

Canola

**best practice management guide
for south-eastern Australia**



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ISBN 978-1-875477-85-2

Canola best practice management guide for south-eastern Australia
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Photo front cover: Brad Collis
Photo back cover: NSW DPI.



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In submitting this report, the researchers have agreed to the GRDC publishing this material in its edited form.

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Design and production:
Coretext, www.coretext.com.au

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1. Introduction

Don McCaffery, NSW DPI

Canola is the major broadleaf rotation crop in the grain producing regions of Australia. Since its introduction to Australia in the late 1960s, canola has grown into the major oilseeds industry, providing national economic benefits in employment, processing, manufacturing and exports.

This guide has been written by a team of experienced research and extension agronomists and industry specialists. It highlights best practice management for canola in south-eastern Australia (New South Wales, Victoria and South Australia). There are 16 chapters in total covering issues from selecting the right paddock, through to harvesting, marketing and oil quality. It is written for anyone involved in the canola industry; growers, agronomists, consultants, students, and others involved in the canola 'value chain'.

Many of the principles presented in the guide are similar across New South Wales, Victoria and South Australia. However, there will be specific regional practices which have not been fully discussed. Users of this guide should refer to alternative publications for more specific information on regional topics and for new technology and new practices as they are developed.

Canola belongs to the botanical family Brassicaceae, which also includes mustard, turnip, wild radish, cauliflower, cabbage and broccoli.

Prior to 1988, canola was known as rapeseed in Australia; the word rape coming from the Latin word 'rapum' meaning turnip.

Ancient civilisations in Asia and the Mediterranean cultivated rapeseed and used its oil, which produces a smokeless white light, for lighting.

It was recorded in India as early as 2000 BC and was grown in Europe in the 13th century. Canola was first grown in Canada in 1942 for use as a lubricant by ships of the Allied Navies.

In 1956 the first edible oil was extracted in Canada. Canola was trialled in Australia in the early 1960s and was first grown commercially in 1969, following the introduction of wheat delivery quotas.

The early varieties were all of Canadian origin and of poor quality by today's standards. The disease blackleg devastated crops in the early 1970s and so breeding programs were established to develop varieties with canola quality edible oil, improved resistance to blackleg, and higher yield potential.

Throughout the 1970s and early 1980s production remained reasonably static below 100,000 hectares.

By the late 1980s, production began to rise, with the release of higher yielding, high-quality, disease-resistant varieties with better agronomic characteristics. At the same

time, the value of canola in cropping rotations was being increasingly recognised.

The first herbicide-tolerant variety was released in 1993, incorporating triazine herbicide tolerance (TT). This allowed expansion into Western Australia and in parts of the eastern states where difficult-to-control weeds had previously limited canola growing. The release of improved TT varieties in the late 1990s resulted in significant sowings in all states, particularly Western Australia (Figure 1.1), and national production topped one million tonnes for the first time. 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 NSW and Victoria.

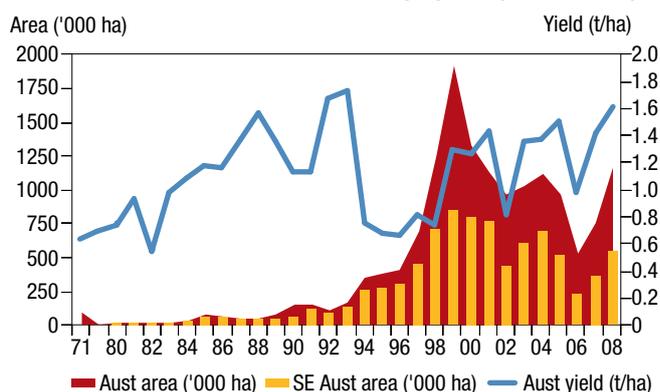
High oleic, low linolenic acid varieties were grown commercially for the first time in 1999. These varieties differ from conventional canola in the fatty acid profile of the oil which increases its uses, especially for deep frying.

Although the first canola hybrid was released in 1988, it has taken till the past few years for hybrids to be grown on a large scale. Canola breeding of the future will focus more on hybrids.

World canola production was about 57 million tonnes in 2008. The major producing countries 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. For the 10-year period

Figure 1.1 Harvested area of canola: Australia total and south-eastern Australia; and average yield (1971–2008)



SOURCE: ABARE estimates, Australian Oilseeds Federation (AOF) industry estimates

1998–2008, Australian canola production has averaged around 1.4 million tonnes per annum, ranging from 512,000 tonnes to 2.46 million tonnes. In 2009 this was worth about \$700 million (farm-gate value) to the Australian economy.

The total Australian oilseed crush capacity is about 1.1 million tonnes, with much of this in the eastern states. Between 550,000 and 650,000 tonnes of canola are 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 about two-thirds in the commercial food service sector. About 20–25 per cent of Australian canola oil is exported. Canola meal, the main by-product of crushed canola, is used as a high protein feed for intensive livestock, mainly in the pig, poultry and dairy industries.

The challenge for growers and the industry over the next few years will be to continue to improve productivity by adopting best practice management and being responsive to climate variability to ensure a stable supply of high quality oilseed for domestic and international markets. Figure 1.1 shows the variability in total Australian canola production and in the three south-eastern states (Victoria, New South Wales and South Australia).

2. Grain quality

Rod Mailer, NSW DPI

Rapeseed and canola both belong to the family Brassicaceae, genus *Brassica*. Canola was developed from rapeseed to produce an oilseed crop with improved nutritional composition. The aim was to produce a crop which had low levels of glucosinolates in the meal and low levels of erucic acid in the oil. Canola oil must contain less than two per cent erucic acid as a percentage of total fatty acids and the glucosinolate level in the meal must be less than 30 µmol of aliphatic glucosinolates per gram of meal. This equates to about 40 µmol total glucosinolates per gram of meal. Table 2.1 shows the typical chemical composition for canola.

Canola is used in salad dressings, margarines, and bottled oil. It is not ideal for deep frying due to the high level of polyunsaturated fatty acids which make it prone to oxidation. It is often blended with other oils, such as olive oil, to enhance its flavour and stability. Canola oil has the lowest level of saturated fatty acids and is second only to olive oil in its high level of monounsaturated oleic acid. Nutritionists agree that mono and polyunsaturated fatty acids are preferable to saturated animal and tropical plant fats (such as palm). Vegetable oils, including canola, are also recommended over animal fats for their lack of cholesterol.

Several types of canola are being developed for different end-uses. These include types with high levels of lauric, stearic or oleic acids, which can be used for detergents, solid margarines or shortening and cooking oils. Other modified canola types with petroselinic and ricinoleic acids may be used for plastics, lubricants and pharmaceuticals but not for human consumption. These new types will need to be given different names so that there is no confusion about the end-products.

HIGH OLEIC, LOW LINOLENIC ACID CANOLA (HOLL)

HOLL is one of the modified canola types discussed above. Traditional canola has about 62 per cent oleic acid, 20 per cent linoleic acid and nine per cent linolenic acid. Oleic acid is monounsaturated and relatively resistant to oxidation, while linoleic and linolenic acids are polyunsaturated. The more unsaturated the oil, the faster it will oxidise and become rancid.

Linolenic acid, in particular, with three double bonds in the carbon chain, oxidises quickly and therefore makes canola

oil unsuitable for high temperature applications such as deep frying.

To make canola more versatile and extend its applications for cooking, HOLL has been produced as an alternative form of canola with higher levels of monounsaturated oleic acid and lower levels of linoleic and linolenic acids. The first of these oils in Australia was marketed by Nutrihealth Pty Ltd under the trade name Monola™.

Monola™ looks like canola, and is managed in the same way, but its fatty acid profile has been changed through conventional plant breeding techniques. It is more expensive than canola oil but can be used for extended periods at high temperatures. Monola™ retains the low level of saturated fats of canola and has a good mix of polyunsaturated and monounsaturated fatty acids.

BRASSICA JUNCEA

Traditional canola cultivars have the characteristic chemical composition shown in Table 2.1, although this may vary slightly between cultivars and due to the influence of environmental conditions. In recent years, *Brassica juncea* has been bred to produce an oil with a fatty acid profile similar to that of canola with low erucic acid and a low concentration of glucosinolates in the meal.

B. juncea is also considered to have characteristics such as drought tolerance which will make the crop more suitable for marginal growing areas of canola. The oil will be used in the same way as *B. napus* canola and the two products may be blended.

Table 2.1 Typical quality parameters of canola, taken from the 2003 canola harvest in Australia*

| Quality parameter | Mean |
|--|-------|
| Oil content, per cent in whole seed @ 6% moisture | 41.5 |
| Protein content, per cent in oil-free meal @ 10% moisture (N x 6.25) | 39.2 |
| Total glucosinolates, µmol/g meal @ 6% moisture | 20.0 |
| Volumetric grain weights, kg/hL | 67.7 |
| Oleic acid content (C18:1), per cent in oil | 61.5 |
| Linoleic acid content (C18:2), per cent in oil | 20.2 |
| Linolenic acid content (C18:3), per cent in oil | 9.1 |
| Erucic acid content (C22:1), per cent in oil | 0.1 |
| Saturated fatty acid content, per cent in oil | 7.6 |
| Iodine value | 112.9 |

* Samples provided by bulk handling companies in NSW, Victoria and South Australia

Figure 2.1 Variation in average oil content in Australian canola 1998–2008

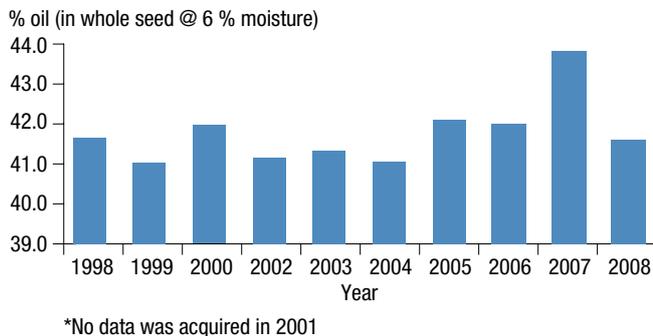
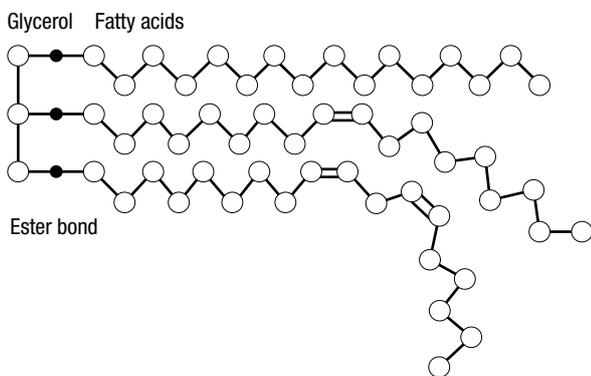


Figure 2.2 Structure of triacylglycerol molecule in vegetable oil



SOURCE: Meadow Lea

OIL CONTENT

Canola is grown primarily for oil and the value of the oil to the industry has been illustrated by the introduction of a bonus payment to growers for high oil content. A basis of 42 per cent oil content has been determined for the Australian industry and crops attract a bonus of 1.5 per cent for every percentage point above that level. A similar penalty rate applies for crops with oil content below 42 per cent. As a result, oil has been the major priority for breeding programs.

The amount of oil may vary between cultivars and, even more so, between environments and seasons (Figure 2.1). Plant breeders have worked for several years to improve oil content and increase total oil yield per hectare. There is a desire to develop drought resistant types which will produce reasonable oil content even under periods of water stress. The oil content in Australian crops can vary from as low as 30 per cent to slightly above 50 per cent.

Several studies have investigated the reasons for variation in oil content, including water and heat stress, sulfur and nitrogen availability, genotype and site effects. The range of low oil content across growing sites appears to relate strongly to areas of low rainfall and water stress.

Oil content is determined by solvent extraction (Goldfische) or by the use of near infrared (NIR) instruments which have

been calibrated against solvent extraction methods. The oil content is expressed at 6 per cent moisture basis. Although the moisture may vary depending on atmospheric humidity, six per cent approximates the average moisture content of canola delivered to grain terminals.

FATTY ACID PROFILES

Triacylglycerols

Edible oils are composed of fatty acids, which are contained in structures called triacylglycerols (sometimes called triglycerides). Each triacylglycerol contains three fatty acids. If fatty acids are liberated by enzymatic (lipase) activity they become free fatty acids which are undesirable products in the oil. As well as the three fatty acids, each oil unit contains a glycerol molecule (Figure 2.2). If one fatty acid is removed, it becomes a diacylglycerol (diglyceride) and if two are removed it is a monoglyceride.

Fatty acids

Common oilseeds contain 13 significant fatty acids and many more minor ones. Fatty acids are long chains of carbon atoms, which differ from each other by the number of carbons (from 14 to 24, Table 2.2). The other difference between fatty acids is the presence or absence of one or more double bonds between the carbon atoms (Figure 2.3). If there are no double bonds, the fatty acid is said to be saturated. If there is one double bond it is monounsaturated. Fatty acids that contain two or more double bonds are polyunsaturated.

The number of double bonds and the length of the chain determine the characteristics of the fatty acid. Saturated fatty acids have much higher melting points than unsaturated ones. For example, oleic acid with one double bond melts at 4°C, whereas saturated palmitic acid melts at 64°C.

Table 2.2 Typical fatty acid profile of canola oil

| Fatty acid | Trivial name | Percentage |
|----------------|--------------|------------|
| 14:0 | Myristic | 0.1 |
| 16:0 | Palmitic | 4.7 |
| 16:1 | Pamitoleic | 0.4 |
| 18:0 | Stearic | 2.4 |
| 18:1 | Oleic | 62.2 |
| 18:2 | Linoleic | 19.7 |
| 18:3 | Linolenic | 8.5 |
| 20:0 | Arachidic | 0.5 |
| 20:1 | Gadoleic | 1.0 |
| 22:0 | Behenic | 0.2 |
| 22:1 | Erucic | 0.1 |
| 24:0 | Lignoceric | 0.1 |
| 24:1 | Nervonic | 0.1 |
| Saturated fats | | 8.0 |
| Iodine value | | 111.0 |

ERUCIC ACID

The level of erucic acid has a major influence on the fatty acid content of canola. Erucic acid is a long carbon monounsaturated fatty acid which has been shown to be nutritionally undesirable in studies with poultry. On the basis of these tests the maximum limit for erucic acid was set for Canadian canola at two per cent. This was also the limit set in the UK for low erucic acid rapeseed (LEAR) and for European rapeseed (for example colza). Since the introduction of canola, plant breeding programs have continued to select for lower levels of erucic acid such that current cultivars are now generally less than 0.5 per cent.

IODINE VALUE

Iodine value is a measure of the degree of unsaturation in fats and oils expressed as the number of grams of iodine which will react with 100 g of fat. This can be determined by iodometric titration (Australian Oilseeds Federation (AOF) 4-2.20). However, it is generally determined by using the fatty acid profile determined by gas chromatography and then applying a simple formula to calculate iodine value. The higher the iodine level, the more unsaturated is the fat and the less stable it will be to oxidation. This would indicate which oils are more stable for cooking or for longer shelf life.

CHLOROPHYLL CONTENT

The green colour in plants is due to the pigment chlorophyll. As plants mature, the chlorophyll breaks down to alternative pigments such as pheophytins and the colour changes from green to yellow or brown. However, chlorophyll in canola seeds can be trapped in the seed cotyledons if the seed

is killed by sudden stress such as frost damage or water stress. The green colour is then preserved and will persist for years in intact seed.

