasp, which will lay eggs inside lucerne aphids, white cabbage moth caterpillars and scarab larvae—and flies such as the tachinid fly.
- Pathogens. These include bacteria, viruses, fungi, protozoa and nematodes. A few of these organisms can enter and multiply rapidly within the host, e.g. *Metarhizium*, Bt, NPV.

Parasitoid and pathogen control agents are usually more successful than predators because they are more host-specific.

### *Trichogramma* wasps

*Trichogramma pretiosum* wasps prey on the eggs of *Helicoverpa* spp., loopers, cabbage moths and others, and are suitable for use in minimally sprayed field crops, maize and vegetables, and for *Helicoverpa* in fruit crops. They are <0.5 mm in size and lay their eggs into moth eggs. The wasp larvae develop into a fully formed wasp inside the moth egg in the process killing the developing caterpillar. *Trichogramma* are supplied as parasitised moth eggs in capsules. These are distributed around the crop and can be applied with water.<sup>5</sup>

### Nuclear polyhedrosis virus (NPV)

Insect viruses are naturally occurring, insect-specific pathogens that have been part of the environment for millions of years and play an important role in the natural control of insect populations. Insects consume the virus from the leaves. The virus then moves through the gut wall and invades the body of the insect, causing the insect to stop feeding and die within 5 days because of the breakdown of its internal organs. The body ruptures after death, releasing virus particles that infect other caterpillars. Gemstar® and Vivus Gold® are commercial products that control *Helicoverpa punctigera* and *H. armigera* with a liquid concentration of virus particles in cotton and selected crops. Typically, they provide 60–90% control of larvae. Both products fit best within an IPM program that uses natural enemies such as ladybeetles and parasites, but can be alternated with synthetic insecticides. As a biological insecticide, efficacy is dependent on environmental conditions for good performance. It needs to be ingested; therefore, coverage of the target area is essential.<sup>6</sup>

<sup>5</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

<sup>6</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

### *Bacillus thuringiensis*

The Bt bacteria produce proteins that are characterised by their potency and specificity to certain species, most of which are agronomically important pests. Mixtures of protein crystals and spores have been sprayed in the same way as a chemical pesticide for many years in horticultural industries, but with variable success in broadacre field crops, Full-Bac® WDG being a notable exception. Full-Bac® WDG is a dry flowable, more suited to application by boom spray than previous formulations. The caterpillar ingests the protein, which then attacks the gut wall, causing holes, and the insect stops feeding. The bacterial spores contained in the protein then leak through the gut wall and cause bacterial infection. The insect will die, either from this bacterial infection or from starvation. This is the process that makes the Bt protein highly specific and environmentally desirable. Insertion of the Bt gene into cotton plants has taken many years to develop, and breeding is ongoing of plants that express higher levels of the Bt toxin. Resistance to Bt is being carefully monitored and controlled with the development of management programs and new research on multiple insect-resistance genes. Novel strains of Bt are being isolated for a wide range of pest families, including beetles, flies and locusts.<sup>7</sup>

## More information

[Integrated Pest Management Fact Sheet](#)

## 7.2 Earth mites

Earth mites are the major pests of seedling canola, especially in central and southern NSW. Damage can be caused by redlegged earth mites and blue oat mites, which often occur in mixed populations. *Bryobia* mites are an increasing problem in some areas. A good mite-control program starts with a population reduction treatment the previous spring (Table 1). Learn to identify these three species of mites to ensure that the correct insecticide and rate is applied to the correct species.

Bare earth treatments. Germinating and establishing crops can be protected by:

- boom spraying the soil surface of previous pasture or high-risk paddocks with a residual insecticide immediately after sowing
- perimeter spraying bare ground in low-risk paddocks, not forgetting to spray around trees, rocky outcrops and dams, and along water flow-lines

If you are unsure of the level of risk from mites, spray the whole paddock. Three bare-earth sprays are registered that will give several weeks of residual protection. Bifenthrin is registered for redlegged earth mite, blue oat mite and *Bryobia* mites, but application rates vary according to the mite species being targeted. Alpha-cypermethrin will control redlegged earth mite, while methidathion is registered for both redlegged earth mite and blue oat mite.

Seed dressings. Imidacloprid (e.g. Gaucho®) and Poncho® Plus (clothianidin + imidacloprid) are registered for use on canola seed for protection against redlegged earth mite, blue oat mite and aphids. Poncho® Plus is also registered to control lucerne flea, wireworm and cutworm. A third seed dressing, Cruiser® Opti (thiamethoxam + lambda-cyhalothrin) is registered for suppression of redlegged

<sup>7</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

earth mite and lucerne flea. These seed dressings will protect emerging seedlings for 3–5 weeks after sowing. Use treated seed following a pasture phase if a well-timed spring spray of insecticide has been applied. Apply a bare-earth border spray where untreated pastures border the canola crop. Seed companies can supply seed pre-treated with imidacloprid, Poncho® Plus and Cruiser® Opti. Cosmos® Insecticidal Seed Treatment (fipronil) is also registered for control of redlegged earth mite in canola. Even where a seed-dressing or bare-earth treatment has been used, it is advisable to check seedling canola regularly for mite damage.<sup>8</sup>

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 on the Tablelands, Slopes and Plains of New South Wales.<sup>9</sup>

### More information

[Nutrient management may double as pest control](#)

<sup>8</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>9</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/insect-and-mite-control-in-field-crops-2013.pdf)

Table 1: Recommended control strategies for earth mites <sup>10</sup>**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

**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

*Feeding*

Mites feed by rasping the surface of the cotyledons and leaves and by sucking up the sap. Feeding is normally from late afternoon until early morning, but continues through the day in calm, cloudy weather. Mites are very active and, if disturbed on a plant, will drop or descend to the ground and disperse to find shelter. Redlegged earth mites usually remain clustered together on the soil or on parts of the leaves during the day. Blue oat mites generally hide by day in the soil beneath damaged plants or under plant debris on the ground. <sup>11</sup>

<sup>10</sup> 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-pests-aphids-mites-millipedes-and-earwigs>

<sup>11</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

## 7.2.1 Redlegged earth mite

The redlegged earth mite is mainly a pest on the Southern and Central Tablelands, Slopes and Plains. It is native to southern Africa and cape weed is its preferred host plant. Other hosts include prickly paddy melon, wild turnip, common sowthistle, Paterson's curse and chickweed (weeds); and canola, lupins, field peas and linseed (field crops). Sometimes mites may move into young winter cereals from a fence line 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.

### 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 overwinter as unladen, 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 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-crop–pasture emergence. 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. READ THE LABEL.

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

### More information

[Persistent pests: aphids, mites, millipedes and earwigs](#)



## More information

[TIMERITE information package](#)

year. For information, phone Australian Wool Innovation toll free on 1800 070 099 or visit the website [www.timerite.com.au](http://www.timerite.com.au).<sup>12</sup>

### 7.2.2 Blue oat mite

Blue oat mites are often confused with redlegged earth mites. There are four recognised species of blue oat mites in Australia: *Penthaleus major*, *P. falcatus*, *P. minor* and *P. tectus*. Accurate identification of the species requires examination by an entomologist. The four species vary in their geographical distribution in Australia. With the exception of *P. minor*, all species have been found in NSW, in some instances in mixed populations. Damage to crops and pastures is incurred in the establishment phase. Host-plant preferences vary with the species, as do their life cycles and tolerances to various pesticides. Host plants include black thistle, chickweed, curled dock, dandelion, deadnettle, prickly lettuce, shepherds purse, variegated thistle and wild oat. Cultivated field-crop hosts include wheat, barley, oats, rye, canola, field peas, lupins and linseed.

#### *Description*

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

#### *Seasonal development*

Overlapping generations of the blue oat mite usually occur between mid-autumn and late spring. Blue oat mites overwinter as aestivating eggs laid in mid-late spring by the second-generation adults. These aestivating eggs are highly resistant to desiccation. They do not begin to develop until late summer–early autumn and they do not hatch until favourable conditions of temperature and moisture occur in the following mid-autumn to early winter.<sup>13</sup>

## 7.3 Lucerne flea

Lucerne flea is an occasional pest of establishing canola crops. The pest is identified by its action of jumping and hopping between plants rather than flying. It is present across a range of soil types in southern NSW. 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.<sup>14</sup>

<sup>12</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

<sup>13</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

<sup>14</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

## 7.4 Slugs

Slugs are a potential problem along the Northern, Central and Southern Slopes, and occasionally adjacent to rivers on the Western Plains. Slugs kill plants at the seedling and rosette stages and can leave large, bare-soil areas. Slugs are favoured by wet springs and summers, where abundant growth and damp conditions provide an ideal habitat. This allows slugs to breed and survive into autumn and winter, when they attack newly sown crops.

Canola sown into dense stubble or adjacent to grassy fence lines, creek banks or damp areas is at greatest risk 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 slug pellets containing metaldehyde.<sup>15</sup>

## 7.5 Diamondback moth

Diamondback moth has been observed in canola crops for many years in NSW. The summer of 2001–02 favoured their build-up and they became a serious pest in the drought of 2002. Few, if any, crops have required spraying since, despite major drought in 2006 and 2009. Caterpillars of diamondback moth do most damage when large numbers are present in seedling crops or when they move from leaves to graze developing pods during crop ripening. Diamondback moth has developed resistance to a range of insecticides. Future management will involve regular monitoring and careful selection of control methods.<sup>16</sup>

### More information

[Diamondback moth in canola. Fact Sheet](#)

<sup>15</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>16</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)



Figure 4: Management of Diamondback moth involves regular monitoring and careful selection of control methods.

## More information

[Reducing aphid and virus risk](#)

[Resistance management strategy for the green peach aphid in Australian grains](#)

[Unified attack on pests and diseases](#)

[Insect pests— resistance, virus vectors and lessons from 2014](#)

[Crop aphids. Back Pocket Guide](#)

## 7.6 Aphids

Aphid flights can occur in autumn and winter in some years and can infest young canola crops. Crops may need to be treated with insecticide to prevent transmission of virus diseases, but also to reduce seedling damage and the risk of spring infestations. The green peach aphid is the major vector of *Beet western yellows virus*, which caused some crop damage in southern and central 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.<sup>17</sup>

Green peach aphid has developed resistance to the synthetic pyrethroid, carbamate and organophosphate groups of insecticides. Transform™ (sulfoxaflor) is a new selective insecticide for control of early-season infestations of green peach aphid.<sup>18</sup>

<sup>17</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>18</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

Aphids can also infest crops in the spring, especially in years of moisture stress. 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. Ensure that the harvest-withholding period (WHP) of the insecticide is adhered to. Seek advice on thresholds and product registrations or permits before spraying.



Figure 5: Aphids can transmit damaging viruses to canola crops. Photo: Melina Miles, DAF

## infocus

### 7.6.1 Recent GRDC-funded research

#### *Take home message*

Compensatory capacity of canola supports the use of less conservative aphid thresholds and increased consideration of natural enemies in controlling outbreaks.

#### *Outcomes and recommendations—management of aphids in canola*

1. Simulated damage through the removal of raceme terminals by cutting provides an adequate way of simulating aphid damage.
2. Trials conducted on the Darling Downs in 2013 and the Liverpool Plains in 2014 show identical trends in terms of crop compensation for simulated aphid damage. Consequently, we have some confidence that the conclusions drawn from these trials will have application to canola crops across a wide range of northern region growing conditions.
3. Removal of the flowering portion of podding racemes (23 days post first flower) did not affect yield, probably because the flowers removed would not have set harvestable pods.
4. Simulated damage to the raceme during the first weeks of flowering had only minimal impact on final yield, except where extreme damage was enacted (66% of, or the entire, raceme removed on every plant).
5. Compensatory capacity and minimal maturity delay following damage to racemes suggests greater opportunity to harness the benefit of natural enemies in controlling aphid outbreaks.

Aphid populations are extremely difficult to work with in the field. Manipulating densities, frequency and persistence of infestations are major constraints to achieving trial outcomes. Therefore, simulated aphid damage is the only viable way to apply consistent treatments across a replicated trial (Figure 1).

The purpose of the simulated aphid trials reported here was to assess the impact of differing levels of damage at different stages of crop development. The trials were designed to evaluate the compensatory capacity of canola to recover yield if damaged by aphids at different stages of crop development. Understanding when canola is most susceptible to aphid-type damage is the first step in determining the need for, and timing of, aphid control in canola.

Experiments 1–3 were conducted on the Darling Downs with dryland canola (43Y85).



Figure 1: The two methods of inflicting simulated aphid damage. Bagging racemes to prevent normal development, used in 2013 only (left), and cutting racemes (right).

### Experiment 1. Bagging canola racemes

Canola raceme development was inhibited by placing bags over the developing main stem raceme to limit development. Three treatments and an untreated control were applied to randomly assigned plots; the primary raceme on all plants was bagged at first flower (treatment 1), 7 days later (treatment 2) and 14 days after first flower (treatment 3), or not bagged (control).

Analysis of grain yields showed that all of the bagged treatments yielded significantly less than the control but were not different from each other regardless of treatment timing (Table 2). The maturity of the plots at the end of the season was very similar to the control, possibly 3–4 days behind in terms of the rate of plant senescence. This result shows that the later flowers (those prevented from developing at +7 and +14 days) contributed little to the final yield, or that soil moisture limited continued growth or compensation in the treated plots.

Table 2: Plot yields (g/plot) from Experiment 1, Darling Downs, where canola raceme development was limited by bagging at 7-day intervals from first flower

SE, Standard error. Means followed by the same letter are not significantly different at  $P = 0.05$ , where l.s.d. = 146 g. Difference between control and treatments significant ( $P < 0.002$ )

Treatment	Yield	SE
Control (unbagged)	1293a	63
Treatment 1. Raceme covered at first flower	988b	18
Treatment 2. Raceme covered at first flower +7 days	989b	62
Treatment 3. Raceme covered at first flower +14 days	949b	25

### Experiment 2. Increasing severity of cutting flowering racemes

The experiment was laid out in the same canola field as used for Experiment 1 to test the effects of damage at different intensities during early flowering. Four treatments were applied with increasing severity at 14 days post first flower, and there was an undamaged control (Table 3).

The damage applied to the plots at 14 days post first flower resulted in a significant yield loss for only the most damaging treatment, in which all developing raceme terminals were cut (top 7 nodes) (Table 3).

The rate of crop senescence was marginally delayed in the two most severe cutting treatments. Crop maturity of treated plots was delayed by ~3–4 days compared with the control.

Table 3: Plot yields (g/plot) from Experiment 2, Darling Downs, where canola racemes were cut with increasing severity at 14 days post first flower

SE, Standard error. Means followed by the same letter are not significantly different at  $P = 0.05$ , where l.s.d. = 242 g. Difference between most severe treatment and other treatments significant ( $P < 0.005$ )

Treatment	Yield	SE
Control (undamaged)	1137a	108
Terminal of raceme cut	1173a	98
Top 3 nodes of raceme cut	1133a	65
Top 5 nodes of raceme cut	1102a	89
Top 7 nodes of raceme cut (nearly all)	841b	111

### Experiment 3. Damage to flowering racemes at late flowering-pod filling

In this experiment, just the flowering portion of filling racemes was removed at 23 days after first flower. There were three treated plots, in which the terminals of 10%, 50% or 90% of the racemes in the plot were damaged, and an undamaged control (Table 4). These treatments were designed to simulate the late terminal infestations commonly observed in late spring.

This damage to the flowering terminals during late flowering-podset had no significant impact on grain yield (Table 4). There was no delay in crop maturity and no significant difference in the rate of crop senescence between treatments.

Table 4: Plot yields (g/plot) from Experiment 3, Darling Downs, where increasing proportions of racemes were damaged during late flowering-pod set

SE, Standard error. There were no significant treatment differences ( $P > 0.05$ )

Treatment	Yield	SE
Control	1246	70
10% of racemes terminal removed	1159	37
50% of racemes terminal removed	1193	65
90% of racemes terminal removed	1204	89

### Experiment 4. Liverpool Plains 2014

The effects of simulated damage on flowering canola were further tested in a second series of experiments at eight sites near Spring Ridge on the Liverpool Plains, NSW. Three treatments were applied (one-third and two-thirds of raceme flowers and whole of raceme removed), with an undamaged control at each site.

The damage was inflicted during the early stages of flowering (within 7–10 days of first flower) at five sites during early August and at three sites where flowering began during late August. An analysis of oil quality and seed characteristics remains to be completed, but harvested grain weights indicated again that main treatment to suffer significant damage was where the entire raceme was removed, leaving plants to regrow completely new flowering structures (Figures 2, 3, 4).

The rate of crop senescence was marginally delayed in the more severe cutting treatments, being 3–5 days behind the undamaged controls, even in the most severe cutting treatment.



Treatment where two-thirds of raceme flowers were removed (top), and 15 days later showing compensation (bottom).

Treatment where entire raceme is removed (top), and 15 days later showing compensation (bottom).

Figure 2: Images of treatments at time of treatment and compensation by the crops 15 days later, near Spring Ridge, Liverpool Plains.

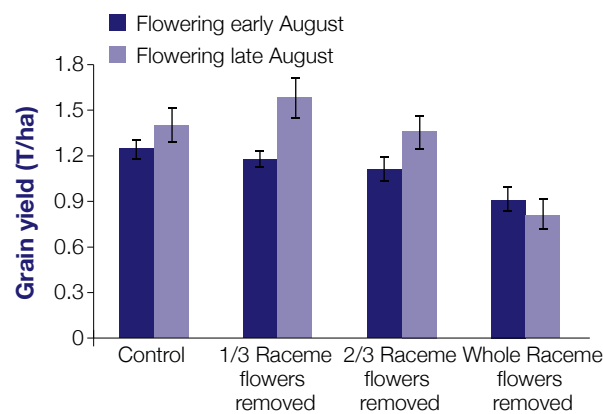


Figure 3: Mean canola yield for treatments applied soon after first flower during early August (five sites) and late August (three sites), near Spring Ridge, Liverpool Plains. Capped lines denote treatment standard error.



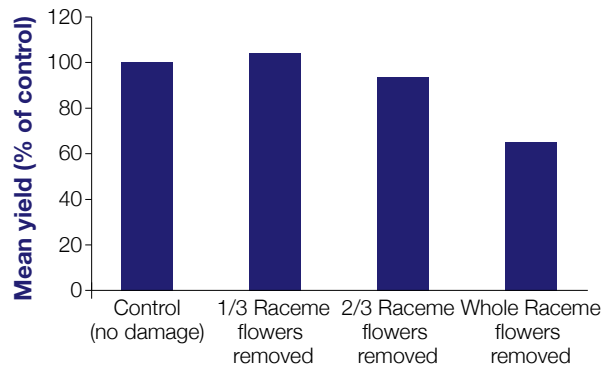


Figure 4: Aggregate treatment yields across all sites near Spring Ridge, Liverpool Plains, expressed as a percentage of the control.

### Conclusions and observations

The bagging of canola racemes during early flowering had a significant effect on yield potential (Experiment 1). By contrast, cutting the racemes (Experiment 2) had an impact on yield only for the most severely damaged treatment that had all raceme terminals from the top seven nodes disrupted (essentially all flowering racemes on the plants). The yield of the other treatments was not significantly affected, although the second most severe treatment did tend towards a lower yield.

The difference in crop response to bagging and cutting is probably caused by the plants continuing to develop racemes under the bag for a significant part of the flowering period rather than deploying assimilates to newer, compensatory racemes from lower down in the plant canopy. This contrasts with the plants where damage was inflicted by cutting, in which compensatory growth of remaining racemes or the initiation of new racemes from adjacent nodes occurred rapidly after damage was inflicted.

Late damage to flowering–podding racemes did not have any effect on crop yield. The flowers removed from the racemes at this stage of flowering would not have set viable pods, so their loss did not have an impact on yield.

Although the physical damage inflicted during these experiments is different from that expected during an aphid infestation, the results suggest that canola has an excellent capacity to compensate for crop damage and that current spray thresholds of ~10% raceme infestation may be more stringent than necessary.

The capacity for compensation and the regular presence of effective natural enemies of aphids in canola provide an excellent opportunity to rely on, and allow time for, biological control by aphid parasitoids and ladybirds during the first weeks of flowering. A delay in enacting a spray decision at the 10% infestation level could be considered to hold low risk and would allow time for biological control. If natural enemies were ineffective, spraying on an increasing level of infestation to the 20–25% level would be unlikely to result in irrecoverable crop damage. Similarly, late infestations of aphids are unlikely to pose a damage threat to canola because the associated raceme disruption mainly affects flowers that contribute little to final yield.

Further study is planned for 2015 to determine a better linkage between the simulated damage in these experiments and actual damage caused by aphids in highly

## **i** More information

[Insect management in faba beans and canola recent research](#)

controlled, small-plot experiments, so that a definitive recommendation can be made on aphid thresholds. In the interim, the work suggests that the use of the 10% raceme infestation as a spray threshold is very conservative.<sup>19</sup>

## 7.7 *Helicoverpa*

*Helicoverpa* (also known as heliothis) caterpillars are an occasional pest of canola in southern NSW and may require control measures if they are present in large numbers. In central and northern NSW, they are a more frequent pest. Because of the seasonal variation in incidence and timing of infestation relative to crop growth stage, growers should seek advice and check the harvest WHP of the chosen insecticide before deciding to spray.

Corn earworm (*Helicoverpa armigera*) and native budworm (*H. punctigera*) are the two pest species of field crops and may be present from mid-September onward. Corn earworm is likely to predominate between February and May.



Figure 5: *Helicoverpa armigera* (PHOTO: QDAFF)

### Seasonal biology

There are generally three or four overlapping generations of caterpillars of the native budworm and corn earworm between September and May in southern NSW, and four or five in northern NSW.<sup>20</sup>

<sup>19</sup> M Miles, P Grundy, A Quade, R Lloyd (2015) Insect management in in fababeans and canola recent research. GRDC Update Papers 25 February 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Insect-management-in-fababeans-and-canola-recent-research>

<sup>20</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

### *Scout crops regularly*

The amount of damage caused by 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 often 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. Periodic outbreaks of caterpillars of both species in summer are often associated with heavy rainfall. Check crops at least a week after heavy rainfall. Look for moths, eggs and very small caterpillars, and treat if necessary. Spraying thresholds are unlikely ever to be more than guidelines for timing sprays. Examine crops at least twice a week during the various danger periods.

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 <sup>21</sup>

### *Spray eggs and very small caterpillars, particularly of the corn earworm*

Corn earworm has developed resistance to many of the pesticides used against it, but the eggs and very small caterpillars (up to 5 mm long) can still be killed if the correct rate of pesticide is used. However, larger caterpillars are not likely to be controlled. <sup>22</sup>

## 7.7.1 Corn earworm

In NSW, corn earworm is largely restricted to within ~150 km of the coast and to inland, irrigated summer-crop production areas. Unlike native budworm, it mainly overwinters locally as pupae in the soil. These pupae are the source of the moths that produce the spring and summer generations of caterpillars. The moths are not strong fliers but can be carried for long distances by wind. They usually initiate infestations locally—within ~100 km of where they developed as caterpillars. During summer, corn earworm moths may be carried by wind into southern NSW from areas to the north (or into northern NSW from southern Queensland) and initiate infestations in crops over a wide area. Pheromone traps or lights do not always attract moths. There may be no forewarning of a probable outbreak of corn earworm unless growers regularly inspect crops to detect moths.

## 7.7.2 Native budworm

Native budworm is widely distributed throughout mainland Australia and during winter breeds in semi-arid parts of Western Australia, South Australia and south-west

<sup>21</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

<sup>22</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

Queensland. These vast inland areas are the sources of the moths that produce the spring generation of caterpillars in NSW (local overwintering pupae in the ground are of little concern). The moths are strong fliers and may be carried for very long distances by wind, to initiate infestations in localities far from where they developed as caterpillars.

### 7.7.3 Descriptions of corn earworm and native budworm eggs and caterpillars

#### *Eggs*

Newly laid eggs are white or yellowish white, dome-shaped, flattened at the base, ribbed and 0.5 mm in diameter. Not all eggs are fertile. Fertile and infertile eggs are laid at the same time, and sometimes all eggs laid are infertile. Fertile eggs change to greenish yellow with an irregular brown or reddish brown ring around the middle. Before hatching, the blackish head and grey body of the caterpillar shows through. They hatch in 3–5 days in warm weather and 6–16 days in cooler weather. Infertile eggs appear cylindrical within ~12 h of being laid and then shrivel to a pyramid shape.

#### *Caterpillars*

Newly hatched caterpillars are 1–1.5 mm long with dark heads and dark-spotted white bodies. 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.

#### *Egg laying*

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. Eggs are laid, usually singly, on the upper parts of plants—vegetative or floral growing points, young tender leaves, stems and flower buds, flowers and fruits. The moths prefer the more advanced and succulent portions of crops for egg laying and usually avoid poorly grown areas. Eggs may not be obvious to the untrained eye because of their minuteness. However, moderate to heavy egg lays should be obvious to trained observers.<sup>23</sup>

### 7.7.4 Resistance-management strategy

Corn earworm has developed resistance to the pyrethroid chemical group (e.g. Decis Options®, Karate®), and the carbamate group (e.g. Lannate® L). However, very small caterpillars (up to 5 mm long) can still be controlled with these and other pesticides. New chemical groups are now available for the control of corn earworm, but often control is slower.

<sup>23</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

Corn earworm caterpillars are found in all irrigation areas. Their main activity is in summer and autumn. Local overwintering pupae are the main source of new infestations each year.

The following strategies are recommended across all cotton and grain industries:

1. Destroying the overwintering pesticide resistant pupae
  - Corn earworm overwinters as pupae in the soil under crop stubble and moths emerge from the pupae in the following spring.
  - Insecticide resistance is carried over between seasons in the pupae.
  - Where large *Helicoverpa* caterpillars are present in crops during March, there is a risk of carryover of resistance to the next season. Cultivate these paddocks to destroy the pupae as soon after harvest as possible and complete by the end of August.
  - Check no-till, late-season crops for pupae. Consider busting if detectable numbers (1 pupa/10 m) are present.
  - Ensure that cultivation creates full disturbance to at least 10 cm deep as follows: on hills, to 10 cm each side of the plant line; on beds, right across the bed to 20 cm beyond the outside rows; on the flat, the whole area.
2. Scout crops regularly
  - Monitor crops twice weekly during danger periods to detect eggs and very small (up to 5 mm long) caterpillars. Infestations are often associated with heavy rainfall.
  - Use advisors for monitoring, because moth activity alone cannot be taken as a guide for spraying and eggs are not readily seen with the naked eye—they are small and often hidden.
  - Pay closer attention to late season *H. armigera* activity on susceptible crops (cotton, summer pulses, late sorghum and late sunflowers).
3. Spray eggs and very small caterpillars
  - Spray to control the eggs and very small (up to 5 mm long) caterpillars. The chemical must make contact with the eggs and caterpillars.
  - Egg laying is usually confined to the period from flower bud formation until flowering ends. At 25°C, it takes 8–10 days from egg lay to 5 mm long caterpillars.<sup>24</sup>
4. Pesticide management
  - Conserve beneficials by using the most selective pesticide available, including appropriate use of NPV products (e.g. Vivus Gold®).
  - Monitor natural enemies and be aware that their activity varies depending on crop types (e.g. they are not very active in chickpeas).
  - Delay the use of disruptive pesticides (pyrethroids, carbamates and organophosphates) in all crops for as long as possible. Review spraying thresholds as a guide to spray timing.

<sup>24</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)

- Where *Helicoverpa* populations are present and above threshold, control them within the limits of insect resistance and available registrations. Ensure that spray applications are accurate and timely. Do not spray in the heat of the day. Use an NPV product (e.g. Vivus Gold<sup>®</sup>) where appropriate to reduce selection for insecticide resistance, but caterpillars must be small (5–10 mm), the product must be applied in the evening, and there should be no rainfall within 24 h. Apply NPV as high-volume spray (with a wetting agent) at 30 L/ha aerially and 100 L/ha by a ground-rig.
- Rotate chemical groups when spraying crops. If more than one spray is needed, use a pesticide from each of the three available groups (organochlorines, synthetic pyrethroids and carbamates) in rotation. Never apply two consecutive sprays from the same chemical group. For example, if a pyrethroid is used to control sorghum midge do not use a pyrethroid to control *Helicoverpa*.
- Remove all farm vegetation likely to encourage the breeding of insect pests. For example, destroy failed or abandoned crops by cultivation or by using herbicides immediately the decision to abandon has been made. Avoid sowing commercial chickpea crops after June. Late flowering crops are a known host for the next generation of *H. armigera*.
- Use ovicide rates of pesticides only where crops are monitored regularly for eggs and larvae and where eggs are targeted.
- Use larvicide (highest) rates where there is no regular crop monitoring and where larvae are targeted. Use information from pheromone traps.
- During August, September and October, pheromone traps will be in place in some districts. Information gained will indicate whether more detailed sampling of spring host crops (e.g. winter cereals, pulses and weeds) is necessary.
- Advisers or growers wanting assurance on the numbers of corn earworm moths laying eggs in their crops should catch moths in a sweep net and determine their identity. (Moths collected in pheromone traps are a poor indicator of which species of larvae will predominate in crops.) As a guide, catch at least 30 *Helicoverpa* spp. moths at random throughout the crop and on flowering weeds in the paddock (ignore the other moths such as tobacco loopers, brown cutworms and common armyworms that may fly in company with the native budworms).<sup>25</sup>

## 7.8 Other soil pests

As with slugs, there are increasing reports of European earwigs causing significant damage to emerging crops, particularly in the South West Slopes region. 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. 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.

<sup>25</sup> 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)



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.<sup>26</sup>

<sup>26</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

## SECTION 8

# Nematode management

## 8.1 Background

Root-lesion nematodes (RLN) can have an impact on canola growth (Figure 1). 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. <sup>1</sup>

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 [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](#). <sup>2</sup>

### More information

[Managing root lesion nematodes: how important are crop and variety choice?](#)

[Root-lesion nematodes](#)

<sup>1</sup> L. Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

<sup>2</sup> GRDC (2015) Root-lesion nematodes. GRDC Tips and Tactics, February 2015, <http://www.grdc.com.au/TT-RootLesionNematodes>



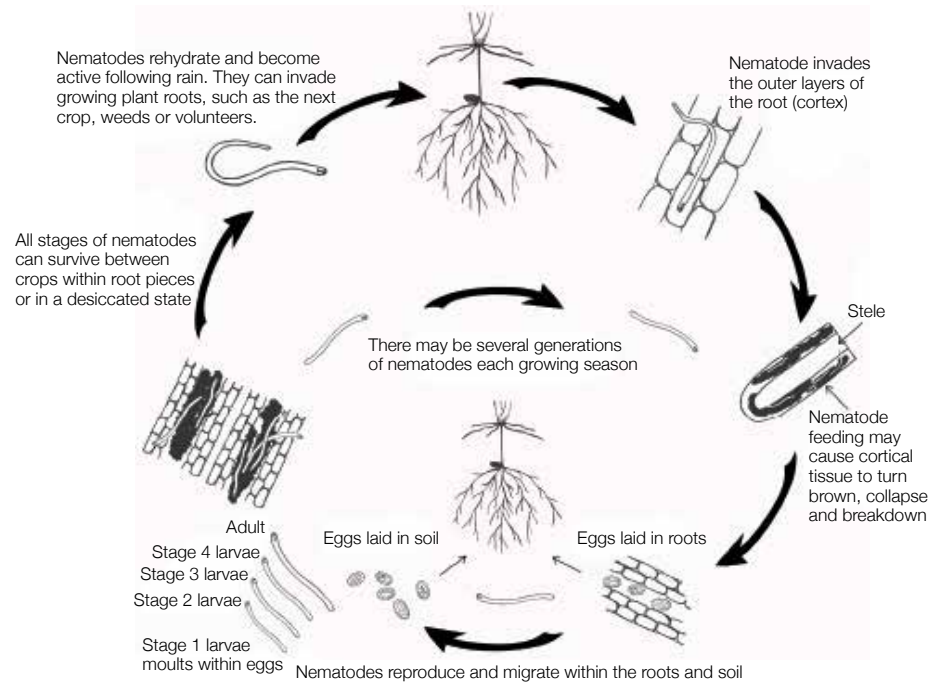


Figure 1: Disease cycle of root-lesion nematode. Adapted from: GN Agrios (1997) Plant pathology, 5th edn. (Illustration by Kylie Fowler)<sup>3</sup>

## in focus

### 8.2 Impact of crop varieties on RLN multiplication

#### 8.2.1 Take-home messages

- Know your enemy—soil test to determine whether RLN are a problem, and which species are present.
- Select wheat varieties with high tolerance ratings to minimise yield losses in RLN infected paddocks.
- To manage RLN populations, it is important to increase the frequency of RLN-resistant crops in the rotation.
- Multiple resistant crops in a rotation will be necessary for long-term management of RLN populations.
- There are consistent varietal differences in *Pt* resistance within wheat and chickpea varieties.
- Avoid crops or varieties that allow the build-up of large populations of RLN in infected paddocks.
- Monitor the impact of your rotation.<sup>4</sup>

<sup>3</sup> GRDC (2015) Root-lesion nematodes. GRDC Tips and Tactics, February 2015, <http://www.grdc.com.au/TT-RootLesionNematodes>

<sup>4</sup> B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication>

## 8.2.2 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.<sup>5</sup>

## 8.2.3 Why the focus on *P. thornei*?

- The species is widespread in the northern grains region. Surveys conducted within northern New South Wales (NSW) and southern Queensland cropping areas consistently show *Pt* presence in ~60–70% of paddocks.
- The species frequently occurs at concerning levels; >2 *Pt*/g soil are found in ~30–40% of paddocks.
- Yield losses in wheat of up to 50% can occur when *Pt*-intolerant wheat varieties are grown in paddocks infested with *Pt*.
- Yield losses in chickpeas of up to 20% have also been measured in Department of Agriculture, Fisheries and Forestry Queensland (DAFF) trials.
- There is no easy solution to RLN infestation. Variety and crop rotation are the current major management tools.