When oil is extracted from green seeds the chlorophyll is transferred to the oil, resulting in green oil. Although green olive oil is acceptable, in canola oil, a green colour is considered to be undesirable. Removal of chlorophyll is both expensive and time consuming and therefore incurs a penalty at the point of sale of the seed to the bulk handling companies.

The AOF Technical and Quality Standards has set a maximum standard for delivered seed of two 'distinctly green' seeds per 100. This is determined by taking 100 seeds applied to masking tape, crushing them with a paint roller and counting the seeds with green cotyledons. This test is recognised as an indicator of chlorophyll content although it is not very accurate. A more accurate measure is to extract the chlorophyll from seeds and measure it with a spectrophotometer (AOF method 4-1.20) or by high performance liquid chromatography.

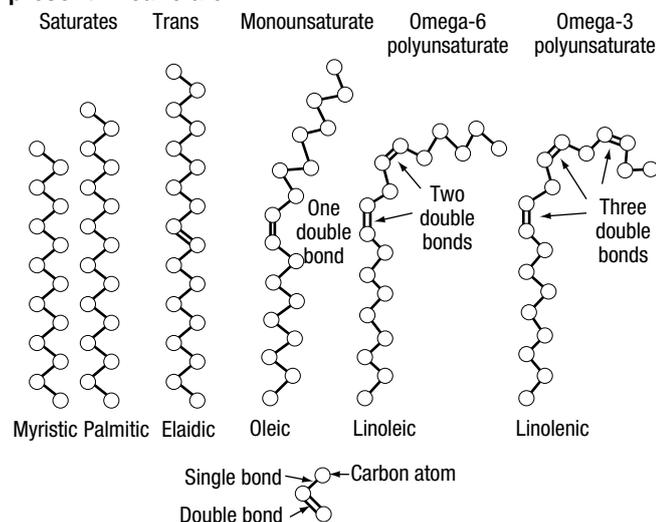
It is difficult to predict the final colour of extracted oil by measuring chlorophyll in the seed. Chlorophyll changes under the influence of heat and light and it is likely that the colour will be less intense after processing the seed. However, a high reading of chlorophyll in the seed should indicate to the processor that chlorophyll and pheophytins will be present in the oil.

CANOLA MEAL

The seed residue remaining after the oil has been removed is referred to as the meal or flour. This by-product of canola is relatively high in protein, vitamins and minerals and is commonly used for animal feed.

Canola has a good amino acid profile and mid range fibre content. It is generally considered that the by-pass protein of canola is suitable for ruminants although some nutritional consultants consider that it lacks rumen degradable protein. Meal quality, including moisture, crude protein and oil content, varies over successive years and in different environments. Table 2.3 includes data on canola meal nutrient composition. Processing conditions may further influence the range in the final quality of these parameters.

Figure 2.3 Structure of the common fatty acids present in canola oil



SOURCE: Meadow Lea

PROTEIN

The protein content of canola meal, like the oil content, varies between sites, cultivars and seasons (Figure 2.4). Protein content is determined by a method of combustion referred to as the Dumas technique. This method is commonly performed using a Leco nitrogen analyser although other instruments are also available. The protein content is expressed on a 10 per cent moisture basis, i.e. for seed at six per cent moisture and 42 per cent oil, when the oil is removed, the meal will contain 10 per cent moisture.

The standard for meal protein is a minimum of 35 per cent at 10 per cent moisture. As oil and protein content are

inversely proportional, if oil is low, meal protein will be higher, and vice versa.

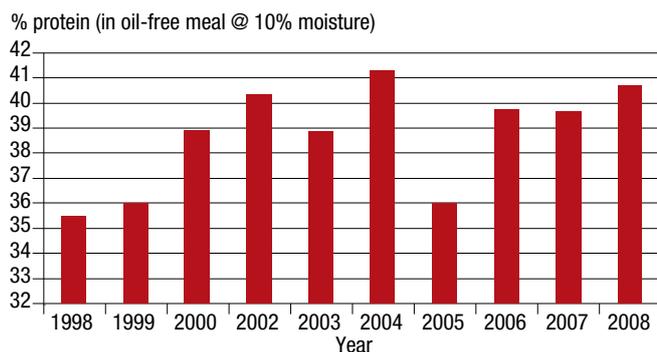
A comparison of Figures 2.1 and 2.4 highlights the relationship between oil content and protein content of the meal. Growing conditions that favour high oil generally result in low protein in the meal. The high oil content in 1996 resulted in low protein in the same year. In the past decade, breeders have changed their priorities to select cultivars that are high in both oil and protein. As a result, protein contents have been increasing despite relatively consistent oil contents, as shown in Figure 2.4.

Table 2.3 Canola meal nutrient composition tables

| Component | Composition |
|--------------------------------|---|
| Moisture (%) | 10.0 |
| Crude protein (N x 6.25; %) | 35.0 |
| Rumen bypass protein (%) | 35.0 |
| Oil (%) | 3.5 |
| Linoleic acid (%) | 0.6 |
| Ash (%) | 6.1 |
| Sugars (%) | 8.0 |
| Starch (%) | 5.2 |
| Cellulose (%) | 4.6 |
| Oligosaccharides | 2.3 |
| Non-starch polysaccharides (%) | 16.1 |
| Soluble NSPs (%) | 1.4 |
| Insoluble NSPs (%) | 14.7 |
| Crude fibre (%) | 12.0 |
| Acid detergent fibre (%) | 17.2 |
| Neutral detergent fibre (%) | 21.2 |
| Total dietary fibre (%) | 33.0 |
| Tannins (%) | 1.5 |
| Sinapine (%) | 1.0 |
| Phytic acid (%) | 4.0 |
| Glucosinolates (µmoles/g) | 16 |
| Bulk density, mash | 16 kg/ft ³ , 565 kg/m ³ |
| Bulk density, pellets | 19 kg/ft ³ , 670 kg/m ³ |

SOURCE: Canola Council of Canada, Feed Industry Guide

Figure 2.4 Average protein content of Australian canola 1998–2008



* No data was acquired in 2001

Proteins are made up of amino acids and the proportions of different amino acids determine the value of the meal for particular applications. The high level of sulfur containing amino acids makes canola meal particularly suitable for poultry diets. The dairy industries also utilise protein meal.

GLUCOSINOLATES

Glucosinolates are chemical compounds present in the meal or flour portion of canola as well as in the green plant material. They are responsible for the crop's cabbage smell and the odour when canola is crushed.

Glucosinolates are a problem for stock fed with canola meal because, in high concentrations, they can affect the animals' thyroid activity and cause goitre. In poultry they have been linked to other nutritional disorders. At current levels, glucosinolates do not appear to cause any problems in feed rations. However, canola breeders are encouraged to further reduce concentrations to enable a greater proportion of meal to be included in animal rations.

Early rapeseed cultivars introduced to Australia, and some subsequent Australian lines, had glucosinolate levels above 100 µmoles/g of oil free meal and well above canola standards. Through plant breeding, today's cultivars have very low levels of glucosinolate, generally less than 20 µmoles/g meal. Glucosinolate levels vary with growing conditions and, in particular, increase with water stress.

VOLUMETRIC GRAIN WEIGHTS

Grain weight is an indicator of grain quality. Grain that has been stressed during maturity will have low grain weight, generally also reflecting low oil contents. Frost or insect damage may also result in low grain weights. Damaged seed may be high in free fatty acids as well as low in oil content. Volumetric grain weights are measured using a Franklin chondrometer and reported as lbs/bushel and kg/hectolitre. In 2003, grain weights for samples provided to NSW DPI from bulk handling companies averaged 67.7 kg/hl.

3. The canola plant and how it grows

Trent Potter, SARDI

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.

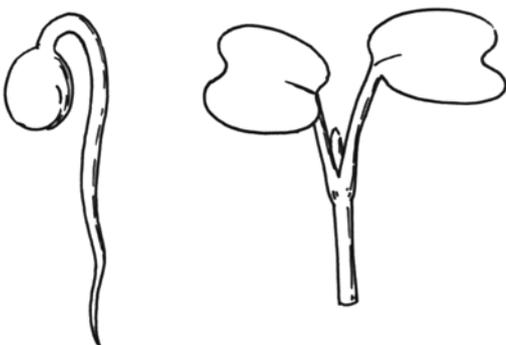
The 10 oilseed rape types grown throughout the world are mainly annual and biennial variants of *B. napus* and *B. campestris*. In Canada, both species are of considerable importance; *B. napus* is the dominant species in Europe and the Indian subcontinent. Each species has an optimum set of environmental 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 the development of a stage of the plant. However, the beginning of each stage is not dependent on the preceding stage being finished (that is, growth stages 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 Zadoks code for wheat growth stages.

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, in the process shedding the seed coat. When exposed to light, the cotyledons part and become green.

Figure 3.1 Canola germination and emergence, stage 0–0.8



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. Early leaves may drop from the base of the stem before leaf production is complete.

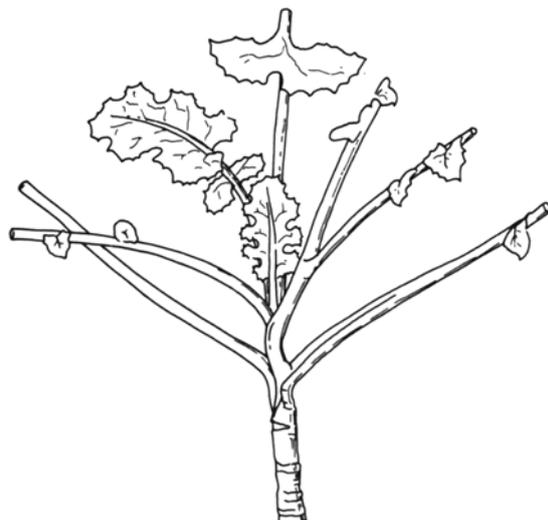
Figure 3.2 Canola leaf production, stage 1



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. A leaf is attached to the stem at each node. Each internode is counted. A well grown canola plant normally produces 15–20 internodes.

Figure 3.3 Stem elongation, stage 2



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

Initially flower buds remain enclosed during early stem elongation and 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. 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, signalling the yellowing bud stage.

Figure 3.4 Canola flower bud development, stage 3



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 3.5 Flowering, stage 4



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 which have extended to more than 2 cm long.

Figure 3.6 Pod development, stage 5



Seed development (stage 6 [6.1–6.9])

Seed development is also seen on the lowest one third of branches on the main stem. 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

Figure 3.7 Seed development, stage 6



Figure 3.8 Seed pods

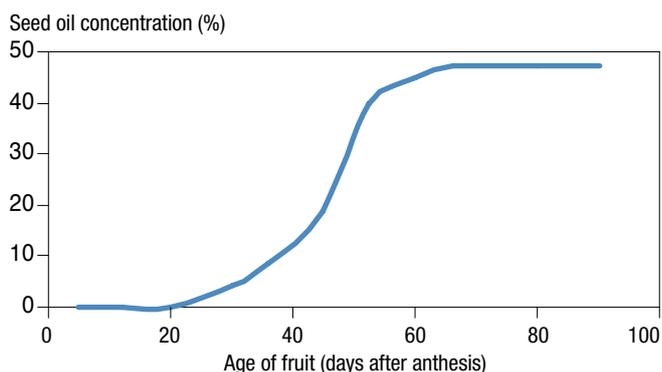


Seed oil concentration in Australian crops increases through seed development following an 'S' curve pattern, which starts 20 days after flowering and reaches a plateau about 60 days after flowering, the time when seed dry weight is about 70 per cent of its final value (Figure 3.9). Final seed oil concentrations usually vary between 30 and 50 per cent (as received). In general, high temperatures during grain filling, terminal water stress, and high nitrogen supply depress final seed oil concentration. Variety has a significant impact, with triazine tolerant varieties typically having lower oil concentrations than conventional varieties, due to 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 is the stage when the seeds have reached their maximum dry weight and the crop can be windrowed. At this time 40–60 per cent of seeds have started to change from green to their mature colour (growth stage 6.4 to 6.5). At this time, seed moisture content is 35–40 per cent and most seeds are firm enough to roll between the thumb and forefinger without being squashed. It is a period of rapid change as 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 per cent for each day too early, due to incomplete seed development. Oil content will also be reduced.

Canola can be harvested when the moisture content of mature seed is eight per cent.

Figure 3.9 Seed oil concentration in Australian crops increases through seed development and reaches a plateau about 60 days after flowering



SOURCE: P. Hocking and L. Mason

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 the most damaging frosts occur when pods are small. Pods affected at this time have a green to yellowish discolouration, then shrivel and eventually drop off. Pods affected later may appear blistered on the outside of the pod and usually have missing seeds (see photo).

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; 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.

Severe moisture stress during pod filling results in seeds being underdeveloped and small.

PHOTO: D. McCAFFERY, NSW DPI



Hail damage may penetrate through the pod wall and affect seed development.

PHOTO: D. McCAFFERY, NSW DPI



4. Crop rotation and paddock selection

Paul Parker, NSW DPI

CROP ROTATION

Any crop rotation should be based on sound principles but remain flexible to allow for variations in the seasonal break, commodity prices and changing circumstances. What happens in one paddock is linked to activities across the farm, such as balancing grazing demands or spreading commodity and financial risk.

It is also important that economic returns from a canola crop are considered for the full term of the cropping rotation and not just on an individual crop basis. Research has shown that the benefits from growing canola can flow on to subsequent crops for two or three years after the initial canola crop. While preparing a simple gross margin on the canola crop will give a guide to the input costs and potential returns, it does not take longer-term benefits into consideration nor does it spread some long-term costs – such as the application of lime – over several crops.

The benefits of having canola in the rotation include:

- reduced incidence of diseases such as take-all, crown rot and common root rot in winter cereal crops grown after canola through the removal of their grass weed hosts. Numerous studies have demonstrated an average yield increase of 20 per cent in wheat crops grown after canola

compared to wheat grown after wheat. If disease levels are high, the yield increase may be significantly more than 20 per cent;

- canola leaves a more friable topsoil which is well suited to the direct drilling of the following cereal crop;
- rotation of herbicide groups reduces the potential for herbicide resistance to develop and for herbicide residues to accumulate in the soil. It also results in better longer-term control of weeds;
- spreads the time available to use machinery and labour because of canola's earlier sowing and harvest timing relative to cereals; and
- provides a range of grain delivery and marketing options. Selling grain off the header at harvest can give growers an early cashflow and reduce on-farm storage demand, while storing or warehousing canola can spread price risk and provide marketing flexibility.

These benefits can result in a more profitable and sustainable farming operation by:

- consistently producing higher yielding, more profitable cereal crops;
- more diversified income from growing a range of crop types;
- an alternative to cereals with an established and stable marketing system;
- improved weed control and herbicide resistance management;



Canola leaves the soil friable for direct drilling a cereal crop, saving fuel and valuable soil carbon.

PHOTO: D. McCAFFERY, NSW DPI

- enabling more efficient use of machinery and labour because of a broader spread of crop preparation, sowing and harvesting operations;
- reduced competition with wheat and other grains for on-farm grain storage as canola is not usually stored on farm; and
- providing a range of marketing options to manage price risk.

While there is no single 'best' cropping rotation, the most efficient rotation is one where disease, weeds and the risk of production failure can be minimised while fertility and profitability are maximised. The most benefit from rotating crops will be achieved by avoiding growing, where practical, a cereal following a cereal crop, or a broadleaf crop following another broadleaf crop.