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.<sup>6</sup>

<sup>5</sup> B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication>

<sup>6</sup> B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication>

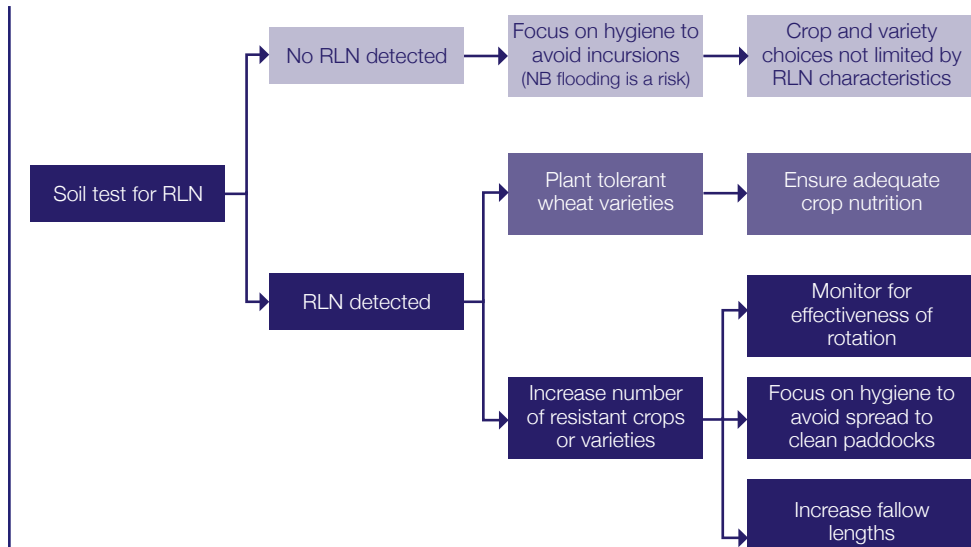


Figure 2: Management flow chart for root-lesion nematode.

### 8.2.4 Soil testing

The first step in the management of RLN is to test the soil and determine whether the problem is present. Testing of soil samples is most commonly conducted via DNA analysis (commercially available as the PreDicta B test from SARDI) with sampling to depths of 0–15 or 0–30 cm.

Vertical distribution of *Pt* in soil is variable. Some paddocks have relatively uniform populations down to 30 or 60 cm, some will have highest *Pt* counts in the 0–15 cm layer, whereas other paddocks will have *Pt* populations increasing at greater depths (e.g. 30–60 cm). Although detailed knowledge of the distribution may be of some value, most on-farm management decisions will be based on the presence or absence of *Pt*, with sampling at 0–15 or 0–30 cm depth providing that information.<sup>7</sup>

To organise testing and sending of soil samples, visit the [PreDicta B website](#).

For testing and interpretation of results contact:

Rob Long, Crown Analytical Services

0437 996 678

[crownanalytical@bigpond.com](mailto:crownanalytical@bigpond.com)

#### More information

[Variety choice and crop rotation key to managing root lesion nematodes](#)

[Impact of crop varieties on RLN multiplication](#)

### 8.2.5 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.

<sup>7</sup> B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication>

- 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.<sup>8</sup>

### Resistance differences between winter crops

The primary method of managing RLN populations is to increase the number of resistant crops in the rotation. Knowledge of the species of RLN present is critical, because crops that are resistant to *Pt* may be susceptible to *Pn*. Canola is generally considered resistant or moderately resistant to *Pt*, along with sorghum, sunflowers, maize, canary seed, cotton and linseed. Wheat, barley, chickpeas, faba beans, mungbeans and soybeans are generally susceptible, although the level of susceptibility may vary between varieties. Field peas have been considered resistant; however, many newer varieties appear more susceptible. Figure 3 shows the mean *Pt* population remaining after a range of winter crops were grown near Weemelah in 2011. Crops were sown in individual trials to enable weed and pest control, and so data cannot be directly compared; however, the data broadly indicate the magnitude of differences in *Pt* resistance between these crops. Assessment of the risk of buildup of *Pt* in different crops (or species susceptibility) shows canola has a low risk of nematode build up. Results shown in Table 1 indicate both low and high starting populations having reduced levels at the end of the season.<sup>9</sup>

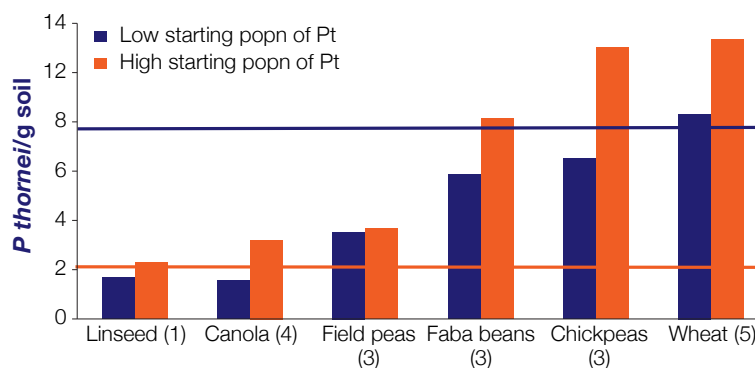


Figure 3: Comparison of *Pt* populations remaining in March–April 2012 following different winter crop species near Weemelah 2011. Numbers of varieties within crops are in parentheses. The two horizontal lines indicate the respective 'low' and 'high' starting levels of *Pt* in March 2011. Soil sampling depth was 0–30 cm.

<sup>8</sup> B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication>

<sup>9</sup> B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication>

Table 1: Comparison of crops for risk of *Pt* buildup and the frequency of significant variety differences<sup>10</sup>

In crops with a range of buildup risk but a dominant category, the dominant category is in bold type

Crop	<i>Pt</i> buildup risk	Variety differences
Sorghum	Low	None observed
Cotton	Low	None observed
Sunflowers <sup>A</sup>	Low	None observed
Linseed <sup>A</sup>	Low	–
Canola <sup>A</sup>	Low to medium	None observed
Field peas <sup>A</sup>	Low to medium	Low
Durum wheat	Low to medium	Moderate
Barley	Low to medium	Moderate
Bread wheat	Low, medium to high	Large
Chickpeas	Medium to high	Moderate to large
Faba beans	Medium to high	Low
Mungbeans <sup>A</sup>	Medium to high?	Moderate to large?

<sup>A</sup>Data from only one or two field trial locations for these crops

<sup>10</sup> B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication>

## SECTION 9

# Diseases

## 9.1 Two major canola diseases: blackleg and Sclerotinia stem rot

Blackleg (caused by *Leptosphaeria maculans*) and Sclerotinia stem rot (caused by *Sclerotinia sclerotiorum*) are two major diseases of canola. Blackleg is less prevalent in northern NSW and Queensland; however, it is critical that blackleg be controlled by growing resistant varieties and having a 3-year break between crops to allow all the stubble to be broken down. Chemical treatment is available if considered necessary.

Several seed dressings only provide suppression of the blackleg fungus, for example those with the active ingredient (a.i.) fluquinconazole (Jockey®, Quantum®, Prowess™), whereas Maxim®XL (a.i.s fludioxonil + metalaxyl-M) provides suppression of blackleg as well as control of *Pythium* spp. and *Rhizoctonia solani*.

Impact®, Bayonet® and Jubilee® (a.i. flutriafol) are in-furrow treatments registered for the control of blackleg.

Sclerotinia stem rot is favoured by wet springs that produce cool, humid conditions in dense crops. Most broadleaf crops and many broadleaf weeds are hosts of *Sclerotinia*, including sunflowers (Figure 1).<sup>1</sup> Growers are advised to incorporate infected residues, maintain farm hygiene, control hosts and rotate with summer/winter cereal crops.<sup>2</sup>

Symptoms include fluffy external growth on the stems, in which numerous black bodies (sclerotia) are found. A possible control measure is a rotation of at least 4 years with no susceptible hosts.<sup>3</sup>

<sup>1</sup> L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

<sup>2</sup> L. Alexander, S. Thompson, M. Ryley, L. Serafin (2015), Sunflower Disease Management, Successful sunflower production using integrated disease management, <http://www.grdc.com.au/TaT-SunflowerDiseaseManagement>

<sup>3</sup> L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

## **i** More information

[Foliar fungal diseases of pulses and oilseeds](#)

[Viral diseases in canola and winter pulses](#)

[Canola diseases. The Back Pocket Guide](#)

[Canola disease update 2015 \(NSW\)](#)

[Canola disease update 2015 \(Vic.\)](#)

[Sunflower Disease Management](#)



Figure 1: Sunflower crops can host sclerotinea. Photo: Sue Thompson, USQ.

Other fungal diseases reported in northern region canola crops include damping off. These diseases are also hosted by other broadleaf crops and weeds.

In 2013, Sclerotinia stem rot affected about 50% of canola crops in northern New South Wales (NSW). Outbreaks are dependent on the season, but the incidence of outbreaks is increasing in high-risk areas such as the high-rainfall zones of northern NSW, indicating that the level of residual inoculum is increasing, particularly under short rotations. The environmental conditions for development of Sclerotinia stem rot are very specific and will not occur every year, so even when the fungus is present, the disease may fail to develop if conditions are dry.

Blackleg is the most important disease of canola and has been reported as present in the northern region. Around 90% of the spores that infect a crop will originate from the previous year's stubble. Spores can travel 1–2 km on the wind, but a buffer of at least 500 m from the previous year's stubble is generally recommended. Two-year-old stubble is an issue only if the seasons have been dry. Treating seed with fungicide can protect seedlings from early infection.

Three virus species, *Beet western yellows virus* (BWYV, syn. *Turnip yellows virus*), *Turnip mosaic virus* (TuMV) and *Cauliflower mosaic virus* (CaMV), have been recorded in canola in Australia. Of these, BWYV is the most common and has potential to cause yield losses, particularly if infection occurs at seedling stage. Aphids spread these diseases from a range of pasture, crop and weed host species.<sup>4</sup>

<sup>4</sup> GRDC (2014) Canola disease management in the northern region. GRDC Gound Cover, 21 March 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-disease-management-in-the-northern-region>

Integrated disease management in canola relies on variety breeding and selection, cultural practices and timely application of chemicals such as fungicides. Burning stubble is not effective against blackleg or Sclerotinia stem rot. See more at: [Canola disease management in the northern region.](#)



## 9.2 Managing 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 at least 500 m, and using a fungicide seed dressing or fungicide-amended fertiliser.

Typically, ~90% of spores that infect new-season crops originate from the previous year's stubble. However, significant numbers of spores from 2-year-old stubble may be produced if seasonal conditions have been dry or the stubble is still largely intact. Spores can travel 1–2 km on the wind, but most originate more locally. A buffer distance of at least 500 m and up to 1 km is recommended. 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 by up to 60%, it is the least effective strategy in managing blackleg and is therefore not generally recommended.

All current canola varieties are now 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 [Blackleg management guide, autumn 2015 Fact Sheet](#) to determine the resistance group for your current canola varieties and select future varieties that belong to a different group.<sup>5</sup>

<sup>5</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

### More information

[Blackleg management guide, autumn 2015 Fact Sheet](#)

[GRDC funding canola stubble screening for fungicide-tolerant blackleg](#)

[2014—Revised spring blackleg management guide Fact Sheet](#)

[Managing blackleg and Sclerotinia in canola. The Back Pocket Guide](#)



## 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  $\geq 3$  years, choose a cultivar from a different resistance group.

## 9.2.1 Four steps to beating blackleg

### Step 1. Determine your farm's risk

Use Table 1 to determine your farm's blackleg risk. Combined high canola intensity and adequate rainfall increase the probability of severe blackleg infection.

Table 1: Regional environmental factors that determine risk of severe blackleg infection

Environmental factors	Blackleg severity risk factor								
		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 2 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 (Figure 2). 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 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.

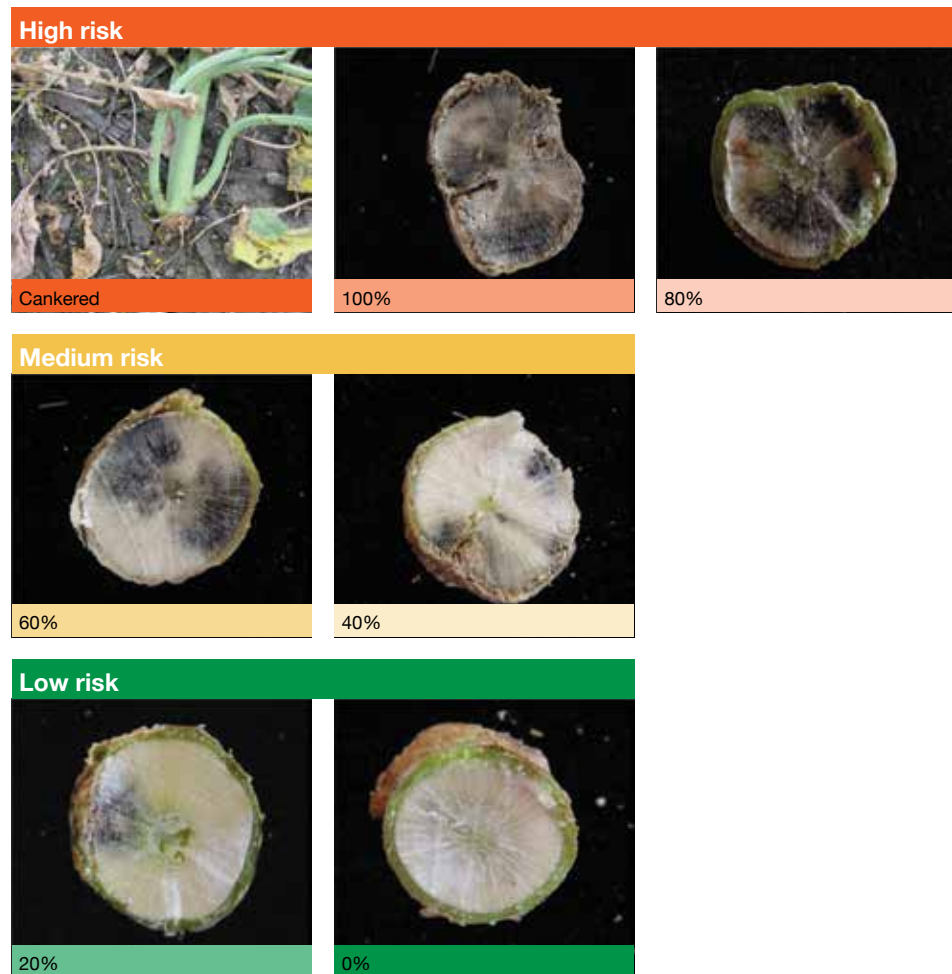


Figure 2: Crop blackleg severity.

### 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 seven management factors listed in Table 2 below (and in the [Blackleg risk management worksheet](#) accompanying the [Blackleg management guide, autumn 2015 Fact Sheet](#)), 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 seven 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.

Table 2: 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	MR	MR-R	R
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 to 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 [Blackleg management guide, autumn 2015 Fact Sheet](#)). You do not need to change resistance groups (cultivars) every year.<sup>6</sup>

<sup>6</sup> GRDC (2015) Blackleg management guide, autumn 2015. GRDC Fact Sheet, 29 April 2015, <http://www.grdc.com.au/GRDC-FS-BlacklegManagementGuide>

### 9.2.2 Blackleg rating

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

#### More information

[Blackleg management guide, autumn 2015 Fact Sheet](#)

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.<sup>7</sup> The blackleg-resistance ratings for all varieties for 2015 are available in the [Blackleg management guide, autumn 2015 Fact Sheet](#) (see Table 3 therein).<sup>8</sup>

## 9.3 Managing Sclerotinia stem rot

Sclerotinia stem rot is a fungal disease that can infect a wide range of broadleaf plants, including canola. Disease development is favoured by prolonged wet conditions in late winter followed by periods of prolonged leaf wetness during flowering.

Yield losses 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 soil-borne 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

<sup>7</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>8</sup> GRDC (2015) Blackleg management guide, autumn 2015. GRDC Fact Sheet, 29 April 2015, <http://www.grdc.com.au/GRDC-FS-BlacklegManagementGuide>

will not occur every year. For example, in dry conditions, even if the fungus is present, the disease may fail to develop.