Although many growers in southern New South Wales have successfully grown canola in a canola-wheat-canola-wheat rotation, the unpredictability of returns from canola due to seasonal conditions and disease has made this a more risky rotation and much less common than a rotation that contains about 25–30 per cent break crops, consisting primarily of canola.

A good rotation could incorporate the following sequence of crops:

- legume pasture (for example medic, clover or lucerne) – to restore nitrogen and build up soil organic matter;
- canola – to use some of the nitrogen fixed and to break cereal root disease cycles;
- cereal crop (for example wheat) – to provide an alternative crop type, utilise more nitrogen and provide alternative options for weed control;
- pulse crop (for example lupins, field peas) – to restore nitrogen and provide a disease break;
- cereal crop (for example wheat) – exploit residual fertility and provide options for weed control prior to pasture; and
- undersown cereal crop (for example barley) – to assist with the rapid establishment of the next pasture phase.

Although the yield potential of canola is usually higher after a legume dominant pasture phase, it can be successfully grown later in the rotation with adequate nitrogen inputs.

In high rainfall, longer season districts, yields in excess of 3.5 t/ha have been achieved where canola has been sown after a long-term legume pasture.

Canola has also been used as a cover crop for the establishment of a pasture at the end of a cropping rotation. Although this can be very successful, it means that one of the major benefits of using canola in the rotation – to maximise the yield potential of a following cereal crop – is lost. However, this could be justified in some situations, for example if adverse seasonal conditions such as drought have affected the planned crop sequence.

Be careful when growing canola on alkaline soils that have been heavily cropped without much fertiliser. Fertilisers containing phosphorus, zinc, nitrogen and sulfur will probably be needed much earlier in the rotation than if only cereals and pulses were grown.

Canola in summer crop rotations

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. This is due to the depletion of soil micro-organisms called arbuscular mycorrhizal fungi (previously known as VAM fungi). They are beneficial soil fungi that assist the uptake of phosphorus and zinc, which would otherwise be unavailable to the crop. Canola does not need these fungi to help it take up phosphorus and zinc 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 like sorghum and cotton that depend on arbuscular mycorrhizal fungi.

Biofumigation

Biofumigation is the chemical effect that some *Brassica* species have on soil micro-organisms in a rotation cropping system. It is thought the breakdown compounds from glucosinolates in decaying roots, called isothiocyanates, suppress soil-borne pathogens which cause cereal root diseases such as take-all and crown rot. However, research has found no biofumigation effect on cereal root diseases from a previous crop of canola, with most of the increased cereal yield due to the removal of the grass weed hosts of the disease.

Paddock Selection

As well as early preparation and good crop management, success with canola depends on careful paddock selection.

The four major considerations when selecting a paddock



to grow canola in rotation with other crops are:

- soil type;
- potential disease problems;
- previous herbicide use; and
- broadleaf weeds.

Choosing more reliable and weed-free paddocks is the best option.

When coming out of a pasture phase, start paddock selection and preparation at least 12 months before sowing to ensure that potential problems are addressed. It is better to soil test during the previous winter and initiate pasture and fallow management early enough to effectively control broadleaf and grass weeds and establishment pests such as redlegged earth mites.

In a continuous cropping rotation, a fallow, hay or green manure crop can reduce the weed burden. Alternatively, use competitive crops such as wheat or barley before canola to assist in the reduction of weed seed numbers. If a pulse is the prior crop, strategic weed control can have significant benefits, especially where problem weeds are difficult to control in canola.

Soil types

Canola generally grows best in fertile soils. In mixed livestock and cropping areas, it is ideally grown immediately after pasture.

High yields can also be obtained after a fallow or a cereal, provided adequate nitrogen fertiliser is used. Canola will not perform well in low fertility paddocks. Generally the best wheat growing soils will produce the best canola crops. Paddocks with a uniform soil type will permit a more even sowing depth, seedling emergence and more even crop ripening.

Avoid growing canola where there are the following problems:

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 if it is a sodic clay that disperses after wetting. The use of gypsum and/or stubble retention on hard setting sodic clay soils can improve seedling emergence and early growth.

Acid soils

Canola is more susceptible to low pH and aluminium toxicity than most other crops. If you expect the pH_{Ca} to be less than 5.0, have the canola paddock soil tested in the previous winter. If acidic subsoil is suspected, take split samples of 0–10 and 10–20 cm depths. Where a pH_{Ca} level of less than 4.7 is combined with an exchangeable aluminium level of three per cent or more, do not grow canola before obtaining specific advice. Other good indicators of possible acidity problems are poor growth in barley and lucerne or where oats and triticale grow better than wheat. Consider using lime when the topsoil pH_{Ca} drops below 5.0. For more information see Chapter 7 on nutrition (page 31).



Soil constraints can severely restrict rooting and hence water and nutrient uptake. The tap root growing horizontally is commonly referred to as 'J rooting'.

PHOTO: J. KIRKEGAARD, CSIRO PLANT INDUSTRY



To assist in managing blackleg, growers may sow a number of canola crops together – this will help maximise distance between the current year's crop and last year's stubble.

PHOTO: D. McCAFFERY, NSW DPI

Waterlogging

Soils become waterlogged when rainfall exceeds the infiltration capacity of the soil. It is most common in soils with a sodic clay subsoil of low permeability. However, hardpans can also induce waterlogging. The presence of 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. Using raised beds has been a successful strategy for reducing the impact of waterlogging in high-rainfall areas of south-western Victoria and Western Australia.

Potential disease problems

Blackleg is the major disease of canola in Australia and can significantly reduce yields, especially in higher rainfall districts (see p. 59).

Research has shown that 95–99 per cent of blackleg spores originate from the previous year's canola stubble. Spores can travel more than one kilometre 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 the disease pressure. Where possible, a buffer distance of 500 metres 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 only provides limited benefits in reducing the disease level as not all the infected stubble or old roots are destroyed. Growing blackleg resistant

varieties in combination with an appropriate fungicide treatment, if necessary, is the best way of minimising yield losses.

Careful paddock selection can also assist in reducing the impact of another potentially serious canola disease, sclerotinia stem rot (*S. sclerotiorum*). Sclerotinia 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, capeweed and Paterson's curse. Growing canola after any of these crops or in paddocks that have had heavy populations of these weeds can increase the risk of sclerotinia stem rot, especially when canola is grown under irrigation or in higher rainfall areas.

Previous herbicide use

Canola is particularly susceptible to a range of residual herbicides. Under certain seasonal conditions (dry) or in particular soils (alkaline) residues from a herbicide applied to a previous pulse or cereal crop can persist into the next cropping season. For example, the sulfonylurea group (for example chlorsulfuron, sulfosulfuron) used in cereal crops have a canola plant-back period of between 24 and 30 months. Similarly, some herbicides registered in pulse crops can have plant-back periods ranging from nine months (simazine), 24 months (flumetsulam) to 34 months (imazethapyr). The use of these herbicides can therefore restrict crop options and prevent canola being sown for up to three 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.

Weeds

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

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

- charlock (*Sinapis arvensis*);
- wild radish (*Raphanus raphanistrum*);
- wild or Mediterranean turnip (*Brassica tournefortii*); and
- wild cabbage or Hare's ear (*Conringa orientalis*).

Each of these weeds has a similar seed size to canola and cannot be easily removed from canola grain samples. As they contain approximately 50 times more erucic acid in the oil and about 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 are usually removed during harvesting. These include shepherd's purse (*Capsella bursa pastoris*), turnip weed (*Rapistrum rugosum*), muskweed (*Myagrum perfoliatum*) and the mustards (*Sisymbrium* spp.). These weeds reduce yield through competition, for example, shepherd's purse may be a problem weed of canola grown after a pasture phase.

If sowing canola into paddocks where any of these *Brassica* weeds are present, select an appropriate herbicide resistant variety. Growing triazine tolerant (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.

Canola sown as a dual-purpose crop can be grazed by a range of stock classes.

PHOTO: N. COUTANCHE, LACHLAN FERTILISERS



John Kirkegaard, CSIRO

DUAL-PURPOSE CANOLA (GRAZING AND GRAIN)

The concept of using canola for grazing and grain (dual-purpose) has been tested in experiments and on commercial farms in southern Australia since 2004 with excellent results.

Dual-purpose canola can increase total crop profitability on mixed farms by providing a source of high-value fodder during the winter feed-gap as well as a high value grain. It provides an alternative to dual-purpose winter wheat where *Wheat streak mosaic virus* has reduced the viability of this option and eases grazing pressure on pastures in winter.

Spring canola types can be sown two or three weeks earlier than normal (early-mid April). Early sowing can result in significant biomass (2–3 t/ha) by mid-winter to fill the winter feed gap. Although any canola variety can be used as a dual-purpose crop, mid to mid-late maturing types for the area will be best suited to an earlier sowing. Other considerations in varietal choice include:

1. the higher biomass production of hybrids compared with conventional or triazine tolerant varieties of similar maturity;
2. weed control options for the variety in relation to chemical withholding periods for grazing; and
3. grazing tends to increase blackleg severity so choose a variety with a high blackleg resistance rating (MR+), especially in high-risk situations.

Canola is palatable to livestock and has high feed value. In 20 separate grazed paddock-scale experiments sheep liveweight gains of 210–300 g/day were achieved with no animal health problems. At least 600 to 800 dry sheep equivalent (DSE) x grazing days/ha were achieved in most cases.

Grazing can commence from the six to eight-leaf stage when plants are well anchored (biomass > 1.5 t/ha) and continue until buds have elongated no more than 10 cm. Grazing later than this growth stage will delay flowering and potentially reduce yield and oil content. Crops with good grazing management can yield the same as un-grazed grain-only crops sown at the standard time (early May) depending on seasonal conditions for re-growth. Topdressing nitrogen after stock removal will maximise regrowth and yield potential.

The following guidelines for growing dual-purpose canola have proven successful:

- select a variety with medium-late maturity for the area, with good blackleg resistance (MR–R) and high vigour – consider herbicide withholding periods in this decision;
- sow in a paddock planned for canola up to four weeks earlier than normal if the opportunity arises (early to mid April) into adequate moisture to ensure even germination;
- commence grazing when plants are well anchored and there is sufficient biomass for grazing, usually at or after the six to eight-leaf stage;



Canola crop showing excellent recovery after grazing.

PHOTO: N. COUTANCHE, LACHLAN FERTILISERS

- ensure sufficient stock are available to capitalise on the high-value forage. Plan on around 600–800 DSE x grazing days/ha (for example, four weeks @ 25 DSE/ ha) and graze evenly for uniform maturity. Few animal health issues have been reported but use the section on “Minimising stock health risks” (Chapter 11) as a guideline;
- remove stock before stem elongation (bolting) to avoid a yield or oil penalty, or graze elongated crops lightly to avoid stock removing the main stem. Heavy or late grazing delays flowering and increases the risk of yield and oil penalties;
- assess the potential yield penalty of grazing against the grazing value and overall system benefits including pasture spelling and break crop benefits in evaluating the concept; and
- consult local agronomists for the latest recommendations and try small areas first.

5. Crop establishment

Leigh Jenkins, NSW DPI

Successful crop establishment is crucial to achieve maximum potential yield. Timeliness of sowing is the most important factor followed by an evenly established and uniform plant stand. Canola has a small seed and should ideally be sown into good moisture at an even and shallow depth.

Successful establishment is linked to crop profitability through:

- higher yields, from quick and uniformly emerging seedlings;
- maximum yields are achieved from crops which have at least 90 per cent ground cover prior to bud appearance;
- improving the ability of canola to withstand insect attack and compete with weeds in the first six weeks;
- even growth and maturity, allowing timely in-crop management decisions such as weed control, fertiliser applications and insect control; and
- more even ripening improving the timing of windrowing and harvest.

PRE-SOWING MANAGEMENT

Soil preparation

To ensure good seed to soil contact, place the seed into a seedbed that is firm, level and moist near the surface. Avoid sowing into loose or 'fluffy' soil. If adequate seed soil contact does not occur, the small canola seed cannot absorb enough moisture from the loose drying soil, resulting in a reduced and/or staggered germination (often occurring over six weeks). Heavy stubble cover on the surface can reduce emergence and early vigour. However, some surface cover is desirable to prevent wind and water erosion and sand blasting on sandy soils.

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.

Generally, pre-sowing operations for dryland crops should be finalised by the end of March or early April in low-rainfall

A uniformly established crop is the foundation for a potential high yield.
PHOTO: F. PRITCHARD, ICF



Crop establishment



Keep as much stubble away from the planting row as possible.

PHOTO: S. BRUCE and J. KIRKEGAARD, CSIRO



Excellent establishment using no-till in South Australia.

PHOTO: SARDI

areas, allowing sowing to commence with the first opportunity rain in early to mid-April. In medium rainfall areas, paddocks should ideally be prepared by mid April. In cooler, long-season, high rainfall districts prepare paddocks by early May.

The definition of low, medium and high-rainfall areas varies between states, as the climate ranges from Mediterranean (winter dominant rainfall) in South Australia through to temperate in southern and central NSW to a summer dominant rainfall pattern in northern NSW.

Sowing equipment

Canola can be established successfully using a wide variety of seeders, from those suited to cultivated seedbeds through to full no-till implements. Tined or disc seeders can be used, depending on factors such as the farming system, soil types, stubble loads, and the grower's personal preferences.

Attention to weed control during the preceding crop rotation is needed to provide weed-free and problem-free sowing. Substituting cultivations before sowing with one or more knockdown herbicides enables better moisture retention and sowing with minimum soil disturbance.

Stubble management

Stubble retention plays a significant role in most modern cropping systems, with many benefits including reduced risk of erosion, maintaining organic matter, increased water infiltration and reduced evaporation.

In the lower rainfall areas of Victoria and South Australia, stubble retention appears to have few negative impacts where stubble loads are less than 4 t/ha. However, in the higher rainfall areas of southern NSW and Victoria, stubble loads of 7–10 t/ha can cause physical problems during sowing, as low summer rainfall limits stubble decomposition. Research has consistently demonstrated that increasing stubble loads (particularly over the seed row), can reduce emergence, plant establishment, growth and, in some instances, yield. On average, a 5 t/ha stubble can reduce emergence by 25 per cent and plant establishment by 33 per cent.

When sowing into stubble, ensure that stubble is pushed away from the sowing row (into the inter-row spaces) to reduce the problems causing poor early crop growth but still maintaining the benefits of stubble cover.

SEED QUALITY

Desirable seed quality characteristics

Seed quality will determine the likelihood of producing a strong healthy seedling and sufficient plant population for a potential high yield. It is usually measured by germination percentage but seedling vigour is equally important.

Under quality assurance (QA) schemes, seed companies supply seed which has been tested for germination and purity. Seed crops are generally produced under irrigation or in high-rainfall zones to maximise seed size and quality. They are grown in isolation from other canola crops to minimise genetic drift and guarantee genetic purity.

Minimum guaranteed standards for canola seed include:

- minimum germination percentage of 85 per cent;
- minimum purity of 99.8 per cent;
- first generation seed;
- tested free of wild radish and other noxious weed seeds; and
- tested free of sclerotes (carrier of sclerotinia stem rot)

Seed source and purity can have a negative impact on subsequent canola crops if seed is retained and grown over a number of years. Canola is a crop which self-pollinates and outcrosses. As a result of out-crossing of individual plants with different characteristics, the characteristics of a variety can 'drift' slightly from one generation to the next. In most instances, the characteristics for which the variety was originally selected tend to regress and the undesirable characteristics tend to become more prominent.