The fungicide Prostaro® (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](#).<sup>9</sup>

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.<sup>10</sup>

## 9.4 Managing viruses

Managing 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.<sup>11</sup>

*Beet western yellows virus* was found in most tested canola crops throughout NSW. However, substantial yield losses appeared to be limited to a few paddocks where early infection occurred. 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*).

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 in standing wheat stubble.

Growers are advised to check canola crops early in the season for aphid presence. If aphids are found, an effective insecticide should be applied.

<sup>9</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

<sup>10</sup> GRDC (2014) Canola disease management in the northern region. GRDC Gound Cover, 21 March 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-disease-management-in-the-northern-region>

<sup>11</sup> GRDC (2014) Canola disease management in the northern region—details. GRDC Gound Cover, 21 March 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-disease-management-in-the-northern-region/Details>

### More information

[Sclerotinia stem rot in canola Fact Sheet](#)

[Canola diseases. The Back Pocket Guide](#)

[Canola disease update 2015 \(NSW\)](#)

[Economics and timing of fungicide application to control Sclerotinia stem rot in canola](#)

## **i** More information

[Beet western yellows virus \(synonym: Turnip yellows virus\) and green peach aphid in canola](#)

[Canola diseases. The Back Pocket Guide](#)

[Watch for chickpea viruses near canola](#)

## **i** More information

[Virus diseases in canola and mustard](#)

[Reducing aphid and virus risk](#)

[Virus development in canola crops during 2014 in New South Wales and implications for the oilseed and pulse industry](#)

There is no indication that the occurrence of BWYV in canola poses a threat to neighbouring pulse crops.

High infestations of aphid species other than green peach aphid were observed in other broadacre crops in June–July 2014. Widespread infestations of cowpea aphid throughout Queensland and NSW resulted in very high levels of infection of *Bean yellow mosaic virus* in faba bean and, possibly, lupin crops.<sup>12</sup>

Of the three virus species recorded in canola in Australia, BWYV is the most common and has potential to cause yield losses in canola. Commercial canola varieties appear resistant to TuMV. However, some lines of condiment mustard and juncea canola (both *Brassica juncea*) have been severely affected by TuMV in trials in northern NSW. The importance of 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 + clothianidin) is recommended to protect crops from early infestation with aphids.<sup>13</sup>

<sup>12</sup> eXtensionAUS. Latest on canola disease—2015 GRDC Update Papers. eXtension, <http://www.extensionaus.com.au/2015-grdc-update-canola-papers/>

<sup>13</sup> P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

**SECTION 10**

# Plant growth regulators and canopy management

Not applicable for this crop.

## SECTION 11

# Crop desiccation/spray out

(For information on windrowing, see [Section 12. Harvest.](#))

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).

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 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 4 days of a desiccant being applied to minimise the potential of losses from shattering. Withholding periods should be adhered to.

Other products not registered for use in canola should not be used as desiccants as issues with chemical residues can potentially affect markets and quality of the canola.

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.<sup>1</sup>

Glyphosate (specifically Weedmaster) has recently been registered for pre harvest application. It should be noted though that the intention is that it is only registered to control weeds present in the crop at that timing not to manage canola maturity i.e. bringing grain moisture down for harvest.

<sup>1</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## More information

[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.](#)

[Using paraquat in canola, wheat or barley warning: crops will cause residue violations](#)



## 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’.<sup>1</sup> Some advantages of direct heading include cost, availability of headers on farm and a higher harvest index on low yielding crops.



Figure 1: Windrowing prior to harvest is the more common practice. (Photo: Rebecca Jennings)

## More information

[Direct heading canola. Fact Sheet.](#)

[Harvest management. Module 7. Better canola.](#)

<sup>1</sup> L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

## 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.
- 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 canola varieties 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 are ideally 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 much less susceptible than a standing crop to wind, rain and hail damage. In the windrow, seeds will reach a uniform harvest moisture content of 8% within 6–10 days of being cut.



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 the advantages of:

- 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;
- 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; and
- helping to control escaped or herbicide-resistant weeds in some cases.<sup>2</sup>

<sup>2</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

### 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  $\leq 8\%$ .<sup>3</sup>

In warmer, drier areas, windrowing is better done when seed reaches 50–60% seed-colour 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.

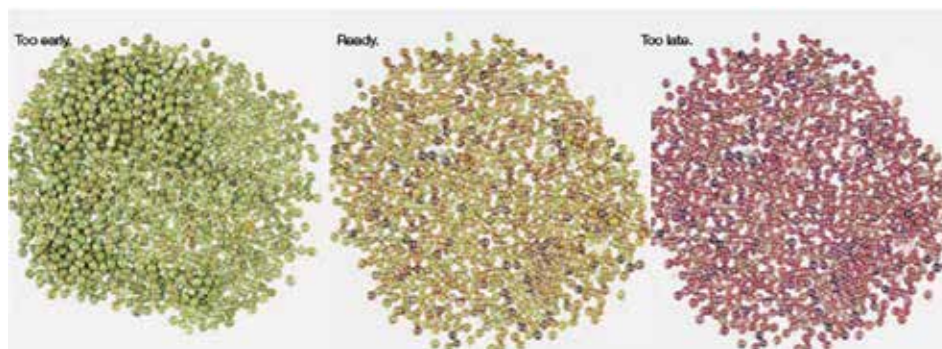


Figure 3: Seed-colour changes determine the optimum time for windrow timing. (Photo: DAFWA)

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

<sup>3</sup> L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

during windowing are obvious, growers are advised to change strategy to direct harvesting or to desiccation followed by direct harvesting.

### **i** More information

[Revisiting canola management can lift returns.](#)

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.<sup>4</sup>

## 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.<sup>5</sup>

Direct heading canola can often be carried out sooner than people think because although the crop stalks may still be green, crop delivery is based on grain moisture, not plant moisture.

Most headers are capable of direct heading canola. Many machines come out of Europe where they regularly direct head crops.

It is critically important to correctly set up the header front, according to the manufacturer's instructions.

Common draper fronts can be used to direct harvest canola, but can be problematic when there is an 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 in in lumps. To counter this, a top cross auger that sits across the back of the header front above the belt can be fitted. 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 which have an auger at the bottom of the table are also capable of direct heading canola.

The crop takes virtually no thrashing to get the grain out of the pods, so machines can be set wide open to handle a significant amount of crop residue.

The incorrect setting up of the reel can cause significant losses in direct heading canola. The reel on the header only comes into play when the crop isn't 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 there to rake the crop into the header

<sup>4</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>5</sup> L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

## **i** More information

[Direct heading canola. Fact-Sheet.](#)

[Direct heading canola delivers at Devenish.](#)

[The benefits of disc seeders direct heading canola and on-farm storage.](#)

[Harvest options for canola—windrowing timing, direct heading, desiccation with Reglone and treatment with Pod Ceal. Effects on yield and oil percentages.](#)

[Harvesting canola in 2013—to windrow or direct head?](#)

[Canola harvest: is direct heading a serious option?](#)

[Early planning the key to canola direct harvesting.](#)

[The nuts and bolts of efficient and effective windrow burning](#)

front because it will create losses from seed shatter. It should only be a backstop for when the crop doesn't feed into the machine.

Harvesters should have sharp cutter bars so they cleanly cut the crop rather than "gnaw" it off.

TO ACCESS THE GRAIN ORANA ALLIANCE HARVEST LOSS CALCULATOR, VISIT:  
<http://www.grainorana.com.au/documents>

## in focus

### 12.3 Comparing windrowing and direct heading

Grains Orana Alliance (GOA) research, which was funded by the Grains Research and Development Corporation, has examined the timing and adoption of pre-harvest practices in the Central West of New South Wales (Table 1). Research findings include:

- Yield loss due to shattering with later windrowing has proved not as severe as 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.<sup>6</sup>

<sup>6</sup> M Street (2013) Harvesting canola in 2013—to windrow or direct head. GRDC Update Papers, 22 August 2013, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/08/Harvesting-canola-in-2013-to-windrow-or-direct-head>

Table 1: Canola harvest treatments, windrow timing and crop maturity<sup>7</sup>

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, 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, 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 the 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 Ceal™.

<sup>7</sup> 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/Harvest-options-for-canola-windrowing-timing-direct-heading-desiccation-with-RegloneTM-and-treatment-with-Pod-CealTM-effects-on-yield-and-oil-percentages>

## **i** More information

[Harvesting canola in 2013-to-windrow or direct head?](#)

[Harvest options for canola—windrowing timing, direct heading, desiccation with Reglone and treatment with Pod Ceal. Effects on yield and oil percentages.](#)

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
- quantifying potential sources of losses—standing crop, windrowing losses, losses while in the windrow <sup>8</sup>

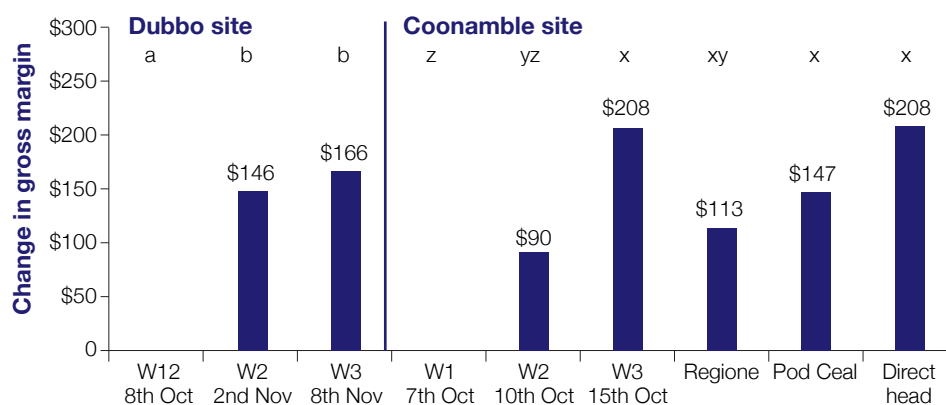


Figure 4: Relative cost-profit difference of various harvest options compared with W1 at the Dubbo and Coonamble canola harvest trials. Treatment values headed by the same letter are not significantly different ( $\alpha = 0.05$ ). <sup>9</sup>

### 12.3.1 Windrowing

This technique is likely to be the most widely used. The majority of canola is currently windrowed. 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.

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<sup>®</sup>).
- 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.

<sup>8</sup> M Street (2010) Harvest options for canola—windrowing timing, direct heading, desiccation with Reglone<sup>™</sup> and treatment with Pod Ceal<sup>™</sup>. 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/Harvest-options-for-canola-windrowing-timing-direct-heading-desiccation-with-RegloneTM-and-treatment-with-Pod-CealTM-effects-on-yield-and-oil-percentages>

<sup>9</sup> 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>



- The optimum timing only lasts 4–6 days depending on the temperature and humidity.
- 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 windrows which are uneven 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.



Figure 5: The majority of canola crops are windrowed prior to harvest.

### 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.<sup>10</sup>

Check withholding periods when using Reglone. See [www.apvma.gov.au](http://www.apvma.gov.au)

<sup>10</sup> 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/Canola-harvest-is-direct-heading-a-serious-option>

## **i** More information

[AOF Harvest Clean](#)

[Down Guidelines](#)

### 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.
- Crops dry out faster after wet weather than 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 an extra 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 it provides a unique elastic, semi-permeable membrane over the filling pods. Timing is earlier than the optimum time for windrowing.<sup>11</sup>

### 12.3.3 Desiccation followed by direct heading

The most common desiccant is diquat (Reglone®), which is registered for aerial application.

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.

<sup>11</sup> 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/Canola-harvest-Is-direct-heading-a-serious-option>

### 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 Canada and Europe. This provides far slower senescence of the plants, considerably reducing pod shattering and providing superior end-of-season grass-weed control.<sup>12</sup>

## 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.<sup>13</sup>

## 12.5 Receival standards

Canola receival standards are presented in Table 2.<sup>14</sup>

Table 2: Commodity standards—canola (from AOF 2014)

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

### More information

[Quality standards, technical information and typical analysis, 2014/15.](#)

[GRDC's Integrated Weed Management Hub.](#)

Links to GRDC Update papers and reports on weed management are available from the [Grain Orana Alliance](#).

<sup>12</sup> 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/Canola-harvest-is-direct-heading-a-serious-option>

<sup>13</sup> L Serafin, J Holland, R Bambach, D McCaffery (2009) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

<sup>14</sup> AOF (2014) Quality standards, technical information and typical analysis. 2014/15. Australian Oilseeds Federation, [http://www.graintrade.org.au/sites/default/files/file/Commodity%20Standards/AOF-Standards\\_201415\\_Final.pdf](http://www.graintrade.org.au/sites/default/files/file/Commodity%20Standards/AOF-Standards_201415_Final.pdf)

## SECTION 13

# Storage

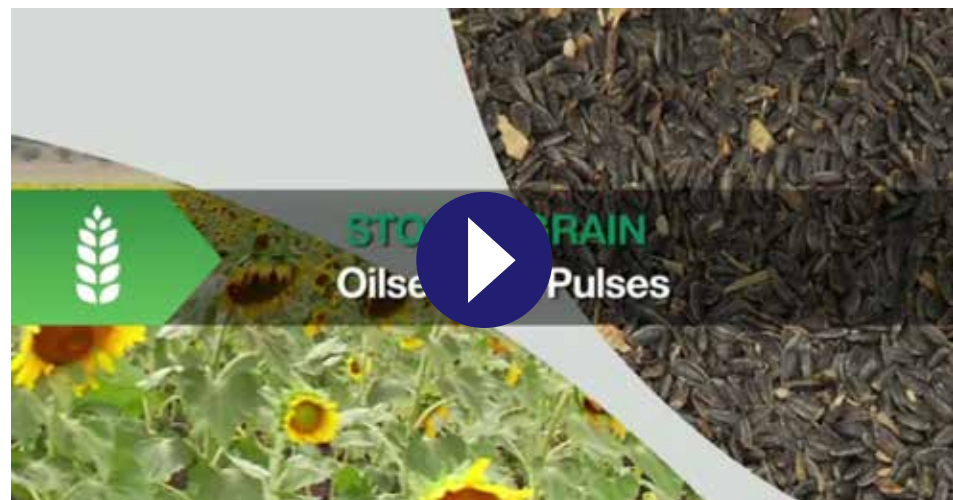
## 13.1 Canola storage at a glance

- 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.<sup>1</sup>

### More information

[Storing oilseeds—Grain Storage Fact Sheet](#)

[Cool and dry conditions maintain canola quality—Farming Ahead](#)



<sup>1</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

## 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.<sup>2</sup>

The decision to store oilseeds requires planning, careful management and a suitable storage system.<sup>3</sup>

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®.<sup>4</sup>

## 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 rust-red flour beetle (*Tribolium castaneum*).

<sup>2</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

<sup>3</sup> GRDC (2014) Storing oilseeds. GRDC Stored Grain Information Hub, <http://storedgrain.com.au/storing-oilseeds/>

<sup>4</sup> GRDC (2014) Storing oilseeds. GRDC Grain Storage Fact Sheet, July 2014, [http://storedgrain.com.au/wp-content/uploads/2014/09/GSFS-9\\_Oil-Seed-July14.pdf](http://storedgrain.com.au/wp-content/uploads/2014/09/GSFS-9_Oil-Seed-July14.pdf)

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.<sup>5</sup>

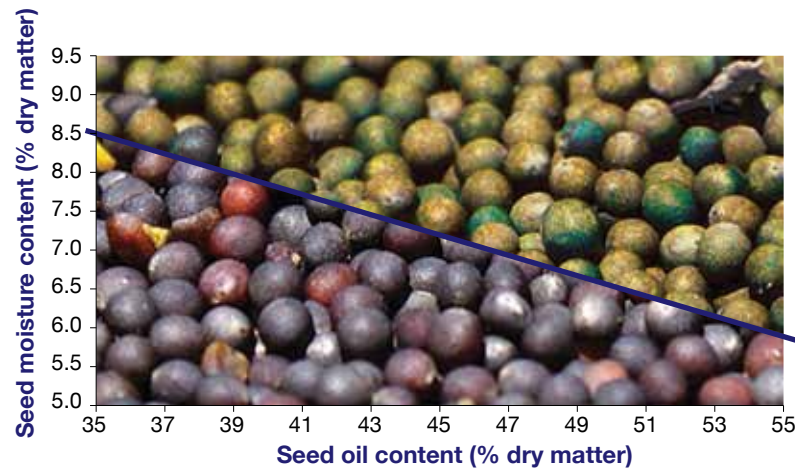


Figure 1: Safe storage conditions for canola at 60% equilibrium relative humidity. The relationship between seed moisture content and oil content is shown at 25°C (yellow line). Canola stored at conditions above the line is at potential risk of seed and oil quality loss. (Source: CSIRO Stored Grain Research 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.<sup>6</sup>

<sup>5</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf/file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

<sup>6</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf/file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)



Figure 2: Aerated, sealable silos.

### 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.<sup>7</sup>

<sup>7</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

## 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 <math><20^{\circ}\text{C}</math>; and
- maintains germination and seed vigour for longer when kept cool and dry.<sup>8</sup>

Canola, being a much smaller seed than cereal grains, adds significantly more back-pressure 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 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.<sup>9</sup>

### 13.6.1 Aeration cooling

Fans providing low airflow rates of ~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 ~<math>\leq 20^{\circ}\text{C}</math> within days. Regular checking of canola in storage is essential. Make visual

<sup>8</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

<sup>9</sup> GRDC (2014) Storing oilseeds. GRDC Stored Grain Information Hub, <http://storedgrain.com.au/storing-oilseeds/>



inspections, check seed moisture, use a temperature probe to monitor bulk seed temperature, and sieve for insects.<sup>10</sup>

### 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.<sup>11</sup>

### 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.<sup>12</sup>

### 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.

Do not use aeration fans with low airflow rates when attempting to dry high-moisture seed.

<sup>10</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

<sup>11</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

<sup>12</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

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.<sup>13</sup>

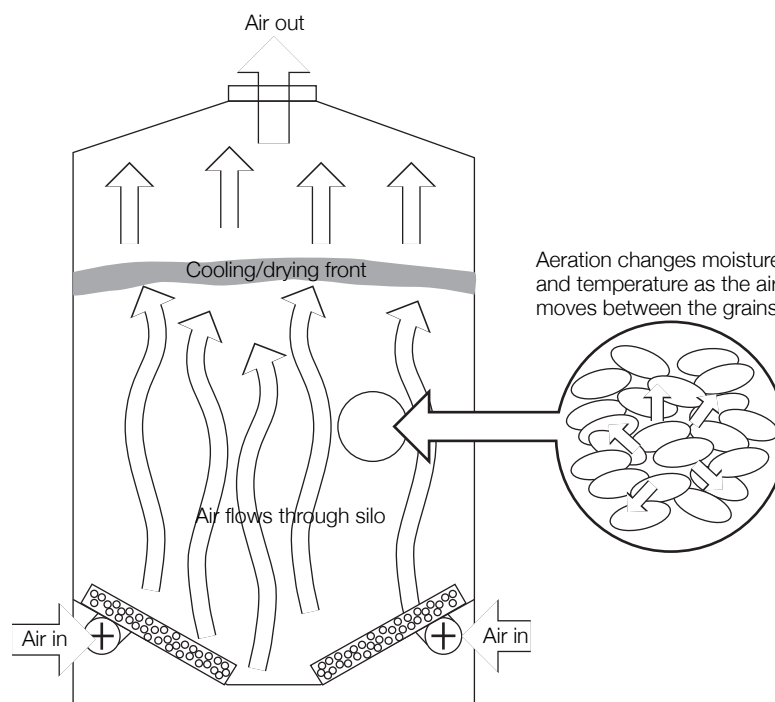


Figure 3: Cooling–drying fronts in the aeration process. (Source: C. Newman, DAFWA)

### 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.<sup>14</sup>

<sup>13</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

<sup>14</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

### 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 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.<sup>15</sup>

## 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*).

<sup>15</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)



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 ~30°C.

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°C, ensure that the fumigation exposure period is ≥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.<sup>16</sup>

<sup>16</sup> 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)

## 13.8 Further reading

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Stored Grain Information Hub for Grain Storage, Quality Control, Insect & Pest Management. GRDC, [www.storedgrain.com.au](http://www.storedgrain.com.au)

Storing oilseeds. Stored Grain Information Hub. GRDC, <http://storedgrain.com.au/storing-oilseeds/>

Vigilant monitoring protects grain assets. Stored Grain Information Hub. GRDC, <http://storedgrain.com.au/monitoring-protects-grain/>

Northern and Southern Regions. Stored grain pests—identification. Stored Grain Information Hub. GRDC, <http://storedgrain.com.au/stored-grain-pests-id-ns/>

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, <http://storedgrain.com.au/aerating-stored-grain/>

Performance testing aeration systems. Stored Grain Information Hub. GRDC, <http://storedgrain.com.au/testing-aeration/>

Fumigating with phosphine, other fumigants and controlled atmospheres. Stored Grain Information Hub. GRDC, <http://storedgrain.com.au/fumigating-with-phosphine-and-ca/>

Pressure testing sealable silos. Stored Grain Information Hub. GRDC, <http://storedgrain.com.au/pressure-testing/>

Grain storage facilities: planning for efficiency and quality. Stored Grain Information Hub. GRDC, <http://storedgrain.com.au/grain-storage-facilities/>

**Phone enquiries:** grain storage specialists: 1800 weevil (1800 933 845)

## SECTION 14

# Environmental issues

## More information

[Phenology of canola cultivars in the northern region and implications for frost risk](#)

[DAFWA: Frost and cropping](#)

GRDC Update papers:  
[What's going on with frost?](#)

[The GRDC National Frost Initiative](#)

[Burnt stubble pre-empts frost risk](#)

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. <sup>1</sup>

## 14.1 Frost

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. <sup>2</sup>

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

<sup>1</sup> 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

<sup>2</sup> J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0004/516181/Proccrop-canola-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Proccrop-canola-growth-and-development.pdf)

**i** More information

[Frost-damaged crops—  
where to from here?](#)

- pods eventually dropping off (Figure 3)
- shrivelling and absence of seeds (Figure 4)



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.



Figure 4: Missing and shrivelled seeds.

### More information

[Diagnosing frost damage in canola](#)

[Pulse and canola—frost identification](#)



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.<sup>3</sup>

#### 14.1.1 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 5–7). Management and recent environmental conditions should be taken into account when identifying any crop disorder.

<sup>3</sup> C White (2000) Pulse and canola—frost identification. The Back Pocket Guide. Reprinted 2003. Department of Agriculture, Western Australia/GRDC, <https://www.grdc.com.au/Resources/Bookshop/2012/01/Pulse-Canola-Frost-Identification-The-Back-Pocket-Guide-GRDC046>





Figure 5: Aphids on canola flower stem.



Figure 6: Sulfur deficiency and aphids. Flower petals retained; pods stunted with yellowing-reddening.



Figure 7: Herbicide damage in lupins.

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. <sup>4</sup>

The optimum temperature range for leaf development of canola is 13°–22°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. <sup>5</sup>

Crops that have been treated with herbicides before or immediately after frosts will often show greater effect. Growers should delay herbicide applications until the crop is actively growing.

<sup>4</sup> C White (2000) Pulse and canola—frost identification. The Back Pocket Guide. Reprinted 2003. Department of Agriculture, Western Australia/GRDC, <https://www.grdc.com.au/Resources/Bookshop/2012/01/Pulse-Canola-Frost-Identification-The-Back-Pocket-Guide-GRDC046>

<sup>5</sup> J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0004/516181/Procrop-canola-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

## 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.
- 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.<sup>6</sup>

### 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 8).

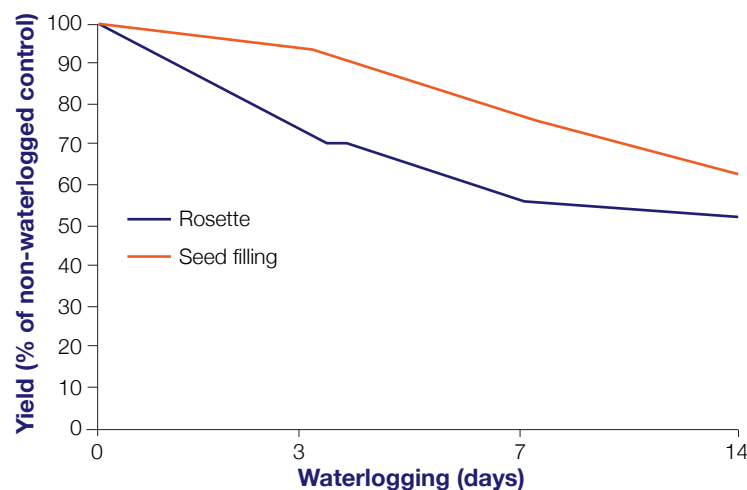


Figure 8: Effect of waterlogging on yield. (Source: Canola Council of Canada 2003)

<sup>6</sup> DAFWA. Diagnosing waterlogging in canola. MyCrop. Department of Agriculture and Food Western Australia, <https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-canola>

## **i** More information

[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.](#)

[Growing canola on raised beds in south-west 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.](#)

[Yield and yield components.](#)

[Improving canola establishment to reduce wind erosion.](#)

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.

The other effects of waterlogging are reductions in root growth, plant growth, plant height, dry matter production and nutrient uptake. <sup>7</sup>

### 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. <sup>8</sup>

### 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. <sup>9</sup>

<sup>7</sup> J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0004/516181/Procrop-canola-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

<sup>8</sup> J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0004/516181/Procrop-canola-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

<sup>9</sup> J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0004/516181/Procrop-canola-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)

## SECTION 15

# Marketing

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

## 15.1 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 production variability and costs can be used to manage and overcome price uncertainty.

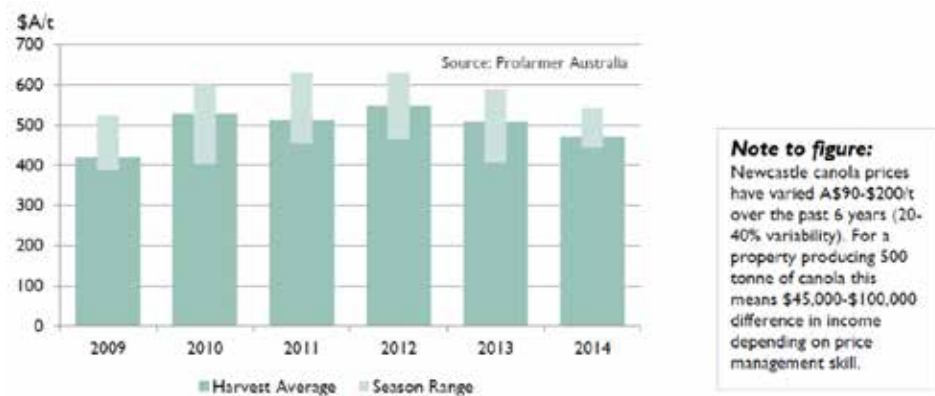


Figure 1: Annual price variation (season average and range) for Newcastle canola.

### 15.1.1 Be prepared

Being prepared and having a selling plan are essential for managing uncertainty. The steps involve forming a selling strategy, and having a plan for effective execution of sales. A selling strategy consists of when and how to sell.

### When to sell

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

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

### How to sell?

This 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 determine what to sell

The key selling principles when considering sales during the growing season are described in Figure 2.

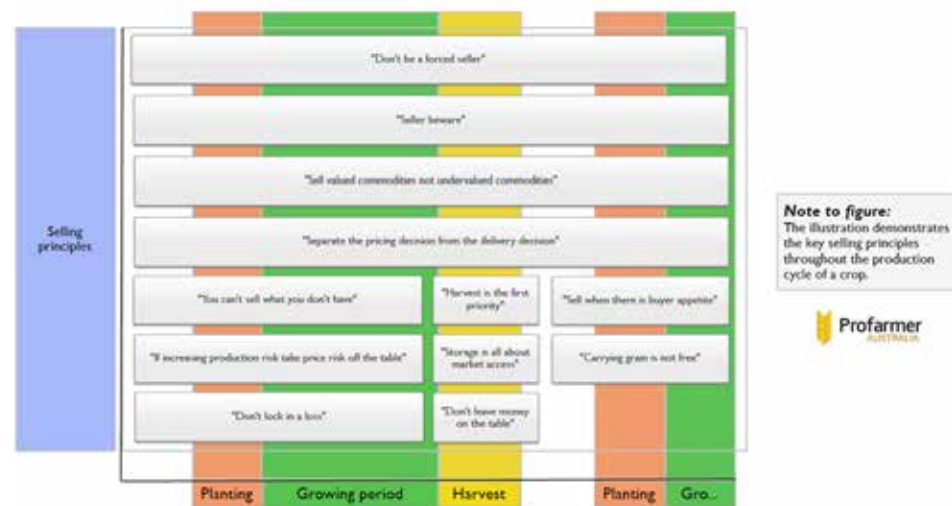


Figure 2: Grower commodity selling principles timeline.

### 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 the risks may be quantified during the production cycle, are described in Figure 3.

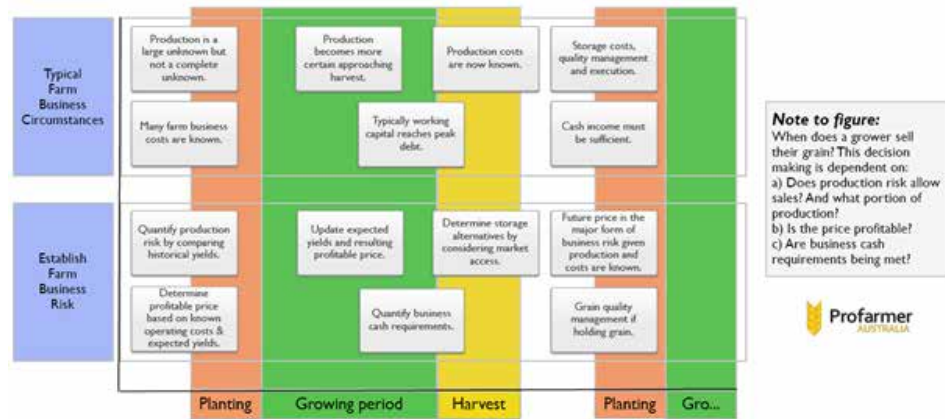


Figure 3: Typical business circumstances and risk.

**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 over committing production.

Establish a production risk profile (Figure 4) by:

- collating historical average yields for each crop type and a below-average and above-average range
- assessing the likelihood of achieving average based on recent seasonal conditions and seasonal outlook
- revising production outlooks as the season progresses

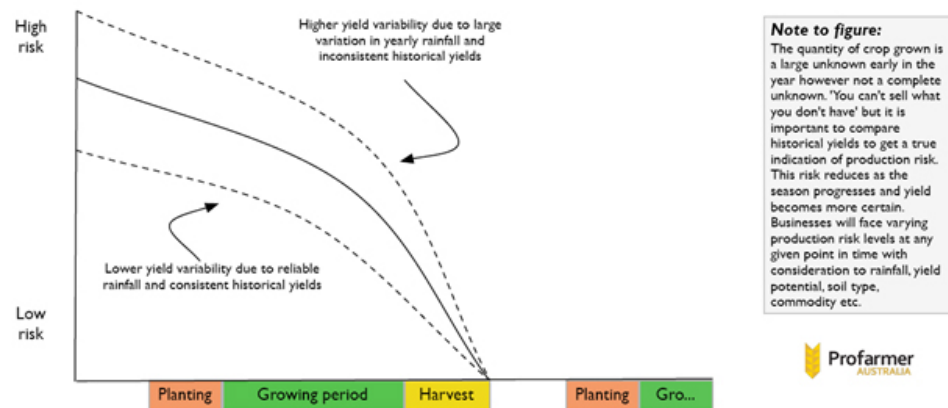


Figure 4: Typical production risk profile of a farm operation.

**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 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.

Estimating cost of production - Canola	
Planted Area	1,200 ha
Estimate Yield	1.45 t/ha
Estimated Production	1,740 t
<b>Fixed costs</b>	
Insurance and General Expenses	\$100,000
Finance	\$80,000
Depreciation/Capital Replacement	\$70,000
Drawings	\$60,000
Other	\$30,000
<b>Variable costs</b>	
Seed and sowing	\$48,000
Fertiliser and application	\$168,000
Herbicide and application	\$84,000
Insect/fungicide and application	\$36,000
Harvest costs	\$48,000
Crop insurance	\$18,000
Total fixed and variable costs	\$742,000
Per Tonne Equivalent (Total costs + Estimated production)	\$426 /t
<b>Per tonne costs</b>	
Levies	\$3 /t
Cartage	\$12 /t
Freight to Port	\$22 /t
Total per tonne costs	\$37 /t
Cost of production Port track equiv	\$463.44
Target profit (ie 20%)	\$93.00
<b>Target price (port equiv)</b>	<b>\$556.44</b>

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

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

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

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

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

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

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

Figure 5: Steps to calculate an estimated profitable price for canola.

The GRDC manual 'Farming the business' also provides a cost-of-production template and tips on skills required for grain selling, as opposed to grain marketing.<sup>1</sup>

### 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.

<sup>1</sup> M Krause (2014) Farming the business. Sowing for your future. GRDC, <http://www.grdc.com.au/FarmingTheBusiness>



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.