Varieties that possess the Clearfield® trait of herbicide tolerance are also subject to this process of 'genetic drift' which means there is no guarantee that farmer-retained Clearfield® varieties will demonstrate the same level of herbicide tolerance as displayed by quality-assured seed.

Use of grower-retained seed

The use of farmer-grown seed is not recommended as it increases the potential for establishment failure and reduced yield and oil content. Studies in Australia and Canada have shown that germination and vigour can be reduced from seed harvested and retained by growers of commercial



Certified seed is your guarantee of quality.

PHOTO: D. McCAFFERY, NSW DPI

crops not grown specifically for seed. Recent studies in Canada have also shown that farmer-saved hybrid seed resulted in a yield reduction of up to 13 per cent, amounting to a significant loss of income.

Canola seed is difficult to clean and contamination from weed seeds helps weeds spread from paddock to paddock across a farm. Also, several diseases of canola are known to be either seed-borne, for example, alternaria leaf spot, or can be carried over with the seed, for example, the sclerotia of sclerotinia stem rot.

Trials conducted around Australia in the mid 1990s showed that it can be false economy for canola growers to retain their own seed for planting. The added costs of cleaning, grading and treating seed, combined with potential reductions in yield and less consistent yield when poor quality seed is used, can result in lower financial returns. As well, successive generations of farmer-retained seed lead to significant variability in several key agronomic traits, such as oil content, plant height, days to flowering and blackleg disease resistance. If you want to retain your own seed, make sure it comes from a weed-free part of your farm and do a germination and vigour test before sowing to ensure that seed quality is good. Do not retain seed from crops that have experienced drought, frost, waterlogging, insect or disease stress during the flowering and pod development growth stages.

Where possible, purchase certified seed or company quality assured seed to ensure minimum germination standards and varietal purity. Inadvertently sowing the wrong variety can have disastrous consequences, particularly where herbicide-tolerant varieties are being used. To avoid the introduction of undesirable weed seeds ask for a copy of the full purity analysis for each line of seed and check it thoroughly. All Seed Industry Association of Australia (SIAA) members and reputable merchants will be able to supply these.

Keep seed labels with a small quantity of seed in a cool dry place. If any problems arise after sowing discuss with an adviser or seed company representative.

Under Plant Breeder's Rights (PBR) legislation, farmer-retained seed, although not recommended, is legal, provided the seed is only used for the purpose of sowing and harvesting subsequent crops. Over-the-fence sales and

trade in PBR protected varieties are illegal, and penalties for infringements are significant.

Pre-sowing seed and fertiliser treatments

Insecticide treatments

Imidacloprid products, such as Gaucho® 600 or Picus, are registered for use on canola seed for protection against redlegged earth mite (RLEM), blue oat mite (BOM) 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 three to four 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 only be applied by registered operators. All seed companies can supply seed pre-treated with imidacloprid.

Fipronil, for example Cosmos®, is registered for control of RLEM in canola. It should be used as part of an integrated pest management (IPM) approach to RLEM management. Fipronil can be applied either on-farm, or off-farm by a contractor or seed company.

Fungicide treatments

Fluquinconazole products, for example 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 treated seed is sown in the season of treatment.

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

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

SOWING METHOD

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

Seed placement

In marginal rainfall areas, drilling seed to a pre-determined depth is the only sowing method recommended.

On heavy clay soils, growers have had success with moisture seeking points, press wheels, rubber tyred rollers and trailing cultipackers. Deep furrow planting, which allows sowing into subsurface moisture through the dry surface soil, is a proven technique in these soils, where rainfall is summer dominant and surface seedbeds are often dry at sowing time. When deep furrow planting, it is critical that moist soil is firmed around the seed but only 2–3 cm of moist soil is covering the seed.

On lighter, sandier soils moisture seeking points in conjunction with 'V' shaped press wheels give excellent results.

When sowing into wet soils, take care to avoid a smearing action by the moisture seeking points, which could reduce crop emergence.

Broadcasting seed through the combine small seed box is unreliable and usually results in staggered germination. Bandseeding is more suited to high rainfall areas.

Thoroughly clean out the seeder after sowing to prevent seed residue from contaminating other crops sown later in the season.

Sowing equipment and calibration

Sow seed through either the main seed box or small seed box of standard wheat sowing equipment. The airseeder 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 as it causes an uneven sowing depth. Diffusers are fitted to the sowing tines of airseeders to stop seed being blown from the seed row. A maximum sowing speed of 8–10 km/hour 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), trailing light harrows or mesh behind the planter. Knife points with press wheels are the preferred option. Avoid heavy harrows with long tines as they can disturb seed placement.

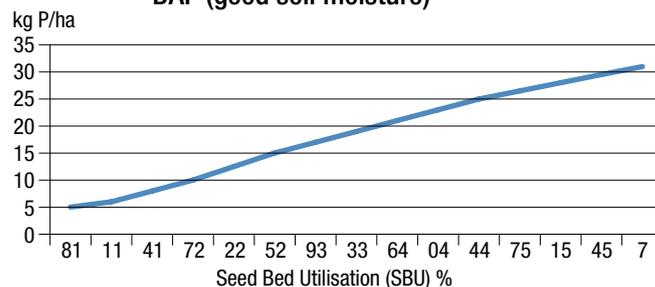
The seed box on most modern airseeders and combines can be calibrated for low seeding rates. Check calibrations from year to year as seed size can change and affect actual sowing rate.

Fertiliser management at sowing

Nitrogen and starter (N & 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 such as MAP and DAP; osmotic or salt effect due to high concentrations of salts produced from soluble fertiliser dissolving in water (both N and P); and seed desiccation from direct moisture absorption by fertiliser in very dry soil.

Fertiliser at high rates is best separated from the seed at sowing by banding. The risk of seed damage from fertiliser increases with (i) narrow sowing tines or discs, particularly at wider row spacing, as fertiliser becomes more concentrated close to the seed, (ii) in more sandy soils; and (iii) in dry soils. Figure 5.1 shows the approximate safe rates of phosphorus that can be sown with the seed using DAP fertiliser (18% N). Seedbed utilisation is used to take into account the width of the seed row and the row spacing. In dry soils, the amounts shown in the graph should be halved.

Figure 5.1 Approximate Safe Rates of P with seed using DAP (good soil moisture)



Seed Bed Utilisation %
 = Seed spacing mm / Row spacing mm x 100
 = 25 mm / 180 mm x 100 = 14%
 In dry soils only use half these rates

SOURCE: R Rainbow, SARDI

Checklist for sowing equipment:

- Accurate calibration for sowing rate.
- Even wear of points for accurate seed placement.
- Narrow points to reduce ridging.
- Front and rear rows of tines level.
- Sow slower rather than faster, to avoid overly shallow depth, seed bounce, or increased soil throw by tines, which effectively results in front tine seed being sown too deep.
- Level ridges behind the seeder. If using harrows, heavy harrows may be too severe and finger harrows too light.
- Avoid seed/super mixes that contain excess rates of nitrogen (see above).

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.

Dry sowing in dry autumns is a means of managing the risk of not getting all of the farm's crop sown on time.

PHOTO: P. BOWDEN, NSW DPI



Wide row spacing

Early-sown canola crops were traditionally sown on 15–20 cm row spacing to suit conventional combine configurations. Wider row spacings suit minimum and no-till systems and can provide moisture conservation in low rainfall (< 350 mm) areas.

In low rainfall areas of winter-dominant rainfall regions, wider rows (30–33 cm) will yield similarly to traditional row spacing, and have become increasingly popular.

In summer-dominant rainfall regions, wider row spacing of either 50 cm, or the blocking of every second tine to produce 60 or 66 cm, have been used with some success but a yield penalty almost always occurs.

Sowing rates should be progressively reduced as row spacing is widened beyond 30 cm, to avoid an excess number of plants competing within the plant row, causing plants to have thinner stems and hence a greater risk of lodging.

Early weed control is more critical with wider row spacing, as the inter-row gap encourages weeds to establish. As previously discussed, starter fertiliser rates need to be carefully managed when sowing in wide rows.

Dry sowing

Benefits of dry sowing

Dry sowing is a valuable management technique in more reliable production districts to both maximise season length and as a risk management tool for getting some of the total farm crop sown on time. Seed is sown into the dry soil to await germinating rain. A dry sown crop which receives good rainfall will emerge much faster than one sown after the autumn break.

If canola is to be sown dry, it must be sown into a

completely dry soil, with no areas of marginal moisture. Otherwise, some seed may germinate on the marginal moisture, resulting in a very uneven and staggered germination, which will prove difficult for ongoing management decisions. Dry sowing is risky where there is little or no subsoil moisture in reserve.

Drawbacks of dry sowing

Dry sowing in low rainfall areas is more risky than in higher-rainfall, longer season areas. It is risky to sow too far ahead

Dry sowing can result in a staggered germination, which can cause subsequent problems with weed and insect control, and harvest.

PHOTO: D. McCAFFERY, NSW DPI



of the germinating rain. The result may be that a longer season variety (later maturing) is effectively planted outside its optimum sowing window.

Specific issues which need to be considered include weed control, sowing depth, paddock conditions, variety choice and the risk of a false break, particularly in marginal, low rainfall areas.

The primary issue with dry sowing is weed control. Paddocks should have had prior weed treatment such as spray topping, fallowing or trifluralin incorporation, or weeds must be able to be controlled using post-emergence herbicides. Herbicide-tolerant varieties are highly recommended when dry sowing, as a broader spectrum of weeds can be economically controlled in-crop.

Sowing depth should be slightly deeper than normal (up to 1 cm) to reduce the possibility of light rainfalls only partially germinating the crop and resulting in a patchy or staggered establishment.

Avoid paddocks which are prone to prolonged waterlogging, or have hardsetting (crusting) soils, particularly where heavy rainfall is possible.

If sowing dry due to a late break, select a faster maturing variety than you would normally sow. Avoid late maturing except in the most reliable of high-rainfall, cool-finish districts, such as south-eastern South Australia and the Western District of Victoria.

Table 5.1 Number of plants established per square metre from different sowing rates and establishment percentages of open-pollinated varieties based on 290,000 seeds/kg

| Sowing rate kg/ha | Establishment percentage | | | | | |
|----------------------|--------------------------|-----|-----|-----|-----|-----|
| | 40% | 50% | 60% | 70% | 80% | 90% |
| 2.0 | 23 | 29 | 35 | 41 | 46 | 52 |
| 3.0 | 35 | 44 | 52 | 61 | 70 | 78 |
| 4.0 | 46 | 58 | 70 | 81 | 93 | 104 |
| 5.0 | 58 | 73 | 87 | 102 | 116 | 131 |

Table 5.2 Number of plants established per square metre from different sowing rates and establishment percentages of hybrids based on 175,000 seeds/kg

| Sowing rate kg/ha | Establishment percentage | | | | | |
|----------------------|--------------------------|-----|-----|-----|-----|-----|
| | 40% | 50% | 60% | 70% | 80% | 90% |
| 2.0 | 14 | 18 | 21 | 25 | 28 | 32 |
| 3.0 | 21 | 26 | 32 | 37 | 42 | 47 |
| 4.0 | 28 | 35 | 42 | 49 | 56 | 63 |
| 5.0 | 35 | 44 | 53 | 61 | 70 | 79 |

Raised beds

Sowing canola into raised beds has proven very successful in southern Victoria. Many soil types in this region (heavy duplex soils and impervious clay subsoils) are prone to severe waterlogging in winter. Raised bed cropping provides a relatively inexpensive and practical drainage solution, enabling growers to successfully produce canola and other crops and obtain much higher yields.

Research in southern Victoria has demonstrated yield improvements of 60 per cent where canola was sown on narrow raised beds (1.5–2.0 m wide and 25 cm high) compared to canola sown on much wider beds (20 to 30 m wide and 20 cm high). Root development and trafficability after rainfall events were also improved and, in subsequent years, indications are that the soil structure of raised beds starts to improve.

Raised beds have also been adopted in some of the wetter areas of south-west Western Australia. They have been trialled in southern NSW but a string of dry years has reduced grower interest.

Sowing rate

Evenness of plant population, both within the row and across the paddock, is more important than having an ideal population. Where plant populations are low, plants compensate by producing extra branches.

For most canola growing regions, the recommended seeding rate for *B. napus* canola is 3–4 kg/ha. Many growers have reduced this rate to 2 kg/ha but only after they have gained considerable experience in the skills and machinery refinements required to produce consistent establishment of the crop under a range of seasonal conditions. The trend towards hybrids with superior seedling vigour over open-pollinated varieties is allowing experienced growers to reduce seeding rates to as low as 1.5–2.0 kg/ha.

Excessively high seeding rates, for example 6–8 kg/ha cause crops to grow too tall with weak spindly stems, making them susceptible to lodging in the spring as flowering and pod development occur.

It is advisable to sow 1.0–1.5 kg/ha heavier than normal when seedbed conditions are not ideal, such as sowing late into cold, wet soils or no-till sowing into dense stubbles.

Within the recommended plant population range, it is better to have too many canola plants than too few, although high plant densities have been linked to an increased incidence of the disease, sclerotinia stem rot.

Typically, about 40–60 per cent of sown seeds establish as plants. However, if conditions are really favourable, establishment can be as high as 80 per cent.

Check the seed size every year, as it can vary depending on how well the seed crop finished in the previous spring. For *B. napus* varieties, the range lies between 250,000 and 350,000 seeds/kg for open-pollinated varieties and between 150,000 and 200,000 for hybrids. Tables 5.1 and 5.2 show the large difference in plant establishment rates for a given seeding rate between open-pollinated varieties and hybrids.

SOWING DEPTH – GENERAL

Canola has a small seed and is not as easy to establish as cereals. Soil temperature and the amount of surface moisture will influence sowing depth. It is better to drill canola at a shallow depth rather than drop it on the surface and attempt to harrow it in.

Plant seed at an even depth of 12–30 mm in most soil types, or deeper if dry sowing. Sown at this depth germination is rapid and the shoot will emerge within 4–5 days in warm moist soil. Deeper sowing, especially in hard setting soils, may result in slow, patchy emergence. Late sowing into cold soils slows emergence to 10–14 days.

New South Wales

Early in the season canola can be sown deeper provided seeds are placed on a firm base of moist soil (particularly when using no-till equipment), as temperatures are higher and the seedbed will dry out faster and to a greater depth. This is particularly important in low rainfall western areas and in self-mulching clays of north-west NSW, where it is better to 'chase' the firm, moist base of soil rather than sow into the loose topsoil which will dry quickly.

Victoria and South Australia

The ideal situation is to drill seed 10–30 mm into warm, moist soil. However, on the friable Wimmera self-mulching clays, it can be sown 30–40 mm deep to avoid temperature and moisture fluctuations near the surface. On soils that are likely to slump when it rains sow canola to as shallow a depth as possible.

Shallow seeding can be used where soil moisture is high or rainfall is imminent. Sowing can be deeper in sandy soils so place seed into moisture but do not exceed 30 mm.

TIME OF SOWING – GENERAL

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

For each week sowing is delayed, yields drop by around five per cent in South Australia and Victoria and around 10 per cent in central and southern NSW. The yield penalty can be even higher in seasons with a dry finish.

In general, sowing at the earliest time within the optimum window pays off in a number of ways, as earlier sown crops:

- generally have higher seed and oil yields as the crop finishes under cooler, moister, conditions. A premium is paid for oil content above 42 per cent;
- allow for better coordination of sowing and harvesting, as these operations for canola are well ahead of wheat;
- grow faster initially and so compete better with weeds; and
- normally have fewer problems with insect pests, such as aphids, in spring.