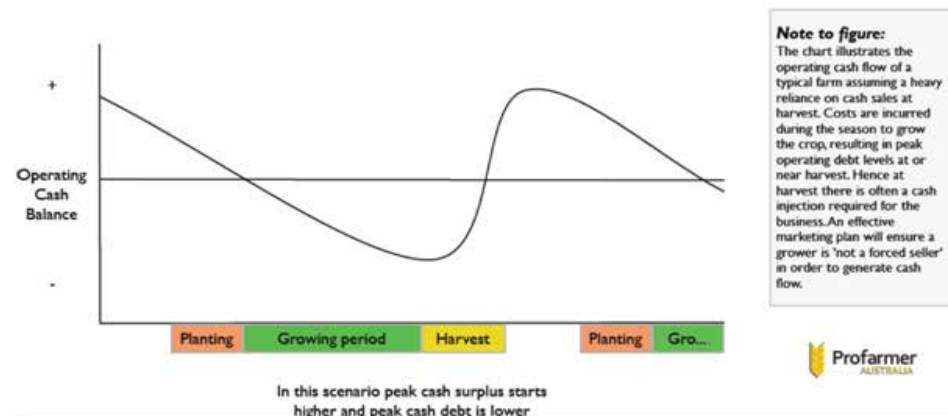


Figure 6: Typical farm operating cash balance, assuming harvest cash sales.

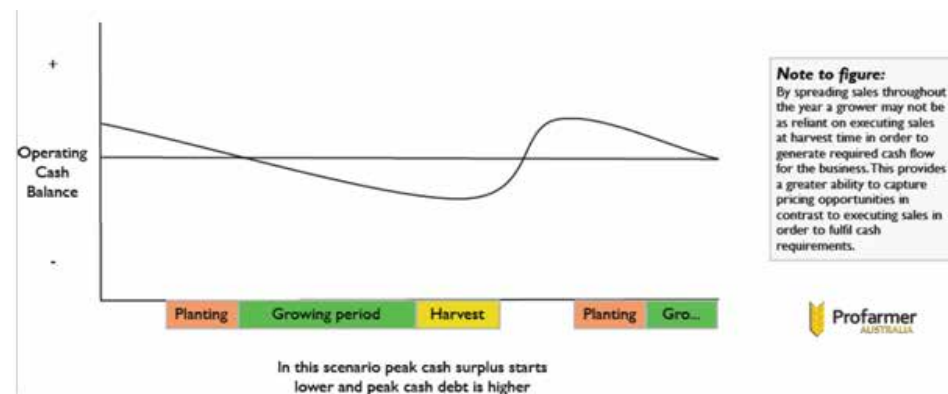


Figure 7: Typical farm operating cash balance, with cash sales spread throughout the year.

### 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).

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	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	Options on futures, floor price pools	Options on futures	Options on futures	Options on futures	Options on futures	none	none
Floating price products	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.

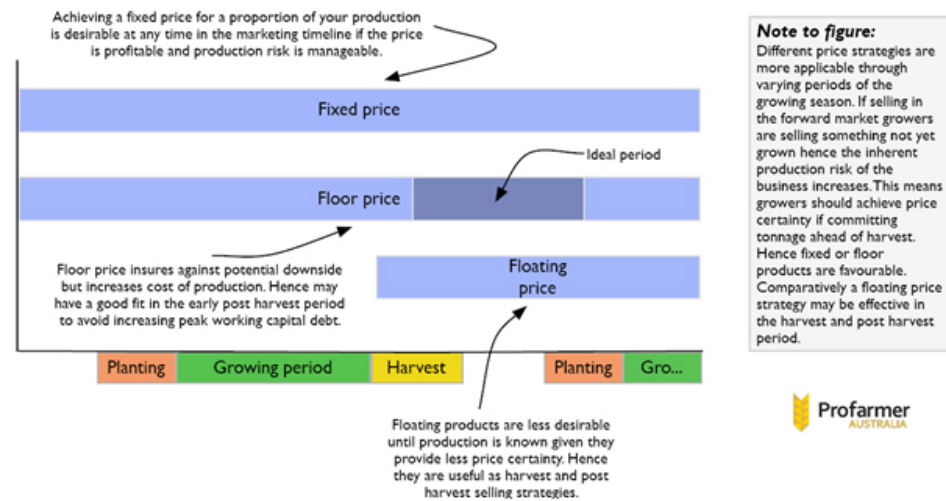


Figure 8: Price strategy timeline through the growing season.

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 known, except when there is a floating component in the price. For example, a multi-grade cash contract with floating spreads or a floating basis component on futures positions.

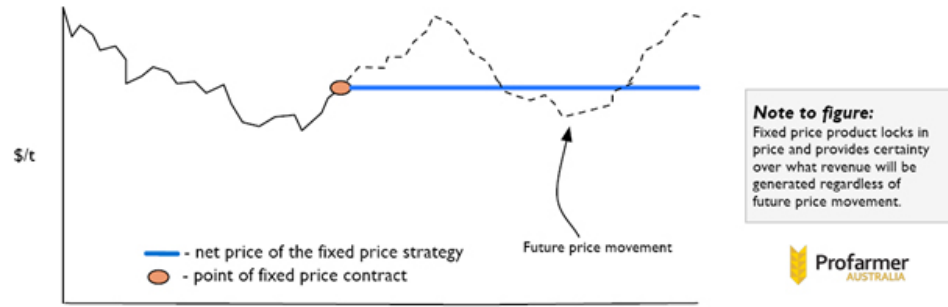


Figure 9: Fixed-price strategy.

**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 whilst capturing any upside (Figure 10). The disadvantage is that the price ‘insurance’ has a cost, which adds to the farm business’s cost of production.

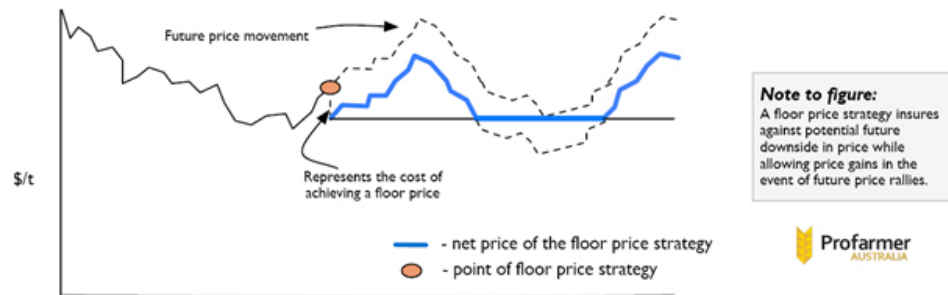


Figure 10: Floor-price strategy.

**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.

### 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).

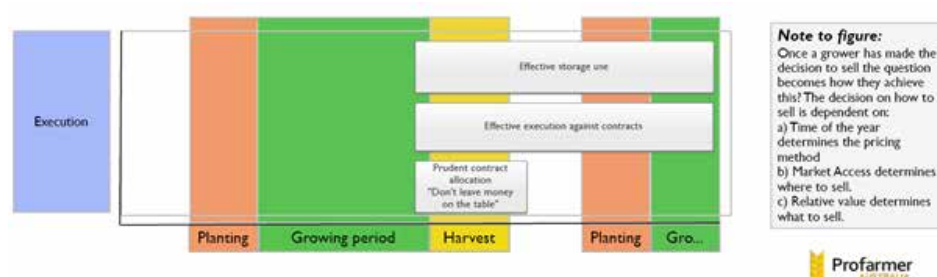


Figure 12: Effective storage decisions.

#### 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 [GrowNotes Canola Northern Region, Section 13. Grain storage.](#)

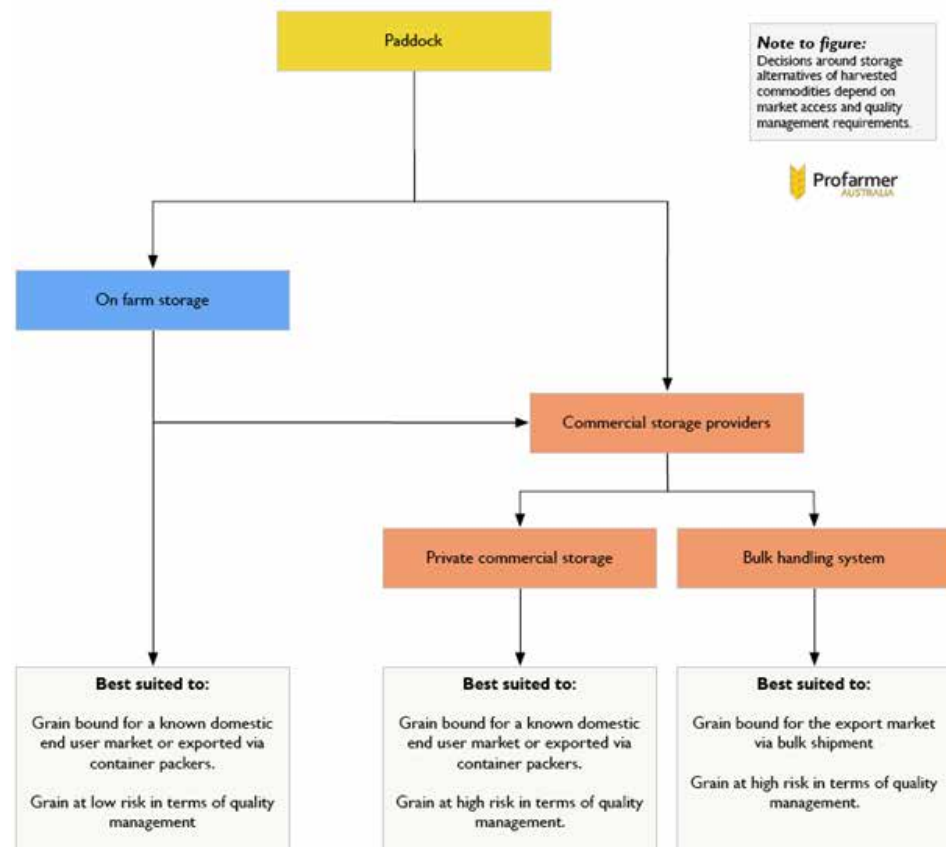


Figure 13: Grain storage decision making.

### 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 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 (see Figure 14).



Figure 14: Newcastle 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 toolbox

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 interest first, by not having conflicts of interest and by investing time in the relationship. Return on investment for the farm business through improved farm-gate prices is obtained by accessing timely information, greater market knowledge and greater market access from the professional service.
3. Futures account and bank-swap facility. These accounts provide access to global futures markets. Hedging futures markets is not for everyone; however, strategies that utilise exchanges such as CBOT 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: <http://www.graintrade.org.au/membership>.

For a list of commodity futures brokers, go to: <http://www.asx.com.au/prices/find-a-futures-broker.htm>.

### *How to sell for cash*

Like any market transaction, a cash grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components, with each component requiring a level of risk management (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 execution management to ensure delivery within the contracted period.
- Payment terms. In Australia, the traditional method of contracting requires title of grain to be transferred ahead of payment; hence, counterparty risk must be managed.

**Timing of delivery (title transfer) is agreed upon at time of contracting. Hence growers negotiate execution and storage risk they may have to manage.**

**Quantity (tonnage) and Quality (bin grade) determine the actuals of your commitment. Production and execution risk must be managed.**

**Price is negotiable at time of contracting.**

**Price point is important as it determines where in the supply chain the transaction will occur and so what costs will come out of the price before the growers net return.**

**Whilst the majority of transactions are on the premise that title of grain is transferred ahead of payment this is negotiable. Managing counterparty risk is critical.**

### GTA Contract No.3 CONTRACT CONFIRMATION

GTA Trade Rules and Dispute Resolution Rules apply to this contract

This Contract is confirmation between:

<b>BUYER</b> Contract No.: _____ Name: _____ Company: _____ Address: _____ Buyer ABN: _____ NGRI No: _____	<b>SELLER</b> Contract No.: _____ Name: _____ Company: _____ Address: _____ Seller ABN: _____ NGRI No: _____
--	--

The Buyer and Seller agree to transact this Contract subject to the following Terms and Conditions:

Commodity: _____ Grade: _____ Quantity: _____ Packaging: _____ Price: _____ Price Basis: _____ Delivery/shipment Period: _____ Delivery Point and Conveyance: _____	GTA Commodity Reference: _____ Inspection: _____ (Open / Destination) Tolerance: _____ (Refer only) Weight: _____ (Open / Destination) Expiry/Free GST: _____ (Deliver, Shipped Free In Store, Free On Board, Ex Ports, etc.)
--	--

Payment Terms: The buyer agrees to pay the seller within \_\_\_\_\_ in the absence of a declaration, payment will be 30 days end of week of delivery.

Levies: \_\_\_\_\_ Any industry, statutory or government levies which are not included in the price shall be covered as required by law.

Disclosure: Is any of the crop referred to in this contract subject to a mortgage, Encumbrance or lien and/or Plant Breeder's Rights and/or EPR liabilities and/or registered or unregistered Security Interest?  NO  YES (Please specify details: \_\_\_\_\_)

Other Special Terms and Conditions: \_\_\_\_\_

All Contract Terms and Conditions as set out above and on the reverse of this page form part of this Contract. Terms and Conditions written on the face of this Contract Confirmation shall override all printed Terms and Conditions on the reverse with which they conflict to the extent of the inconsistency. This Contract confirms the entire agreement between Buyer and Seller with respect to the subject matter of this Contract.

**Recipient Created Tax Invoice (RCTI)**  
 To assist with the processing of the Goods and Services Tax compliance, the buyer may prepare, for the seller, a Recipient Created Tax Invoice (RCTI). If the seller requires this service, they are required to sign this confirmation.  
 Please issue a RCTI (Please specify: \_\_\_\_\_)

**Incorporation of GTA Trade & Dispute Resolution Rules:**  
 This contract expressly incorporates the GTA Trade Rules in force at the time of this contract and Dispute Resolution Rules in force at the commencement of the arbitration, under which any dispute, controversy or claim arising out of, relating to or in connection with this contract, including any question regarding its existence, validity or termination, shall be resolved by arbitration.

Buyer's Name: _____ Buyer's Signature: _____ Date: _____	Seller's Name: _____ Seller's Signature: _____ Date: _____
--	--

This Contract has been executed and this form serves as confirmation and should be signed with a copy returned to the buyer/seller immediately. ©2014 Edition  
GTA, the GTA number and logo

**Grain Trade Australia is the industry body ensuring the efficient facilitation of commercial activities across the grain supply chain. This includes contract trade and dispute resolution rules. All wheat contracts in Australia should refer to GTA trade and dispute resolution rules.**

Figure 15: Typical cash contracting as per Grain trade Australia standards.

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. Figure 16 depicts the terminology used to describe pricing points along the grain supply chain and the associated costs to come out of each price before growers receive their net farm-gate return.



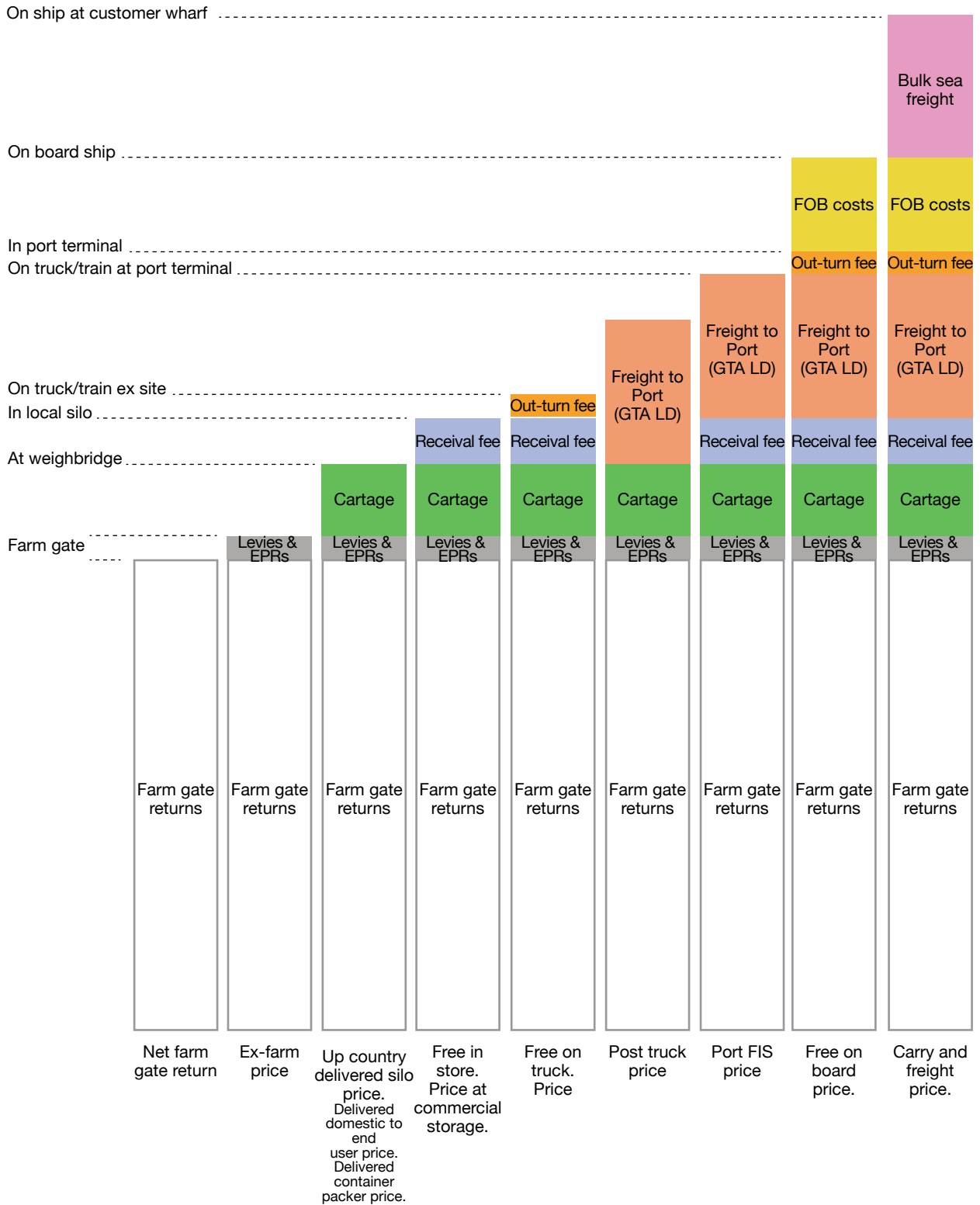


Figure 16: Costs and pricing points throughout the supply chain.