Because canola seed is very small it takes longer than cereals to establish. Late sowing into cold soils further reduces plant growth, making canola seedlings more vulnerable to disease, insects, slugs and other constraints. Late sowing also results in canola maturing when the weather is typically warmer and drier. Hot weather during the flowering to pod-set stages may cause pods to be aborted, fewer seeds per pod and reduced oil content.

In general, sowing later to avoid frost is not a good strategy as canola flowers for 4–6 weeks and can usually compensate for aborted flowers if frosts occur at early to mid flowering. Canola is most susceptible to frost during late flowering/early pod fill as a heavy frost can destroy immature seeds. Canola usually tolerates frosts better than cereals. In western and northern zones of NSW, early maturing varieties should not be sown early as September frosts may coincide with the pod-fill stage.

Late-sown paddocks must be well prepared and planned for canola as, in higher rainfall areas, poorly drained paddocks may be at greater risk with later sowings.

The optimum time to sow may depend on a range of factors but the relative maturity of a variety is important. Mid and mid-late maturing varieties should be sown early in the recommended sowing window for a particular region, and early maturing varieties sown later.

Establishment check

Carry out crop establishment counts within four weeks of emergence to review the success of the sowing operation and help decide whether the seed rate or equipment needs to be adjusted for next year's crop. The impact of establishment pests (such as earth mites, aphids, slugs or

Table 5.3 Recommended sowing times for south-eastern Australia

| | | APRIL | | | | MAY | | | | JUNE | | | | JULY | | COMMENTS |
|---------------------|------|-------|--------|--------|-----|-----|--------|--------|--------|-------|---|---|---|------|---|---|
| NSW - Region | Week | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | |
| Northern – West | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | | Sowing time should be balanced against frost risk at late flowering/pod-fill. |
| – East | | | | Yellow | Red | Red | Red | Red | Yellow | Green | | | | | | The sowing window is extended for higher rainfall areas of central and southern Liverpool Plains. |
| Central – West | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | | Capitalise on any sowing opportunity from 10 April. | |
| – East | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | Yield potential declines by 10% per week after mid-May. | |
| Southern – West | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | Select early maturing varieties if sowing in May. | |
| – East | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | Yield potential declines by 10% per week after 20 May. | |
| Southern Irrigation | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | Early establishment reduces the potential damage from waterlogging in heavy clay soils. | |

| | | APRIL | | | | MAY | | | | JUNE | | | | JULY | | COMMENTS |
|---------------------|------|-------|---|--------|-------|--------|-----|--------|--------|-------|---|---|---|------|--|--|
| Victoria – Region | Week | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | |
| Mallee | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | | Early sowing time gives highest yield potential. |
| Wimmera | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | Yield potential declines by 5-7% per week after mid-May. | |
| North Central | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | Yield potential declines by 5-7% per week after mid-May. | |
| North East | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | Yield potential declines by 5-7% per week after mid-May. | |
| South West | | | | | Green | Yellow | Red | Red | Yellow | Green | | | | | Optimum sowing time for well-drained soils. Delaying sowing till August-September is a strategy for soils prone to winter waterlogging. | |
| Northern Irrigation | | | | Yellow | Red | Red | Red | Yellow | Green | | | | | | Early establishment reduces the potential damage from waterlogging in heavy clay soils. Crops can be sown slightly later than in southern NSW. | |

| | | APRIL | | | | MAY | | | | JUNE | | | | JULY | | COMMENTS |
|-----------------|------|-------|--------|-----|-----|-----|-----|--------|--------|--------|-------|---|---|------|---|--|
| SA - Region | Week | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | |
| Low rainfall | | | Yellow | Red | Red | Red | Red | Yellow | Green | | | | | | | < 375 mm per annum Early sowing time gives highest yield potential. |
| Medium rainfall | | | Yellow | Red | Red | Red | Red | Red | Yellow | Green | | | | | | 375-450 mm per annum |
| High rainfall | | | Yellow | Red | Red | Red | Red | Red | Red | Yellow | Green | | | | | > 450 mm per annum |

- Best sowing time
- Later or earlier than desirable, possible yield reduction:
 - earlier – too vegetative, lodging, disease and/or frost risk
 - later – spring moisture and heat stress
- Too late for good yields, unless favourable spring

soil dwelling pests) can also be assessed at this time.

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

In NSW ideal plant populations (plants per square metre) are:

- central and southern wheatbelt – 40–60;
- irrigation – 40–60 (up to 75 if sown late);
- northern wheatbelt – 30–50; and
- low rainfall areas – 30–50.

In Victoria, ideal plant populations (plants per square metre) are:

- Mallee, Wimmera, Northern, North-east – 30–50;
- northern irrigation districts – 40–60 (up to 75 if sown late); and
- southern Victoria – 50–75.

In South Australia, optimum plant density range (plants per square metre) varies with rainfall:

- low rainfall (250–350 mm) – 40–70; and
- medium rainfall (350–500 mm) – 50–80.

Managing low plant establishment

While plant populations as low as 20 plants per square metre can still produce good yields, such crops are more susceptible to weed competition. Also, the variable pod development on these plants makes timing of windrowing difficult to determine, especially if germination has been staggered.

At less than 15 plants per square metre, the crop is likely to be patchy and lower yielding. Before re-sowing or abandoning a crop, always double check with an experienced agronomist or grower, because plants can compensate remarkably well and the yield potential may be equal to or higher than a better established but later sown crop.



6. Canola in the low-rainfall cropping zone

Trent Potter, SARDI; Neil Fettell, John Holland, Greg Brooke, NSW DPI; and Felicity Pritchard, ICF

Canola can provide the same rotational benefits in the low-rainfall zone as in the more traditional growing regions of the medium to high rainfall zones. The most important agronomic benefits are cereal root disease control, nematode control and management of herbicide resistant weeds. Research has shown that the average yield benefits following wheat crops range from 20 per cent in southern NSW and up to 54 per cent in some trials in South Australia. In the presence of severe cereal disease these benefits could be larger.

Farms are generally much larger in drier environments. Because of the uncertainty with seasons in these environments, there is generally less emphasis on cropping, more long fallowing and, often, more emphasis on grazing and pasture. For these reasons, canola is often viewed as an opportunistic crop rather than a permanent part of the rotation, which it is in higher rainfall areas.

Canola is grown over a wide range of environments, including those where growing season rainfall is low. In south-eastern Australia these areas include: north-west NSW, where crops are grown on predominantly stored moisture; western areas of central and southern NSW, where a combination of stored soil moisture and in-crop rainfall is important; and the 300–350 mm annual rainfall zone of Victoria and 250–350 mm zone in South Australia, where crops are grown predominantly on in-crop rainfall. Canola is not a particularly drought resistant crop so, in marginal environments, techniques to reduce the risk of moisture and high temperature stresses are critical.

While many principles are similar across the range of environments of the low rainfall cropping zone, some factors, such as optimal plant population and row spacing, will be different, depending on subsoil moisture, sowing time and growing season temperatures.

Key factors for success with canola in the low-rainfall zone

Techniques which can be employed include:

- only sowing canola when adequate subsoil moisture is present;
- no-tillage to conserve soil moisture;
- early sowing so that maturing crops avoid high spring temperatures;
- choosing early to early-mid maturing cultivars;
- matching plant population and row spacing to the situation; and
- correct nutrition to maximise water use efficiency.

These factors are discussed in detail following.

Adequate subsoil moisture or in season rainfall

Canola plants are good at utilising subsoil moisture provided the soil profile is free of subsoil constraints, such as hardpans and sodic subsoils. The plant has a vigorous tap root system and is able to extract moisture from depth, particularly if sown early, allowing the crop some buffering against the hot, dry conditions which can occur in spring.

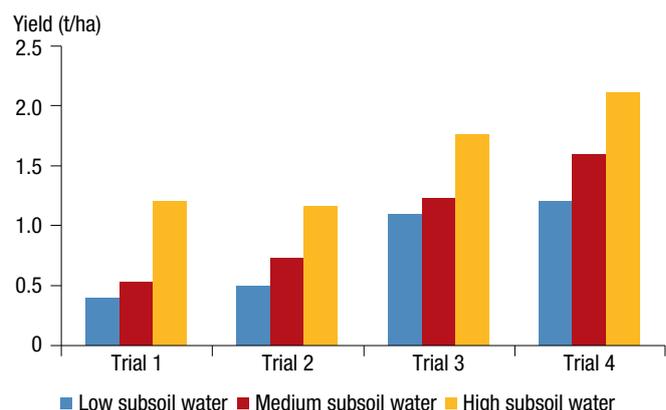
In north-western NSW, it is essential to have adequate subsoil moisture at sowing. At least 1 m of wet soil at sowing is critical to carry the crop through the season as in-crop rainfall can be minimal. In western areas of central and southern NSW, 70 cm of wet soil is recommended. In South Australia and Victoria, crops are grown predominantly on growing season rainfall but some growers will not sow without some subsoil moisture. It is important to remember that, because of the wide range of soil types, water holding capacity of different soils is also highly variable and therefore is more important in some regions.

Research in southern NSW showed that deep subsoil moisture (below 1.2 m) can contribute 15 kg/ha/mm extra yield compared to only 8–11 kg/ha/mm of growing season rain. The soil profile must have adequate moisture throughout and be free of subsoil constraints to allow the crop roots to access this deep subsoil moisture. In seasons with well above average rainfall, subsoil moisture may not be important. Figure 6.1 shows the importance of subsoil moisture for central and southern NSW.

No-tillage

On well-structured soils, no-tillage has been shown to improve fallow moisture storage. Stubble of a previous crop slows evaporation from the soil surface, and the crop can utilise a higher proportion of rainfall. No-tillage, combined

Figure 6.1 Response of canola yield to starting soil moisture in four comparisons at Condobolin NSW, in 2002 and 2003



Canola in the low-rainfall cropping zone



No-till canola crop establishing well near Nyngan NSW. PHOTO: G. BROOKE, NSW DPI



Optimal row spacing will vary for different low rainfall environments.

PHOTO: P. PARKER, NSW DPI

with stubble retention, maintains sowing moisture in the surface layers of the soil, and can extend the period when it is possible to sow canola after the previous rainfall event. Sowing can also occur on smaller rainfall events, which are common in the low-rainfall cropping zone. Low disturbance seeding is preferable when sowing early as less soil drying occurs. Rain following conventional sowing often leads to crusting. This problem is reduced by stubble retention and no-till seeding. Modern guidance systems and controlled traffic allow inter-row seeding in no-till systems.

Early sowing within the sowing window

In the absence of severe frost, generally the earlier the crop is sown the higher the potential yield. Sowing time for canola is a compromise between sowing late enough to minimise frost injury in the early spring and early enough to minimise high temperatures and moisture stress. Early sown crops can better utilise stored moisture from depth. However, if crops are sown too early they may flower in mid winter and therefore be frosted.

Optimal sowing time for the low rainfall zones of NSW, Victoria and South Australia is discussed in detail in Chapter 5. To summarise, expect a yield penalty of five per cent per week in South Australia and Victoria, and 10 per

cent per week in NSW for each week's delay in sowing past the optimum time. Delayed sowing can also reduce oil content by about 0.5–0.8 percentage oil points per week.

Variety maturity x sowing time interaction

Although the general rule is for early sowing for maximum yield and oil content, varieties with an appropriate maturity class need to be chosen for a given sowing time. Do not sow early maturing varieties early. Mid April sowing of early maturing varieties can result in frost damage during pod filling and this can be costly in better seasons.

Early flowering and maturing cultivars avoid some of the high temperature and moisture stress likely in spring. *Brassica juncea* (Indian mustard) has been developed for lower rainfall areas. The main advantages over canola are better heat and moisture stress tolerance.

Plant population

In the low rainfall zone, aim for a lower plant stand than in medium and high rainfall zones. A uniform plant stand is critical for reaching yield potential in this zone. It improves weed competition, promotes more even growth and maturity and sets the crop up for the best possible yield.

Recommended plant populations are discussed in Chapter 5 for each area within the low rainfall zone of south-east Australia. Plant population targets are generally lower in the low-rainfall zone of NSW (30–50 plants/m²), where subsoil moisture is more critical. In South Australia, 40–70 plants/m² is recommended, as the crop relies more on in-crop rainfall. The Victorian Mallee has similar targets to NSW.

Row spacing

Row spacing configurations in the low rainfall zone have been adopted to suit stubble retention and no-till seeding as much as any consideration for the crop. Optimal row spacing will vary depending on subsoil moisture, sowing time and growing season temperatures.

In the summer dominant rainfall areas of north-west NSW, growers use wide rows (60–66 cm) to manage stored soil moisture because of greater uncertainty of in-crop rainfall. Row spacings of 30–33 cm are widely used in the low-rainfall western areas of central and southern NSW, in the Victorian Mallee and in South Australia, although some narrower (18–25 cm) spacings are still used. Wider rows tend to result in lower establishment rates for a given seeding rate, presumably due to seedling competition within the plant row. Wider rows also promote taller plants if there are too many plants in the plant row.

Correct nutrition

Less than optimal nutrition can reduce yields and lower water use efficiencies in marginal environments. Ensure nitrogen, phosphorus and sulfur rates are adequate to achieve the target yield. Zinc may also be required on alkaline grey soils. To calculate fertiliser requirements refer to Chapter 7. Do not apply more than 10 kg/ha nitrogen with the seed in low-rainfall areas, especially when sowing early into warm soils, and take care with nitrogen rates with the seed on wider row spacings.

7. Nutrition and soil fertility

Paul Parker, NSW DPI

As with any crop, it is critical for profitability to closely match canola's nutritional requirements with target yields.

Canola requires high inputs per tonne of grain for the major (macro) nutrients nitrogen (N), phosphorus (P) and sulfur (S) compared with other crops (Table 7.1). However, on a per hectare basis, canola's nutritional requirements are similar to cereals, as yields are usually about 50 per cent of wheat.

Nutritional requirements will vary depending on soil type, rainfall, rotation and target yield. Canola crops will not achieve potential yields if any of the major nutrients, or trace elements, are deficient. Crops which have a higher yield potential, such as those sown early, will have a higher demand for nutrients.

A good knowledge of a paddock's history and fertility

status (preferably determined from soil tests), in conjunction with the crop's expected nutrient removal, will help in determining the type of fertiliser, the rate and when to apply it.

Soil testing

Soil testing for the macro nutrients is the most reliable way to determine the chemical and nutrient status of the soil. Apart from deep soil nitrogen tests, soil tests should be done well before the crop is sown to ensure adequate time for laboratory testing and interpretation of the results.

NITROGEN

Role and deficiency symptoms

Nitrogen is an essential nutrient for plant growth and plays an important role in the formation of many plant compounds, including proteins and chlorophyll. Nitrogen deficiency will



Table 7.1 Comparison of the average amount of the major nutrients removed per hectare per tonne of grain and stubble for a range of crops, including canola and wheat

| | Nitrogen (kg/ha) | | Phosphorus (kg/ha) | | Potassium (kg/ha) | | Sulfur (kg/ha) | |
|--------|------------------|---------|--------------------|---------|-------------------|---------|----------------|---------|
| | Grain | Stubble | Grain | Stubble | Grain | Stubble | Grain | Stubble |
| Canola | 40 | 10 | 7 | 2 | 9 | 26 | 10 | 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 |



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

reduce plant vigour and yield. Nitrogen is very mobile within the plant and if a deficiency occurs, it is readily moved from the older leaves into the younger growing tissue.

The nitrogen content of a canola plant (expressed as a percentage of dry matter) is highest at the full rosette stage, when deficiency symptoms are often quite visual. Generally, the older leaves become pale green to yellow, and may develop red, pink or purple colours. Plants will be stunted and the crop will not have achieved full ground cover 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.

Unfortunately, some visual symptoms are similar to other nutrient deficiencies (for example, phosphorus and sulfur) which can result in incorrect diagnosis. Tissue tests combined with a good knowledge of the paddock's history (including past fertiliser use and crop yields) will assist in giving a more accurate assessment of the most likely deficiency.

Estimating nitrogen requirements

Canola is ideally grown in soils high in nitrogen fertility; for example, as the first or second crop following several years of legume-dominant pasture. However, paddock fertility is often inadequate so additional nitrogen is required to produce both high yields and good seed quality.

Canola removes 40 kg of nitrogen for each tonne of grain. But the crop requires up to three times this amount of nitrogen to produce this yield (referred to as the efficiency factor). This is because the plants must compete with soil microorganisms for nitrogen, and also some of the nitrogen taken up by the plants is retained in the stubble, senesced

leaves and roots. A good canola crop will produce twice the weight of stubble as grain, giving a harvest index (HI) of about 33 per cent. Although the nitrogen content of canola stubble is only about one per cent, a 4 t/ha stubble will remove an additional 40 kg/ha on top of the 80 kg/ha nitrogen removed in the 2 t/ha of grain. So, for a 2 t/ha grain yield, 200 kg/ha of nitrogen is required through a combination of soil nitrogen, in-crop mineralisation and applied fertiliser.

The best technique to determine a crop's potential nitrogen requirement is through a combination of nitrogen removal (total nitrogen in the estimated grain yield x efficiency factor) plus the amount of nitrogen 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 down to 60 cm in the major canola producing areas. They can also be done during the growing season to determine if topdressing is required.

Available soil nitrogen (calculated from deep nitrogen test + estimate of in-crop mineralisation) = 125 kg/ha. As a rough 'rule of thumb' the in-crop mineralisation is calculated as:

$$\begin{aligned} \text{Growing season rainfall (GSR-mm)} \times \text{organic carbon (\%)} \times 0.15 \\ \text{Fertiliser N required for crop} &= \text{Total N required} - \text{Available soil N} \\ &= 200 - 125 \\ &= 75 \text{ kg N/ha} \end{aligned}$$

Nitrogen requirement calculator

Nitrogen removed in grain = Target yield x 40 (kg nitrogen per tonne removed in grain)

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

Example:

| | |
|------------------------|--|
| Estimated target yield | 2 t/ha |
| N removal in grain | 2 t x 40* kg N/t = 80 kg N/ha (* from Table 7.1, page 31) |
| Total N required | = 80 x 2.5 = 200 kg N/ha |

Nitrogen fertiliser rates

Fertiliser N required for crop = Total N required – available soil N

Using the above example:

| | |
|---|--|
| Available soil N (calculated from deep N test + in-crop mineralisation) | = 125 kg/ha |
| Fertiliser N required for crop | = 200–125 = 75 kg N/ha (or 163 kg/ha urea). |

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

Other formulae are available for calculating nitrogen requirements but these need more detailed inputs which can be provided by consultants or agronomists.

Nitrogen fertiliser application strategies

The total amount of nitrogen applied is more important than the time of application. However, an increasing number of growers apply only a portion of the total estimated amount of nitrogen required prior to or at sowing with the remainder topdressed onto the crop during the growing season. This helps to minimise the risk of crops growing too bulky early in the season, potentially leading to lodging or haying off. Delaying nitrogen application also spreads the financial risk in adverse seasonal conditions. Conversely, if conditions are favourable for higher than targeted yields, then growers are able to adjust their program and apply additional nitrogen to ensure crop needs are met.

Maximum nitrogen rates at sowing

As germinating canola seeds are sensitive to fertiliser burn, take care at sowing to minimise the risk of reduced seedling emergence. Refer to the section on 'Sowing with fertiliser' in Chapter 5 for more detail.

The actual amount of nitrogen that can be applied with the seed will depend on factors such as soil moisture, temperature and row spacing. Wider row spacings will concentrate the amount of fertiliser, so apply lower rates in these situations.

Pre-drilling v broadcasting

When high rates of nitrogen are applied before sowing, the best results are achieved by drilling it in bands (below seeding depth) rather than broadcasting it on the soil surface. Banding results in a slower release of nitrogen during the growing season. It also reduces the risk of leaching and avoids excessive early growth. Broadcasting can result in increased losses by volatilisation, particularly on alkaline clay soils.

Pre-drilling all nitrogen is useful and convenient in areas with low leaching losses (such as the grey clays), ensuring early uptake of nitrogen by the crop, which is critical for canola. However, splitting or delaying nitrogen applications reduces some of the financial risk by allowing growers to make a decision two to three months later when they have more information about potential yield and seasonal conditions.

Where reasonable soil nitrogen levels are present, for example, at least 40–60 kg N/ha, a starter fertiliser containing some nitrogen and all phosphorus needs can be used at sowing and additional nitrogen topdressed during the season. Mono-ammonium phosphate (MAP) is the most popular starter fertiliser.

Topdressing

The aim of nitrogen management is to ensure good healthy vegetative growth prior to bud formation, which occurs in most regions during July (NSW) or August (Victoria). The decision to topdress should be based on seasonal conditions and weather predictions for the remainder of the crop cycle. Remember, weather predictions are only

a probability of future rainfall. Splitting or delaying nitrogen applications allows growers to topdress when they have a better idea of potential yield. For highest yields, topdressing is best undertaken before stem elongation. Plant uptake is at its highest during stem elongation so if nitrogen deficiency symptoms occur around this time, topdress immediately. Topdressing at early to mid flowering can be beneficial if the crop is likely to run out of nitrogen during pod fill.

If you are not confident in your ability to assess the need for nitrogen, use test strips. Just after the crop is up, measure a 10 m by 10 m square and apply 1.5 kg of urea. Keep the plot 20 m away from the fence line and compare it to the whole crop. After rain, assess for colour and vigour. The more deficient the crop, the sooner a result is seen. Topdress immediately if colour and vigour improve in the test strip area.

Tissue tests can provide additional information on the nitrogen status of the crop and can help in fine tuning topdressing rates during the season.

An adequate supply of nitrogen during pod fill is important to maximise seed oil content. However, excessive nitrogen can reduce seed oil content as the plant uses it to increase protein at the expense of oil content.

Nitrogen sources

Generally there is no difference in yield response between nitrogen sources — anhydrous ammonia applied to the soil prior to sowing, urea or ammonium sulfate. Check prices by comparing the cost of 1 kg of nitrogen from each source. Ammonium sulfate is usually only used where the crop also requires sulfur.

Urea is normally chosen because it has a high analysis (%) of nitrogen, is cost competitive, and does not affect soil pH. It can be readily incorporated into the soil before sowing or topdressed by ground rig or by air.

Topdressed urea is most successful when it is washed into the soil by at least 6–10 mm of rain soon after application or it dissolves when applied to moist soil. If it dissolves in moist soil and is not washed in by rain there is a higher risk of loss of nitrogen to the atmosphere by volatilisation. Rainfall amount, surface soil pH, texture, wind velocity and ground cover all affect nitrogen losses through volatilisation. Losses are lowest on acidic red soils and highest on alkaline clay soils.

Urea can be readily topdressed onto plants. The fertiliser granules will not damage plants, as they will roll off onto the ground if the leaves are dry. It is important not to overlap or leave gaps during topdressing as crop maturity differences will result. If crops are topdressed with a combine during the vegetative stage, they recover well from wheel tracks without affecting yield potential.

Urea is the preferred source of nitrogen to add to irrigation water but the timing of the first spring irrigation is often too late for the most efficient uptake by the crop. A urea or urea/ammonium nitrate (UAN), solution is also suitable to use as a foliar spray but only at low rates of nitrogen.



Severe phosphorus deficiency showing plant stunting and delayed maturity.

PHOTO: R. COLTON, NSW DPI

PHOSPHORUS

Role and deficiency symptoms

Phosphorus (P) plays an important role in the storage and use of energy within the plant. A lack of P restricts root development (resulting in weaker plants) and also delays maturity, 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 nitrogen. 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. P 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.

Fertiliser placement

In the soil, phosphorus is very 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 of P during the early growth stage when phosphorus requirement is at its highest. Many soils (particularly if exchangeable aluminium is present) are able to tie up P, making it unavailable to plants. Therefore, banding the fertiliser can reduce the amount tied up as less fertiliser is in contact with the soil compared with broadcasting. Phosphorus fertiliser banded close to the seed gives better yield responses than phosphorus 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 phosphorus uptake.

Phosphorus requirements

If a wheat crop responds to P, a rate that is at least equivalent should be used when sowing canola. It is important to get the P rate right at sowing as topdressing is ineffective.



Phosphorus deficiency shows as distinct pink-purple of the tips and margins of older leaves.

PHOTO: P. HOCKING CSIRO

A maintenance application of 7–8 kg/ha of phosphorus is needed for every tonne of canola you expect to harvest. If a soil test result indicates a high soil phosphorus level, then lower rates of phosphorus could be applied. In some situations, where soil phosphorus levels are very high it may be uneconomic to apply phosphorus. If more is applied than is removed by the grain, it will be added to the soil phosphorus bank and may be available for following crops or pastures to utilise. However, a significant proportion (up to 50 per cent) of applied fertiliser P can ultimately become 'fixed' into organic and inorganic forms that are largely unavailable for crop uptake.

Most soil phosphorus tests are based on the Colwell P test. If these tests indicate less than 20 mg/kg then phosphorus is considered low (depending on soil type and rainfall) and a response is likely. However, if the soil P level is high (> 40 mg/kg P) a response to phosphorus is less likely, unless the soil is acid (pH_{Ca} less than 4.8) and has a low cation exchange capacity (less than 5cmol (+)/kg), in which 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 phosphorus fertiliser decisions. A Colwell P level of around 40 mg/kg provides opportunity for some seasonal adjustment to fertiliser rates.

SULFUR

Role and deficiency symptoms

Sulfur (S) is crucial for canola in the synthesis of oil and protein as well as for the plant's vegetative development. Sulfur is needed in the formation of chlorophyll in leaves, and therefore for growth.

Canola has a much higher requirement for S than wheat or legume crops.

Sulfur deficiency symptoms include the following:

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

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

Soil sulfur

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

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

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

Where higher rates of sulfur are needed, the most economic way is to apply gypsum pre-sowing. Elemental sulfur-amended fertilisers can assist with sulfur requirements but elemental sulfur needs to be converted to sulfate sulfur before plant uptake can occur. This can delay its availability to the growing seedling.

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



Sulfur deficiency symptoms appear in the rosette stage as pale mottled leaves which may be cupped and have purple margins.

PHOTO: H. BURNS, NSW DPI



Trials around 1990 confirmed paddock observations of the late 1980s of canola's high requirement for sulfur. Flowers are a pale yellow.

PHOTO: A. GOOD, INCITEC

POTASSIUM

An adequate supply of potassium (K) is important to provide plants with increased disease, frost and drought resistance, as well as increased carbohydrate production. Canola crops take up large amounts of potassium during growth but most of it remains in the stubble with only a small proportion removed in the grain. Although deficiency symptoms have been uncommon in the past, they are becoming more frequent on sandy soils in higher rainfall zones where hay has been cut in previous years. In Western Australia, a problem of poorer cereal growth outside the header trails has been linked to the movement of potassium in canola stubbles at harvest. Canola crops subsequently grown in these paddocks also show similar symptoms indicating that the overall potassium level of the paddock is marginal.

Although soil tests, especially the balance of exchangeable cations, can provide a guide to the potassium level, tissue tests are the most reliable method to determine whether a potassium fertiliser is needed.

Avoid sowing potassium fertiliser with the seed as it could affect germination.

OTHER ELEMENTS

BORON

Role and toxicity and deficiency symptoms

Canola requires boron (B) in small amounts but it can cause both deficiency and toxicity problems. In most canola growing areas, boron deficiency is the more likely problem, but in some alkaline and sodic soils, such as the Wimmera and Mallee in Victoria, toxic levels of boron occur at 40 cm or deeper in the soil. Boron toxicity has the two-fold effect of reducing growth as well as reducing the rooting depth of plants. In soils with high subsoil boron, there is little that can be done to ameliorate the problem but boron-tolerant canola types are being investigated.

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

Over a number of seasons, growers and agronomists have observed crops with a reduced number of seeds set within pods. These symptoms are consistent with low boron levels. Unlike seeds killed by frost, where the residue of the dead seed is visible, with boron deficiency the

individual seeds fail to develop, resulting in a missing seed, or seeds, in the pod.

Canola requires 6–10 times more boron than wheat. In southern NSW, canola-wheat rotations over 10 or 11 years continuous cropping have resulted in much boron being removed. As well, many soils, especially the lighter sandy-loam acidic soils which are low in organic matter and are common throughout southern NSW, are low in boron. Under this cropping system a range of crops and pastures, including canola and subclover, frequently have either marginal or deficient levels of boron. In some areas of the South West Slopes region of NSW yield, responses to applied boron have been up to 20 per cent.

Boron deficiency causes seedling plants to bunch, the leaves become long, narrow, with a cupped shape, thicker than normal and brittle, causing them to snap easily. Deficiency is more likely during periods of low moisture availability or where liming has reduced the availability of boron.

Fertiliser requirements

Tissue testing is the best way to confirm a deficiency, especially as the symptoms of sulfonylurea herbicide damage are similar. If there is a deficiency, apply 1–2 kg/ha of boron. High rates of boron are used in herbicides to sterilise soil, so it is critical that only recommended rates are applied where a deficiency has been identified.

Boron deficiency was confirmed here by tissue testing but symptoms can be confused with manganese toxicity.

PHOTO: P. PARKER, NSW DPI



MOLYBDENUM

Role and deficiency symptoms

Molybdenum (Mo) is important to plants to enable them to convert nitrates from the soil into a usable form within the plant. Deficiency is more common when soil acidity falls below pH_{Ca} 5.5 but is difficult to diagnose other than by a tissue test. It can be avoided by applying molybdenum at a rate of 50 g of actual molybdenum per hectare once every five years. The most common method of use is the application of 150 g/ha of the soluble form sodium molybdate (39 per cent Mo) sprayed onto the soil surface. Molybdenum is compatible with pre-emergent herbicides and can be thoroughly incorporated into the soil before sowing.

Fertiliser requirements

While fertilisers containing Mo can be used at sowing, the rate of Mo they contain is less than recommended and they are more expensive than using sodium molybdate. Molybdenum treated single superphosphate (Moly super) applied during the pasture phase is very cost effective and should supply enough Mo for the canola crop.

ZINC

Deficiency symptoms

Zinc (Zn) deficiency appears in crops as poor plant vigour, with areas of poorer growth alongside healthy, apparently normal plants giving the crop a patchy appearance. Although there are few reports of zinc deficiency in canola, growers should be cautious. Zinc is routinely applied to alkaline soils in the Victorian Wimmera and the clay soils of northern NSW.

Zinc deficiencies can occur in the following situations:

- soils are strongly alkaline, pH_{Ca} greater than pH 7.0, with high phosphorus levels;
- long periods of fallow; and
- 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.