## **i** More information

[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](#)

[Clear Grain Exchange—getting started](#)

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 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 paid.

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.
- Only sell a small amount of grain to unknown counterparties.
- Consider credit insurance or letter of credit from the buyer.
- Never deliver a second load of grain if payment has not been received for the first.
- Do not part with title of grain before payment or request a cash deposit of part of the value ahead of delivery. Payment terms are negotiable at time of contracting; alternatively, the Clear Grain Exchange provides secure settlement whereby the grower maintains title of grain until payment is received by the buyer, and then title and payment are settled simultaneously.

Above all, act commercially to ensure 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.

## **i** More information

[GTA Grain contracts—managing counterparty risk](#)

[Clear Grain Exchange title transfer model](#)

[GrainGrowers Guide to managing contract risk](#)

[Counterparty risk: A producer perspective—Leo Delahunty](#)

*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.



Figure 17: Newcastle canola v. Australian Premium White No. 1 wheat.

If the decision has been made to sell canola, ICE (Intercontinental Exchange®) canola may be the better alternative if the futures market is showing better value than the cash market (Figure 18).

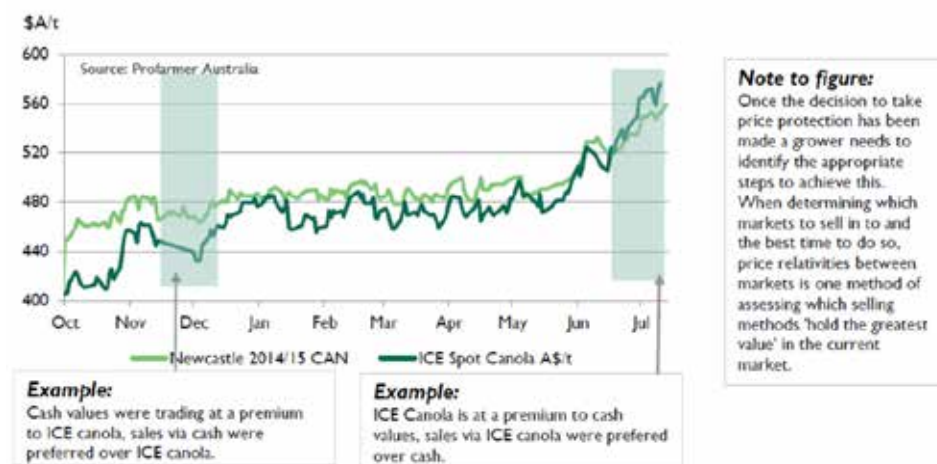


Figure 18: vNewcastle canola v. Intercontinental Exchange (ICE) canola (AU\$/t).

### 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 their lower priced contracts.
- Allocate their best loads (highest oil and lowest admix) to their higher priced contracts.

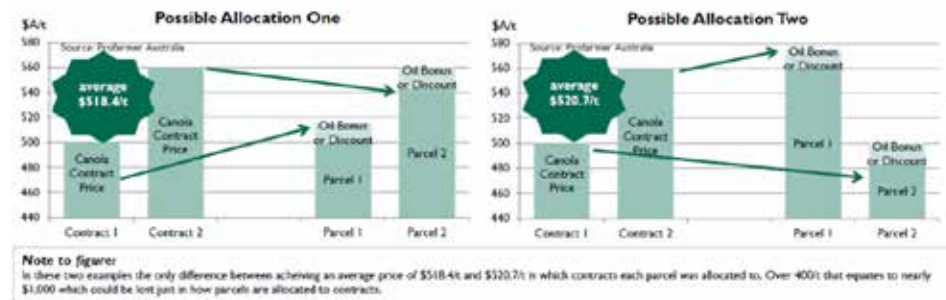


Figure 19: Examples of contract allocation of grain.

### Read market signals

The appetite of buyers to buy a particular commodity will differ over time depending on market circumstances. Ideally, growers should aim to sell their commodity when buyer appetite is strong and stand aside from the market when buyers are not 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:

1. The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate buyer appetite is strong. However, if there is one buyer \$5/t above the next best bid, it may mean cash prices are susceptible to falling \$5/t if that buyer satisfies their buying appetite.
2. Monitoring actual trades against public indicative bids. When trades are occurring above indicative public bids it may indicate strong appetite from merchants and the ability for growers to offer their grain at price premiums to public bids. The chart below plots actual trade prices on the Clear Grain Exchange against the best public indicative bid on the day.

## 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

## 15.2 Northern canola market dynamics and execution

### Price determinants

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 ~75% of the national canola crop, which accounts for ~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.

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 (Figure 20).



Figure 20: Newcastle canola v. offshore markets.

Figure 21 below 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 is a considerable influencer of prices.

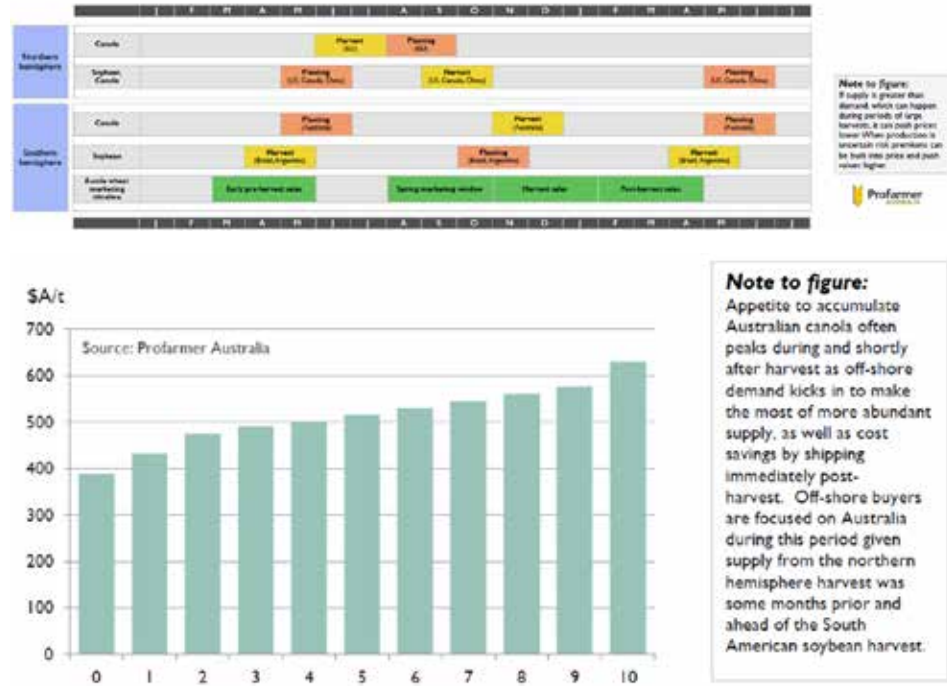


Figure 21: Upper panel: seasonal factors influencing global canola prices; lower panel, Newcastle canola price distribution.

**Ensuring market access**

A large proportion of canola grown in the northern region of Australia is exported in bulk for human consumption (Figure 22); therefore, a 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.

New South Wales (NSW) also has a prominent domestic canola market that can generate premiums to the bulk export markets and provide a return to on-farm storage for growers well positioned to service these crushers. In addition, Victorian demand is greater than production in most years; hence, canola from NSW 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 much larger role to access domestic end-user markets. Australian canola crushers are located at Newcastle and Manildra to the north, and then Cootamundra, Wagga Wagga, Numurkah and Melbourne in the south.

The level of canola exports in containers from NSW remains very low at ~1% of production; however, it can provide price premiums 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.

The supply-chain flow options are illustrated in Figure 23.

	New South Wales		National total	
	Implied tonnes	% of production	Implied tonnes	% of production
Bulk	360,000	40%	2,300,000	74%
Container	6,000	2%	90,000	2%
Domestic use	340,000	38%	750,000	24%

Figure 22: Market destinations for canola—New South Wales and national 5-year averages.

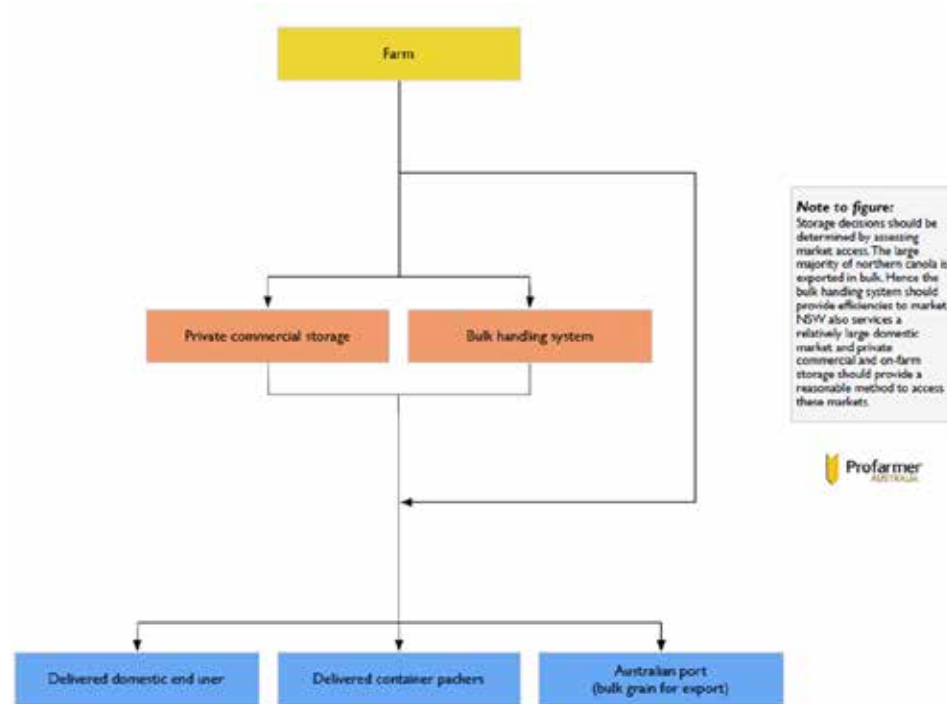


Figure 23: Australian supply chain flow for canola.

### Executing tonnes into cash

The key to effectively executing sales is determining which grades to sell and which to hold. Niche canola grades such as GM canola are often best sold during harvest or shortly after, given that buyer appetite often drops away post-harvest, there being fewer buyers for GM canola than 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 24).

Export pace is strongest shortly after harvest (Figure 25). 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, generating a return on farm infrastructure without running the risk of the domestic buyers adequately covering their requirements.



Figure 24: Melbourne non-GM v. GM canola price.

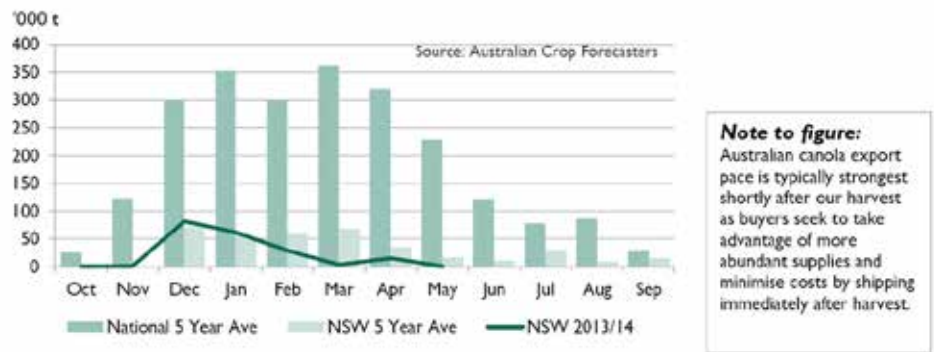


Figure 25: Monthly export pace of canola.

**Risk-management tools**

An Australian cash price has three components: futures, foreign exchange, and basis (Figure 26). Each component affects price. A higher futures and basis and a lower exchange rate will create a higher Australian grain price.





Figure 26: 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.

Table 2: Advantages and disadvantages of the products available to manage canola prices

	Description	Advantages	Disadvantages
Spot cash contracts	Futures, foreign exchange, basis all locked at time of contracting	Simple to use. Locks in all components of price. Cash is received almost immediately (within payment terms).	Immediate grain delivery required. Sales after harvest require storage which incur costs. Locks away three pricing components at the same time. Risk of counterparty default between transfer and payment.
Forward cash contracts	Futures, foreign exchange, basis all locked at time of contracting	Simple to use. Locks in all components of price (no uncovered price risk). No storage costs. Cash income is a known ahead of harvest	Often inflexible and difficult to exit. Locks away the three pricing components at the same time. Future delivery is required resulting in production risk. Counterparty default risk must be managed.
Futures contracts	Futures, foreign exchange, basis are able to be managed individually	Liquid markets enable easy entry and exit from the marketplace. Locks in only some components of price, hence more flexible than cash contracts. Price determined by the market, and is completely transparent. No counterparty risk due to daily clearing of the contracts.	Requires constant management and monitoring. Margin calls occur with market movements creating cash-flow implications. Grain is required to offset the futures position, hence production risk exists. Cash prices may not move inline with futures, hence some price risk. You still have to sell the underlying physical grain.
Over-the-counter bank swaps on futures contracts	Futures, foreign exchange, basis are able to be managed individually	Based off an underlying futures market so reasonable price transparency. Liquid markets enable easy entry and exit from the marketplace. Locks in only some components of price, hence more flexible than cash contracts. Counter party risk is with the Bank, hence it is low. The bank will manage some of the complexity on behalf of the grower, including day to day margin calls.	Costs vary between \$5-10/t at the providers discretion. Requires constant management and monitoring. Grain is required to offset the futures position, hence production risk exists. Cash prices may not move inline with futures, hence some price risk. You still have to sell the underlying physical grain.
Options on futures contracts	Futures, foreign exchange, basis are able to be managed individually	No counterparty risk due to daily clearing of the contracts. No margin calls. Protects against negative price moves but can provide some exposure to positive moves if they eventuate. Liquid markets enable easy entry and exit from the marketplace. Price risk can be reduced without increasing production risk. Price determined by the market, and is completely transparent.	Options can be costly and require payment upfront. The value of options erode overtime as expiry approaches - depreciating asset. Perceived to be complicated by growers. Move in option value may not completely offset move in cash markets. You still have to sell the underlying physical grain.

### More information

[Oilseeds industry—delivering high quality products to local and global markets](#)

[Grain market lingo—what does it all mean?](#)

For more information and worked examples on how each pricing component affects canola price, refer to the GRDC publication: [Grain market lingo—what does it all mean?](#)

## SECTION 16

# Current projects

## Project Summaries of GRDC-supported projects in 2013-14

Each year the GRDC supports several hundred research and development, and capacity building projects.

In the interests of improving awareness of these investments among growers, advisers and other stakeholders, the GRDC has assembled summaries of projects active in 2013-14.

These summaries are written by our research partners as part of the Project Specification for each project, and are intended to communicate a useful summary of the research activities for each project investment.

The review expands our existing communication products where we summarise the R&D portfolio in publications such as the Five-year Strategic Research and Development Plan, the Annual Operating Plan, the Annual Report and the Growers Report.

GRDC's project portfolio is dynamic with projects concluding and new projects commencing on a regular basis. Project Summaries are proposed to become a regular publication, available to everyone from the GRDC website.