Fertiliser strategies

Where responses to zinc are known to occur, incorporate zinc into the soil before sowing canola. In northern NSW and irrigation areas, broadcast rates of 10–20 kg of zinc per hectare are common where summer crops such as maize and sorghum are also grown. These rates supply enough zinc for five or more years.

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

Zinc oxide is the cheapest and most concentrated form of zinc 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 only a short-term correction and need to be applied before



Zinc deficiency appears as bronzing on the upper leaf surface and may occur in neutral to alkaline soils.

PHOTO: B. HOLLOWAY, SARDI



Death of the canola flower head as a result of calcium deficiency.

PHOTO: D. McCAFFERY, NSW DPI

symptoms are obvious soon after crop emergence, or where a Zn deficiency has been identified through tissue analysis.

MAGNESIUM

In recent years, magnesium 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 magnesium deeper in the profile. Low surface magnesium levels are probably due to low levels of sulfonyleurea herbicide residues and the harvesting of subclover hay, where large quantities of magnesium 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.

CALCIUM

Calcium (Ca) is important in plants as it assists in strengthening cell walls, thereby giving strength to the 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 calcium deficiency. Calcium deficiency is not common but it can occur in acid soils especially if the level of exchangeable calcium 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.

SALINITY AND SUBSOIL CONSTRAINTS

Canola is moderately tolerant of salinity, with a similar level of tolerance as wheat but slightly lower than barley. Published data suggests that canola can tolerate soil electrical conductivity (EC) levels of 6.5 deci Siemens (dS/m) average throughout the root zone. Subsoil constraints such as hardpans, high alkalinity or acidity, boron toxicity, sodicity and very high levels of salinity can reduce canola yield potential. Subsoil constraints to canola yield have been identified in many areas of north-western Victoria and southern NSW.

SOIL ACIDITY AND LIMING

Canola will grow in a wide range of soils from pH_{Ca} 4.5 (acid) to 8.5 (alkaline). Soil tests for pH should be taken in the winter/spring prior to growing canola especially if soil acidity problems are likely. Collect samples from the surface (0–10 cm) as well as at depth (10–30 cm) to check for subsoil acidity such as an acid ‘throttle’ or band.

On alkaline soils, which are more typical on the northern slopes and plains of NSW (deep cracking grey or brown clays) and in the Wimmera and Mallee regions in Victoria, additional zinc often needs to be applied to the crop.

Acid soils are more typical of the higher rainfall zones

in NSW and Victoria. They can contain toxic amounts of aluminium or manganese and may need lime to be applied to the paddock before canola is sown. Most, but not all, acidic soils have high aluminium levels. Canola should not be sown into soils with a pH_{Ca} below 4.5 and not below 4.7 if exchangeable aluminium levels exceed three per cent. Acidity problems may occur in either or both the surface or subsoil layers.

Canola is one of the most sensitive crops to high levels of aluminium which can drastically reduce growth and yield potential. Aluminium (Al) is much more detrimental than manganese (Mn) because it kills the plant’s root tips, resulting in shallow, stunted root systems that are unable to exploit soil moisture or nutrients to depth.

Aluminium toxicity symptoms

Often patches of stunted plants occur within the crop (where aluminium levels are highest), which usually indicates a more serious aluminium toxicity problem.

Note that all nutrient levels shown on a soil test are an average for the paddock and that actual levels will vary as soils are rarely uniform across the whole paddock. For example, if a soil test result indicates that the available aluminium level is three per cent of the cation exchange capacity (CEC), the actual level could vary from 0–6 or seven per cent.

Late sowings and low levels of organic matter may accentuate the problem, particularly when canola is sown after a long cropping history.



Aluminium toxicity appears in the crop as patchy areas of stunted plants and poor growth.

PHOTO: R. COLTON, NSW DPI

Manganese toxicity symptoms

Manganese toxicity is a less frequent problem, which shows up as patches within the crop that develop bright yellow margins on the leaves. Symptoms are more common in crops grown in warmer, lighter sandy soils and during periods of moisture stress. Plants usually recover when soil moisture levels improve following rain.



Yellowing of canola leaves from the margins is the main symptom of manganese toxicity.

PHOTO: D. McCAFFERY, NSW DPI

Liming

The most effective treatment for Al and Mn toxicity is to apply lime to raise the soil pH_{Ca} above 5.0. Lime rates depend on the pH to depth and the CEC of the soil. A high quality lime is usually applied at 2–4 t/ha. Shallow incorporation is sufficient to ameliorate surface soil acidity but deep ripping is required to incorporate the lime into the subsoil. Deep ripping will also reduce soil strength and improve soil drainage. Where possible, lime should be applied and incorporated to a depth of 10 cm at least two to three months prior to sowing, and preferably six to eight months before.



Liming to alleviate acid soils not only benefits canola, but the whole farming system.

PHOTO: B. RAMSEY, INCITEC PIVOT

FARMER TEST STRIPS

Farmers should conduct their own trials to assess nutrient needs. Visual assessment can be misleading, so make trial evaluations in harvested yield. A simple trial can be done on a measured area along one side of a paddock (wider than the header) that can be harvested and weighed in bulk or checked with the header's yield monitor. Test strips are usually quick to do by adjusting the feeding mechanism to apply different rates of fertiliser in the strips along the paddock. Alternatively, seek help from your agronomist or consultant.

Herbicides are central to any weed management strategy in canola.

PHOTO: G SAUNDERS, ARTISAN DESIGN



8. Weed management

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Canola is highly susceptible to weed competition during the early stages of growth, making early weed control essential. Although canola's competitive ability improves markedly once the crop canopy has closed, serious yield losses can occur beforehand.

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

Weed control in canola must utilise the range of available herbicide and non-herbicide options, that is, integrated weed management (IWM). For simplicity, herbicide control is discussed in the first part of this chapter and IWM is covered in the second part.

WEED MANAGEMENT WITH HERBICIDES

If weeds are very dense, they represent a greater threat to yield, especially if herbicide control is poor. Table 8.1 shows the impact of initial weed density and herbicide control percentage on final weed density.

In the above case, if herbicide control drops by 20 per cent, the final weed densities jump to 2500, 250 and 25 plants/m² respectively. Therefore, the greater the initial weed density, the higher the final number of weeds, especially if herbicide effectiveness is reduced. In addition, if large numbers of weeds are sprayed, the likelihood of herbicide resistant biotypes being present increases. Constant spraying of high weed numbers, especially with the same mode-of-action (MOA) herbicide group, will accelerate the evolution of herbicide resistant weed populations.

The choice of weed management strategies will depend



Table 8.1 Impact of initial density on final weed numbers

| INITIAL DENSITY (PLANTS/m ²) | FINAL WEED DENSITY | |
|--|--------------------------------------|--------------------------------------|
| | 95% control (plants/m ²) | 75% control (plants/m ²) |
| 10,000 | 500 | 2500 |
| 1000 | 50 | 250 |
| 100 | 5 | 25 |

Table 8.2 Common weed management problems and potential strategies

| EXAMPLE WEED(S) | HERBICIDE OPTION(S) | COMMENTS |
|--|--|---|
| Wild radish, wild turnip and shepherd's purse | TT canola or Clearfield® canola or Roundup Ready® canola (see Note 1) | Watch herbicide residues Identify paddocks clearly Include as part of an IWM plan |
| Barley grass, brome grass | Selective grass (fop and dim – Group A) herbicides, many options or Roundup Ready® canola. | Monitor for herbicide resistance High risk if already used more than 6-8 times |
| Vulpia | Trifluralin in standard canola or TT canola ± trifluralin or Roundup Ready® canola | Trifluralin efficacy improves with better incorporation |
| Subclover, medics, certain thistles and capeweed | clopyralid | Subclover and medic can be very dense in dry sown ley paddocks |
| Wireweed / black bindweed | trifluralin and/or Clearfield® canola | Use both if weed pressure high, otherwise avoid paddock |
| Wild oats | tri-alleate or Roundup Ready® canola | Add trifluralin if annual ryegrass present |
| Group A-B resistant ryegrass | trifluralin and/or TT canola or Roundup Ready® canola | Do not treat dense infestations Consider fallow or forage crop |
| Toad rush | TT canola or Dual Gold® post-sowing, pre-emergence | Competes strongly for available nitrogen in wet seasons |

Note 1: Where TT canola is mentioned, a mix of atrazine and simazine is assumed. Where Clearfield® canola is mentioned, use of OnDuty® or Nufarm Intervix® herbicide is assumed. Where Roundup Ready® canola is mentioned, use of Roundup Ready® herbicide is assumed.

Note 2: See herbicide labels for full spectrum of control, potential for tank mixes and application instructions for each herbicide.



Growing herbicide-tolerant canola is a key management strategy to manage Group A and Group B-resistant annual ryegrass in cereals.

PHOTO: C. PRESTON, UNIVERSITY OF ADELAIDE

on the species present and their resistance status.

Table 8.2 shows examples of some common problem weeds and options for herbicide control.

Trifluralin

Research has shown that trifluralin can reduce density and early growth of emerging canola plants if crops remain stressed over a prolonged period (more than seven weeks after sowing). However, the advantages in weed control will normally compensate for any potential early damage caused by sub-optimal application practices.

Trifluralin can be applied using the 'incorporate before sowing' (IBS) technique which calls for low trash levels and a fine soil tilth. The herbicide is incorporated with two cultivations, the second of which is a cross-working.

Increasingly, trifluralin is being applied using the 'incorporate by sowing' technique, which enables its use in no-till, direct drill and minimum till seeding. Plant residues such as stubble will bind trifluralin and reduce the amount of herbicide available for weed control. This is one reason why direct sowing use of trifluralin has higher rates than when it is used in a prepared seedbed. See label for details.

Continued use of trifluralin has led to the evolution of trifluralin resistant annual ryegrass and an increase in weeds not well controlled by this herbicide. Growers and advisers need to plan carefully to avoid trifluralin resistance

developing, particularly when the weeds are already resistant to the Group A and B herbicides.

Triazine herbicides

Triazine herbicides are best applied as a split application, firstly before crop emergence and again when the crop and weeds have emerged. This lessens the risk of crop damage that would occur from applying the full rate before crop emergence and also helps control a wider range of weeds for a longer period.

Simazine or atrazine?

Simazine must only be used pre-emergence, while atrazine can be used pre and post-emergence. Normally, a mix of simazine and atrazine (1–1.5 L/ha of each) is used pre-emergence to broaden the spectrum of weeds controlled. Also, simazine is less soluble and therefore less prone to leaching through the soil. Only atrazine can be applied after the crop has emerged.

Pre-emergence application

Applying the herbicide before the crop emerges gives better control of annual grass weeds such as annual ryegrass. Triazines can be applied up to one week before sowing.

- Pre-sowing – used where good rain has been received and it is the start of the sowing window. Incorporation

of the herbicide to a depth of 5 cm will improve control. Full disturbance sowing can be used to incorporate the herbicide.

- Post-sowing – relies on rain (20–30 mm) following spraying to move the herbicide into the soil. Weed control levels will be lower if no rain falls for 3–4 weeks. This method is often used where large areas of canola are to be sown and for minimum till situations.

Post-emergence application

An adjuvant is added to atrazine to increase absorption of the herbicide into weed leaves. The post-emergence split improves the control of broadleaf weeds.

Effect of dry conditions

Triazine herbicides are primarily absorbed through plant roots, particularly in grasses. If not incorporated pre-sowing the herbicide will remain on the soil surface and will gradually vaporise until rain washes it into the soil. Weed control will be poor as weeds can emerge through the herbicide.

Dry conditions will also increase the plant-back period for sensitive crops because soil moisture is needed for the herbicide to fully decompose.

Plant-back periods

Triazine herbicides are persistent in alkaline soils ($\text{pH}_{\text{Ca}} > 7.0$). For these soils, limit the total rate of triazine herbicides to 2 L or 1.1 kg granules per ha. Read the herbicide label for application rates and check plant-back periods as a part of the rotational plan for the paddock. If the TT canola crop

fails following application of the triazine herbicide, only crops tolerant to these herbicides can be sown. Sowing time may be too late for lupins or faba beans. In northern NSW cropping systems following through to sorghum or maize would be the safest option.

Note that the triazine herbicides will kill conventional, Clearfield® and Roundup Ready® canola. Ensure that paddocks are correctly identified, particularly for spray contractors.

Clearfield® varieties

Clearfield® (imidazolinone [IMI] tolerant canola) varieties are a suitable option in some paddocks. Clearfield® varieties have a similar weed control spectrum to the TT varieties, although the main weakness is capeweed. However, caution in their use is needed because Group B herbicide resistance is widespread.

In acidic soils, the breakdown of IMI herbicides is slower than in neutral or alkaline soils. Read the herbicide label and check plant-back periods as part of the rotational plan for the paddock.

Note that OnDuty® and Intervix® herbicide will kill conventional, TT and Roundup Ready® canola. Ensure that paddocks are correctly identified, particularly for spray contractors.

Roundup Ready® varieties

Roundup Ready® (glyphosate-tolerant canola) varieties are a suitable option in some paddocks. Glyphosate is a broad spectrum herbicide providing good control of grass weeds and of many, but not all, broadleaf weeds. Only Roundup Ready® herbicide is registered for use. Glyphosate can only be applied up to the six-leaf stage otherwise crop damage could occur. Read the herbicide label and follow the crop management plan. Remember that glyphosate used alone will not control Roundup Ready® canola volunteers that germinate over summer or autumn after crop harvest. If using glyphosate for summer herbicide or knockdown application mix another herbicide at a rate that will control canola volunteers. Follow the crop management plan.

Note that Roundup Ready® herbicide will kill conventional, Clearfield® and TT canola. Ensure that paddocks are correctly identified, particularly for spray contractors.

Dry sowing

Only dry sow paddocks with potentially low weed numbers.

Dry sowing conditions prevent pre-sowing knockdown (for example, glyphosate) weed control. When rain falls after sowing dry, weeds and crop emerge together and significant yield loss may occur before it is possible to control the weeds.

Soil active herbicides will not be effective under dry soil conditions and have the potential to allow some weeds to grow through the herbicide layer.

Trifluralin will not activate in dry soil, remaining tightly bound to soil particles. If the trifluralin has been well incorporated it will remain in the soil for several weeks until



Effects of accidental spraying of the wrong herbicide on the wrong variety. Here the Clearfield® herbicide OnDuty® was sprayed onto a conventional variety.

PHOTO: P. LOCKLEY, NSW DPI



Sulfonylurea residues in the pipe from the dump valve to the spray tank.

PHOTO: B. BUCHANAN, SYNGENTA)

Herbicide residues in spray tanks can be very damaging to canola, especially sulfonylurea herbicides.

PHOTO: P. PARKER, NSW DPI

there is sufficient soil moisture to activate it. Presence of soil moisture will increase volatilisation losses.

Canola needs to have reached a certain growth stage before post-emergent herbicides can be safely applied, such as when controlling clover with clopyralid.

Herbicide damage

Canola is highly susceptible to the phenoxy (Group I) herbicides 2,4-D and MCPA. Take care when spraying adjacent cereal crops to avoid spray drift and let neighbours know when you are sowing canola.

Canola is also extremely susceptible to low concentrations of the widely used residual sulfonylurea (SU) (Group B) herbicides. These include the cereal herbicides Glean[®], Logran[®], Ally[®] and Hussar[®]. Do not plant canola after a cereal crop treated with these herbicides until the specified plant-back period has elapsed. It is safe to sow those Clearfield[®] varieties nominated on the OnDuty[®] or Intervix[®] labels. Alkaline soils (pH_{Ca} above 7.0) have longer plant-backs. Consult the plant-back information on the herbicide label.