Projects are assembled by GRDC R&D investment Theme area, as shown in the PDF documents available. For each Theme a Table of Contents of what is contained in the full PDF is also provided, so users can see a list of project titles that are covered. The GRDC investment Theme areas are:

- [Meeting market requirements;](#)
- [Improving crop yield;](#)
- [Protecting your crop;](#)
- [Advancing profitable farming systems;](#)
- [Maintaining the resource base;](#) and
- [Building skills and capacity.](#)

The GRDC values the input and feedback it receives from its stakeholders and so would welcome your feedback on any aspect of this first review. This way we can continue to improve and extend this summary.

To send us your feedback please email us at [feedback@grdc.com.au](mailto:feedback@grdc.com.au)



## SECTION 17

# Key contacts

## James Clark - Chair

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Hunter Valley grower James brings extensive knowledge and experience in dryland and irrigated farming systems to the Northern Panel. He has been a member of the panel since 2005 and chairman since 2008. James says the panel's role is to capture and invest in growers' priorities and empower them to adopt new production gain opportunities. He strongly believes the grains industry needs to continue building RD&E capacity to ensure growers remain competitive.

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## Loretta Serafin - Deputy Chair

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Loretta has more than 12 years' experience as an agronomist in north-west NSW and currently works with the NSW DPI in Tamworth. She is a technical specialist for northern farming systems and provides expertise and support to growers, industry and agronomists in the production of summer crops. She has a passion for helping growers improve farm efficiency and sees her role as a conduit between advisers, growers and the GRDC to ensure that growers' needs are being met.

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## John Sheppard

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John, a panel member since 2006, has a wealth of practical farming experience and brings a wheat breeder's perspective to the panel. He views the panel as an opportunity for growers and professionals to work together to shape the future of the industry, and develop best management practices, as well as new varieties and products. He is particularly interested in genotype-by-environment interaction and the preservation of genetic resources.

M 0418 746 628

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## Jack Williamson

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Jack, a private agricultural consultant, runs a broadacre commodity production farm in Goondiwindi. Previous roles as a territory sales manager for Nufarm and as a commercial agronomist for McGregor Gourlay Agricultural Services have given Jack extensive farming systems knowledge, and diverse crop management and field work experience. Jack is a member of the Northern Grower Alliance (NGA) local consultative committee and Crop Consultants Australia, and was previously president of the MacIntyre Valley Cotton Field Day Committee. M 0438 907 820

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## Julianne Dixon

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Jules is manager of AMPS Research and a passionate agronomy consultant, communicator and industry advocate. Her role involves the development and expansion of self-funded, privatised research, development and extension. Her experience in project management and strategic development extends across all facets of an integrated grains business. She has an established network in eastern Australia and Western Australia, including researchers, leading growers, agronomy consultants and commercial industry. M 0429 494 067

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## Keith Harris

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Keith has served on the Northern Panel since 2011 and brings more than 30 years' experience in property management. Keith, based on the Liverpool Plains, NSW, consults to Romani Pastoral Company on the management of its historic holdings 'Windy Station' and 'Warrah', near Quirindi. He sees the main aim of the panel as representing growers and conducting research that provides growers with the tools they need to maximise property performance and minimise risk. M 0428 157 754

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## Kelly Becker

Based at Theodore, Queensland, Kelly is a certified mungbean and chickpea agronomist and also advises growers on wheat, corn and sorghum crop production. She has been involved with variety trials on a commercial basis and industry farm practice trials as an agronomist. She strives to be proactive within the industry and aims to assist growers to improve farming operations by ensuring that they are up to date with new practices and technology.

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## Penny Heuston

Penny brings extensive experience to her second term on the Northern Panel. She is committed to maximising the profitability of grain production in a low-rainfall environment through increased productivity and good risk management practices. She was principal in a farm advisory business in central west NSW and worked with growers across north-west NSW before joining Delta Agribusiness, where her main focus is the Warren, Nyngan, Tottenham and Gilgandra areas.

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## Rob Taylor

Rob is a grain grower at Macalister on Queensland's Darling Downs and farms 2300 hectares of maize, sorghum, wheat, barley and chickpeas on the Jimbour Plain. Rob is currently chair of the Agrifood Skills Initiative for the Western Downs Regional Council area. Rob views his role on the panel as taking information and feedback from growers, advisers and researchers to the GRDC to ensure research is targeted.

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## Will Martel

Central NSW grower Will has served on the Northern Panel since 2011. Previously he worked in a Quirindi grain trading company and with Brisbane-based Resource Consulting Services (RCS) where he benchmarked more than 400 growers across Australia on their performance, focusing on whole-farm profitability rather than individual enterprise gross margins. His main role on the panel is identifying investment areas that will enable growers to remain economic and environmentally sustainable.

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## Dr Stephen Thomas - GRDC Executive Manager Commercial

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Before joining the GRDC Steve held a senior position with the NSW Department of Primary Industries at Orange. In early 2009 he was appointed executive manager practices at the GRDC and in 2011 was appointed executive manager research programs. Currently Steve holds the position of executive manager commercial. He sees the GRDC's role is to interact with growers regularly to determine their needs and focus on the big picture across entire farming systems.

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## Sharon O'Keeffe - GRDC Northern Regional Manager

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Sharon is the Northern Regional Manager for the Grains Research Development Corporation (GRDC), based in Boggabri NSW. Sharon's role is to identify and oversee regional research, development and extension (RD&E) needs, manage the regional delivery of information and promote the GRDC's products and services. Her role strengthens links between GRDC panels, researchers, industry, advisors and growers. Sharon holds a Masters in Agriculture and a Bachelor of Rural Science (hons).

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E: [sharon.okeeffe@grdc.com.au](mailto:sharon.okeeffe@grdc.com.au)



## David Lord - Panel Support Officer

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David operates agricultural consultancy Lord Ag Consulting. For the past four years he has worked as a project officer for Independent Consultants Australia Network (ICAN), which has given him a good understanding of the issues growers are facing in the northern grains region. David's new role is Northern Panel and Regional Grower Services support officer.

M 0422 082 105

E [northernpanel@gmail.com](mailto:northernpanel@gmail.com)



## SECTION 18

# References

## A: Introduction

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- AEIGC. Australian grain note: canola. Australian Export Grains Innovation Centre, [http://www.australianoilseeds.com/oilseeds\\_industry/quality\\_of\\_australian\\_canola](http://www.australianoilseeds.com/oilseeds_industry/quality_of_australian_canola)
- Canola. Wikipedia, <http://en.wikipedia.org/wiki/Canola>
- CanolaInfo (2015) Where does canola come from? CanolaInfo, <http://www.canolainfo.org/canola/where.php>
- B Colton, T Potter. History. Australian Oilseeds Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0010/2701/Chapter\\_1\\_-\\_History.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0010/2701/Chapter_1_-_History.pdf)
- GRDC (2004) Canola nutrition in the northern region. GRDC Media Centre, Hot Topics, 28 April 2004, <http://www.grdc.com.au/Media-Centre/Hot-Topics/Canola-nutrition-in-the-northern-region>
- GRDC (2010) Growing hybrid canola. GRDC Canola Fact Sheet, August 2010, <https://www.grdc.com.au/~media/D4B939DB8790453FB2D6CBD04CA11B78.pdf>
- JF Holland, MJ Robertson, S Cawley, G Thomas, T Dale, R Bambach, B Cocks. Canola in the northern region: where are we up to? Australian Oilseeds Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0018/4446/CANOLA\\_IN\\_THE\\_NORTHERN\\_REGION\\_WHERE\\_ARE\\_WE\\_UP\\_TO.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0018/4446/CANOLA_IN_THE_NORTHERN_REGION_WHERE_ARE_WE_UP_TO.pdf)
- D McCaffrey (2009) Introduction. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)
- OGTR (2002) The biology and ecology of canola (*Brassica napus*). Office of the Gene Technology Regulator, [http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/canola-3/\\$FILE/brassica.pdf](http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/canola-3/$FILE/brassica.pdf)

## Section 1: Planning and paddock preparation

---

- C Borger, V Stewart, A Storrie. Double knockdown or 'double knock'. Department of Agriculture and Food Western Australia.
- R Daniel (2013) Weeds and resistance—considerations for awnless barnyard grass, *Chloris* spp. and fleabane management. Northern Grower Alliance, <http://www.nga.org.au/module/documents/download/225>
- 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)



- GRDC (2012) Make summer weed control a priority. Southern Region. Summer Fallow Management Fact Sheet, GRDC January 2012, <https://www.grdc.com.au/Downloads.ashx?q=-/media/8F16BE33A0DC4460B17317AA266F3FF4.pdf>
- GRDC (2015) Root-lesion nematodes. GRDC Tips and Tactics, February 2015, <http://www.grdc.com.au/TT-RootLesionNematodes>
- D Grey (1998) Water-use efficiency of canola in Victoria. 9th Australian Agronomy Conference, <http://www.regional.org.au/au/asa/1998/5/181grey.htm>
- B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf)
- P Hocking, R Norton, A Good (1999) Crop nutrition. Australian Oilseeds Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0013/2704/Chapter\\_4\\_-\\_Canola\\_Nutrition.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0013/2704/Chapter_4_-_Canola_Nutrition.pdf)
- 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)
- A Mead, K Hertel, C Cole, H Nicol. Constraints to canola yield in central and southern NSW. Australian Oilseeds Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0017/4580/Constraints\\_to\\_canola\\_yield\\_in\\_NSW.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0017/4580/Constraints_to_canola_yield_in_NSW.pdf)
- 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)
- 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, <https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Nitrogen-and-water-use-efficiency-of-canola-and-mustard-in-South-Australia>
- V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. GRDC Integrated Weed Management Hub, <http://www.grdc.com.au/GRDC-Booklet-WUJE>
- L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)
- M Widderick, H Wu. Fleabane. Department of Agriculture and Food Western Australia.

## Section 2: Pre-planting

---

- R Brill, L Jenkins, M Gardner (2014) Canola establishment; does size matter? GRDC Update Papers, 5 February 2014, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Canola-establishment-does-size-matter>
- 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-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)
- R Mailer (2009) Grain quality. In Canola best practice management guide for eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

- P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)
- L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, <http://www.nvtonline.com.au/wp-content/uploads/2013/03/Crop-Guide-Canola-Northern-NSW-Planting-Guide.pdf>

### Section 3: Planting

---

- BCG (2015) Calculating canola seeding rates. News article. Birchip Cropping Group, [http://www.bcg.org.au/cb\\_pages/news/The-time-for-sowing-canola-is-upon-us-making-it-important-to-revisit-our-understanding-on-seeding-rates-Getting-this-right.php](http://www.bcg.org.au/cb_pages/news/The-time-for-sowing-canola-is-upon-us-making-it-important-to-revisit-our-understanding-on-seeding-rates-Getting-this-right.php)
- R Brill, L Jenkins, M Gardner (2014) Canola establishment; does size matter? GRDC Update Papers, 5 February 2014, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Canola-establishment-does-size-matter>
- 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)
- 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, <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>
- P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)

### Section 4: Plant growth and physiology

---

- 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)
- 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, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Canola-growth-and-development-impact-of-time-of-sowing-TOS-and-seasonal-conditions>

### Section 5: Nutrition and fertiliser

---

- 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>
- R Daniel, M Gardner, A Mitchell, R Norton (2013) Canola nutrition: what were the benefits from N, S and P in 2012? GRDC Update Papers, 5 March 2013, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Canola-nutrition-what-were-the-benefits-from-N-S-and-P-in-2012>
- GRDC (2014) Canola nutrition in the northern region. GRDC Media Centre, 28 April 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-nutrition-in-the-northern-region>
- P Hocking, R Norton, A Good (1999) Crop nutrition. 10th International Rapeseed Congress, <http://www.regional.org.au/au/gcirc/canola/p-05.htm>

- R Norton, J Kirkegaard, J Angus, T Potter. Canola in rotations. Australian Oilseed Federation, [http://www.australianoilseeds.com/\\_data/assets/pdf\\_file/0014/2705/Chapter\\_5\\_-\\_Canola\\_in\\_Rotations.pdf](http://www.australianoilseeds.com/_data/assets/pdf_file/0014/2705/Chapter_5_-_Canola_in_Rotations.pdf)
- P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)
- L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)
- M Street (2011) Sulfur nutrition in canola—gypsum vs. sulphate of ammonia and application timing. GRDC Update Papers, 20 April 2011, <https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Sulfur-nutrition-in-canola-gypsum-vs-sulphate-of-ammonia-and-application-timing>
- M Street (2013) Sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 26 February 2013, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Sulfur-strategy-to-improve-profitability-in-canola-in-the-central-west-of-NSW>
- M Street (2014) Review of sulfur strategy to improve profitability in canola in the central west of NSW. GRDC Update Papers, 18 February 2014, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Review-of-sulfur-strategy>

## Section 6: Weed control

---

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

## Section 7: Insect control

---

- 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](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf)
- P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)
- M Miles, P Grundy, A Quade, R Lloyd (2015) Insect management in in fababeans and canola recent research. GRDC Update Papers 25 February 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Insect-management-in-fababeans-and-canola-recent-research>
- L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.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-pests-aphids-mites-millipedes-and-earwigs>

## Section 8: Nematodes

---

- B Burton (2015) Impact of crop varieties on RLN multiplication. GRDC Update Papers, 1 March 2015, <http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication>
- GRDC (2015) Root-lesion nematodes. GRDC Tips and Tactics, February 2015, <http://www.grdc.com.au/TT-RootLesionNematodes>
- L. Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

## Section 9: Diseases

---

- eXtensionAUS. Latest on canola disease—2015 GRDC Update Papers. eXtension, <http://www.extensionaus.com.au/2015-grdc-update-canola-papers/>
- GRDC (2014) Canola disease management in the northern region. GRDC Gound Cover, 21 March 2014, <http://grdc.com.au/Media-Centre/Hot-Topics/Canola-disease-management-in-the-northern-region>
- GRDC (2015) Blackleg management guide, autumn 2015. GRDC Fact Sheet, 29 April 2015, <http://www.grdc.com.au/GRDC-FS-BlacklegManagementGuide>
- P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf)
- L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)

## Section 11: Desiccation

---

- 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)

## Section 12: Harvest

---

- AOF (2014) Quality standards, technical information and typical analysis. 2014/15. Australian Oilseeds Federation, [http://www.graintrade.org.au/sites/default/files/file/Commodity%20Standards/AOF\\_Standards\\_201415\\_Final.pdf](http://www.graintrade.org.au/sites/default/files/file/Commodity%20Standards/AOF_Standards_201415_Final.pdf)
- 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)
- S Jeffrey (2014) Growers encourage to drive down weed seed banks at harvest. GRDC Media Centre, 29 October 2014, <http://grdc.com.au/Media-Centre/Media-News/North/2014/10/Growers-encouraged-to-drive-down-weed-seed-banks-at-harvest>
- 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/Canola-harvest-Is-direct-heading-a-serious-option>

- L Serafin, J Holland, R Bambach, D McCaffery (2005) Canola: northern NSW planting guide. NSW Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0016/148300/canola-northern-NSW-planting-guide.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf)
- 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/Harvest-options-for-canola-windrowing-timing-direct-heading-desiccation-with-RegloneTM-and-treatment-with-Pod-CealTM-effects-on-yield-and-oil-percentages>
- 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>
- M Street (2013) Harvesting canola in 2013—to windrow or direct head. GRDC Update Papers, 22 August 2013, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/08/Harvesting-canola-in-2013-to-windrow-or-direct-head>

## Section 13: Storage

---

- 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](http://www.australianoilseeds.com/_data/assets/pdf_file/0019/9082/MODULE_8_-_Safe_Storage_of_Canola_Philip_Burrill_-_V2_Sep_2012.pdf)
- GRDC (2014) Storing oilseeds. GRDC Stored Grain Information Hub, <http://storedgrain.com.au/storing-oilseeds/>
- GRDC (2014) Storing oilseeds. GRDC Grain Storage Fact Sheet, July 2014, [http://storedgrain.com.au/wp-content/uploads/2014/09/GSFS-9\\_Oil-Seed-July14.pdf](http://storedgrain.com.au/wp-content/uploads/2014/09/GSFS-9_Oil-Seed-July14.pdf)

## Section 14: Environmental issues

---

- DAFWA. Diagnosing waterlogging in canola. MyCrop. Department of Agriculture and Food Western Australia, <https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-canola>
- J Edwards, K Hertel (2011) Canola growth and development. PROCROP Series. New South Wales Department of Primary Industries, [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0004/516181/Procrop-canola-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf)
- 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, [http://www.grdc.com.au/uploads/documents/GRDC\\_Canola\\_Guide\\_All\\_1308091.pdf](http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf)
- C White (2000) Pulse and canola—frost identification. The Back Pocket Guide. Reprinted 2003. Department of Agriculture, Western Australia/GRDC, <https://www.grdc.com.au/Resources/Bookshop/2012/01/Pulse-Canola-Frost-Identification-The-Back-Pocket-Guide-GRDC046>

## Section 15: Marketing

---

- M Krause (2014) Farming the business. Sowing for your future. GRDC, <http://www.grdc.com.au/FarmingTheBusiness>