Boomspray contamination with herbicides such as sulfonylurea can kill canola. As little as 20 milligrams per hectare of chlorsulfuron (less than one thousandth the label rate) has caused severe injury to canola seedlings. Some commonly used grass herbicides have the ability to 'strip' SU residues out of boomspray tanks and lines and into the spray solution. Check the equipment decontamination procedure on the label of each herbicide as procedures vary with the type of herbicide. Also check with spray equipment manufacturers or suppliers to find out where herbicide residues can accumulate as parts of the machine may need

to be dismantled and thoroughly cleaned.

Drift of SU herbicides onto adjacent paddocks can lead to severe damage to canola, either as soil residue from a previous drift event, or from a drift event after canola emergence.

Weed control guides

NSW Department of Primary Industries (DPI) produces a comprehensive annual guide, *Weed Control in Winter Crops*, which details the herbicide choices available for canola. The booklet is available on request from NSW DPI offices or can be downloaded from the NSW DPI website (www.dpi.nsw.gov.au). Regulations governing pesticide use vary between states. Contact the relevant state agency for pesticide and weed control information.



Burning windrows can kill weed seed and reduce seedbank numbers.

PHOTO: C. PRESTON, UNIVERSITY OF ADELAIDE

INTEGRATED WEED MANAGEMENT

Herbicide resistance has evolved in about 25 weed species in Australia. It should also be noted that a number of weeds have evolved resistance to several herbicide mode-of-action (MOA) groups. Some populations of annual ryegrass have evolved resistance to all the selective MOA herbicide groups. The 'herbicide only' approach to weed control is not viable over the long term. Herbicide resistance is forcing a growing number of producers to look at a longer-term approach to weed control and introduce a range of non-herbicide tactics to control weeds.

To maintain or increase the current level of cropping intensity and diversity, effective herbicides are essential. In order to keep herbicides effective, producers and advisers must adopt a more integrated approach to weed management.

Integrated weed management (IWM) is a system for managing weeds over the long term, particularly for the management and minimisation of herbicide resistance.

IWM incorporates the use of as many different weed control techniques as possible within a farming system, with a focus on preventing seed set of any weed escapes. In certain situations, less profitable techniques may have to be used in the short term to get longer-term control of weeds and improved returns. An example of this in canola would be windrowing the crop, followed with a knockdown herbicide to prevent any weeds from seeding. Windrowed stubble could also be burned to kill weed seeds.

Essential principles of an IWM program include:

1. Monitor levels of weed control.
2. Stop weeds from setting seed and thus keep seedbanks small.
3. Use as many weed control tactics as possible, together with good agronomy to grow competitive high yielding crops.

1. Monitor levels of weed control

As discussed earlier, weed control techniques do not give complete control when used alone. Weed escapes need to be identified and controlled before they set seed.

2. Stop weed seed set – keep weed seedbanks small

The key to keeping seedbanks small is to prevent, or at least greatly reduce, inputs of fresh seed. To achieve this, it is important to aim for high levels of weed control using a combination of control methods.

THE 'DOUBLE KNOCK'

No one tactic will control 100 per cent of weeds, so introducing a second tactic (the second knock) to kill the survivors of the first always gives the best control. The most common example of this is a pre-sowing application of glyphosate, followed by full cultivation sowing. The use of no-till seeders removes this second knock so an application of Spray Seed® or paraquat 5–10 days after the glyphosate and just prior to planting will control the survivors of the glyphosate application. Using a pre-emergent herbicide followed later in the season by a post-emergent herbicide can be considered a double knock if targeting the same weed species.

Thoroughly cleaning farm machinery can reduce the spread of resistant or troublesome weeds between and within farms.

PHOTO: NICOLE BAXTER



Keeping seedbanks small reduces the chances of resistant weeds being present when herbicides are applied. This will vary with weed species and herbicide MOA group. For example, with annual ryegrass the gene for Group B resistance has an average initial frequency of 1 in 15,000, making it common in annual ryegrass populations, while the average initial frequency of the gene for glyphosate (Group M) resistance is about 1 in one billion, making it rare.

A smaller seedbank also means a smaller potential weed problem.

3. Use as many weed control tactics as possible

Effective crop competition is the start of good weed control. Choosing the best adapted variety and sowing quality seed on time at the optimum depth for the conditions with the best nutrition gives all weed control tactics a head start.

Tactics suitable for weed control in canola include:

- Burning previous crop residues to kill weed seeds. This must be planned before harvest of that crop.
- Herbicides:
 - knockdown;
 - pre-sowing;
 - post-emergent; and
 - harvest-aid or salvage spray – as long as weed seed set is controlled.
- Wick wiping – applying glyphosate through a wiper to control weeds that are taller than the crop.
- After harvest – applying a knockdown herbicide for late emerging and maturing weeds
- Green or brown manure – where there has been a ‘blow-out’ of herbicide resistant weeds.
- On-farm hygiene – sow weed-free seed, clean machinery

Table 8.3 Weed control options other than selective herbicides

| Crop system | Additional weed control options |
|-------------|--|
| 1 | Pre-sowing control, competitive crops, burning header trails and weed seed collection at harvest. |
| 2 | Pre-sowing control, competitive crops, burning header trails, weed seed collection at harvest, and crop topping of pulse crops. |
| 3 | Pre-sowing control, competitive crops, burning header trails, weed seed collection at harvest, crop topping of pulse crops and silage/hay production or brown/green manuring. |
| 4 | Pre-sowing control, competitive crops, burning header trails, weed seed collection at harvest, crop topping of pulse crops, silage/hay production or brown/green manuring and pasture topping, grazing management, ‘winter cleaning’ and fallow. |

before entering property or from paddock to paddock, weed-free fence lines and roadsides.

The more diverse the crop system, the more applicable the cultural options become. Below are four possible crop systems:

1. Cereal-canola-cereal-cereal-canola
2. Cereal-canola-cereal-pulse-cereal-canola
3. Cereal-canola-cereal-pulse-forage-cereal-canola
4. Pasture-pasture-pasture-canola-cereal-pulse-cereal-pasture-pasture-pasture.

Crop system 1 is used more often than the more diverse systems because of its higher short-term returns. However, the more diverse systems, especially those including a forage or pasture phase, have the longer-term benefit of a lower risk of developing herbicide resistance and more opportunities to control weeds. Table 8.3 demonstrates that more diverse cropping systems allow for a wider range of weed control tactics, particularly non-herbicide tactics.

9. Pests of canola and their management

Greg Baker, SARDI

A number of insects and mites can damage canola crops. Most are usually of only limited importance. Some, such as the redlegged earth mite, blue oat mite, lucerne flea, cutworms, aphids, Rutherglen bug and caterpillars of diamondback moth, corn earworm and native budworm, cause severe and widespread losses in some years. Significant damage is most likely to occur during establishment and from flowering until maturity. Growers should be prepared to treat each year at, or soon after, sowing to control mites and budget for an aerial spray between flowering/podding and maturity.

CULTURAL CONTROL OF ESTABLISHMENT PESTS

Canola crops often follow a pasture phase. Pasture is the natural habitat of some establishment pests, including redlegged earth mite, blue oat mite and false wireworms. These pests can be reduced by a period of fallow between cultivation of the pasture and sowing of the crop.

Early ploughing and maintaining a clean fallow by occasional cultivations are often beneficial. Weedy fallows and the retention of cereal stubble can promote pest build-up or provide shelter for pests.

Many weeds provide food for insect pests. Large populations may develop or shelter in grassy or weedy headlands and then move into nearby crops. Clean cultivation of headlands during summer and autumn stops pests from breeding or sheltering there.

ESTABLISHMENT PESTS

Regular monitoring is essential to detect pest activity early before significant damage to germinating canola can occur. Once canola seedlings are severely damaged they do not recover. Many of the establishment pests can quickly create large bare areas which will require resowing.

The damage caused to germinating canola by a number of pests (for example, several false wireworm species, slugs, common white and white Italian snails, European earwigs) can be difficult to distinguish and therefore attributed to the wrong pest. Correct identification of canola pests and pest damage is vital to ensure appropriate management.

Redlegged earth mite (*Halotydeus destructor*) and blue oat mite (*Penthaleus major*, *P. falcatus*, *P. tectus* sp. n.)

Both redlegged earth mite (RLEM) and blue oat mite (BOM) (a complex of several species) feed on the cotyledons and

leaves of seedlings by a rasping and sucking action. Heavily infested plants have mottled and then whitened cotyledons and leaves. Very severely damaged plants die and severely damaged plants usually remain stunted and weak. Sometimes the seedlings are killed before they emerge.

The mites normally feed from late afternoon until early morning but in calm, overcast weather feeding continues



Mites attack seedlings as soon as, or even before, they emerge, weakening or even killing them.

PHOTO: A. PHILBY, NSW DPI



Redlegged earth mite. Actual length 1 mm. Silvery patches indicate mite damage.

PHOTO: R. COLTON, NSW DPI



Damage from earth mite feeding. Note white-silvering effect.

PHOTO: P. UMINA, UNIVERSITY OF MELBOURNE



during the day. They are very active and when disturbed on a plant will drop or descend to the ground and quickly hide in the soil or under vegetation.

RLEM and BOM are similar in appearance in all their life stages and they both prefer light, sandy or loamy, well drained soils. They often occur together in crops and pastures on the tablelands, slopes and plains of southern NSW, where they may cause crop damage. In northern NSW, BOM causes all of the mite damage to canola. In some regions of northern NSW, BOM is more tolerant to the registered insecticide rates that may result in chemical control failures.

Canola is a good host for breeding of *P. falcatus* and RLEM, but *P. major* and *P. tectus* sp. n. cannot successfully breed in canola. It may therefore be an ideal crop in rotation programs where either *P. major* or *P. tectus* sp. n. is prevalent.

Both adult mites are eight-legged, oval shaped and about 1 mm long. Redlegged earth mites have somewhat flattened black bodies and pinkish orange legs and mouthparts; blue oat mites have rounded, dark blue to black bodies, bright red or bright pinkish red legs and mouthparts, and a red spot in the centre of the lower back.

Both RLEM and BOM survive over summer as eggs. With RLEM, the final generation adults produce these eggs (known as aestivating or diapause eggs) in mid to late spring. By contrast, BOM produce aestivating eggs in autumn almost immediately after emergence and continue

producing these eggs throughout the period when adults are active. Neither the RLEM or BOM eggs hatch until favourable conditions of temperature and moisture occur in the following mid autumn to early winter. BOM eggs generally hatch in autumn earlier than those of RLEM. Both RLEM and BOM develop through two to three generations a year.

Control of RLEM the previous spring. The size of the overwintering RLEM egg population can be greatly reduced by treating mite-infested pasture paddocks with a systemic (foliage absorbed) insecticide during August or early September, the year before sowing. If this management procedure is not carried out, canola sown into pasture paddocks is at risk from RLEM. To help achieve the optimal spray date consult the TIMERITE® website (www.timerite.com.au). Because BOM can produce overwintering eggs from autumn through to spring, chemical control strategies aimed at reducing the spring diapause generation do not work for this species.

Control at sowing. Three insecticidal control tactics are available:

1. Sowing insecticide-treated seed
2. Bare-earth spraying the soil surface immediately after sowing
3. Spraying the seedling foliage with a systemic insecticide. For this tactic to be effective the mites must be detected early. Monitor carefully for mites every two or three days by estimating mite numbers in a 10 x 10 cm (100 cm²) ground area. Repeat at 5–10 sites in the crop. Avoid monitoring in bright light by choosing cloudy days and/or early morning or late afternoon. Treat if 10 or more mites are found per 100 cm² sample.

Cutworms (*Agrotis* spp.)

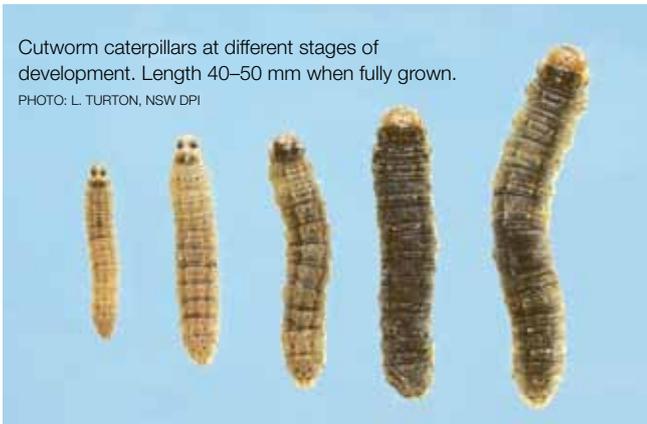
Cutworm caterpillars can occasionally cause serious damage. They climb the seedlings and young plants and eat the leaves, or cut the stems near ground level and eat the top growth.

Large patches of the crop may be damaged if caterpillars are numerous during establishment. They usually feed in the evening and at night and sometimes pull the young plants into the ground.



A cutworm caterpillar feeding on young canola seedlings.

PHOTO: J. SYKES, NSW DPI



Cutworm caterpillars at different stages of development. Length 40–50 mm when fully grown.
PHOTO: L. TURTON, NSW DPI



Larvae and adults (below) of bronzed field beetle.
PHOTOS: G. BAKER, SARDI



A false wireworm larva (about 40 mm long) with the remains of a canola seedling.
PHOTO: J. SYKES, NSW DPI



Inspect emerging and established crops in the evening, or at night, for cutworms. The caterpillars are 40–50 mm long when fully grown and grey-green, dark grey or nearly black, often with dark spots on the back and sides of the body. Treat promptly when they are feeding. Spot spraying may be all that is needed.

False wireworms (family Tenebrionidae); including bronzed field beetle (*Adelium brevicorne*) and grey false wireworm (*Isopteron punctatissimus*)

False wireworms have become a serious pest of germinating canola, probably due to the increased use of minimum or zero tillage. The larvae can stunt or kill the

seedlings by feeding on their roots and stems (seedling part attacked depends on the wireworm species), which may result in light thinning of the crop through to destruction of large areas (bare patches). Because different species can differ in their feeding behaviour, correct species identification of wireworm larvae is critical for choosing appropriate control methods.

Clean cultivating paddocks and headlands can control false wireworms during summer and autumn. The overwintering beetles must eat to live and, in the absence of shelter and food plants, they either die or disperse to more suitable areas.

Examine the soil for false wireworms before sowing because treatment after sowing is not practicable. The larvae are usually found at the junction of the loose, drier cultivated soil and the undisturbed moister soil below. They have hard, round, smooth, yellow-brown or blackish bodies with pointed upturned tails or a pair of raised spinelike processes on the end segment and are 8–40 mm long when fully grown.

Soil-incorporated insecticides used prior to sowing and seed dressings are commonly used to prevent larval attack. Broad-scale use of insecticides may have a severe impact on non-target organisms.

Post-sowing compaction may improve seedling vigour and germination while blocking the pathways and cracks used by the larvae.

The larvae of bronzed field beetle chew stems of young canola plants at ground level, causing plant death. The larvae are dark brown and grow up to 11 mm long and

Damage to young canola from bronze field beetle larval feeding. Note larvae on soil surface at base of plant.
PHOTO: A. DORE, DAFWA



Larva of vegetable weevil; about 13 mm long when fully grown.
PHOTO: L. TURTON, NSW DPI



Adult vegetable weevil.
PHOTO: SARDI



Brown pasture looper. Length 35–40 mm when fully grown.
PHOTO: L. TURTON, NSW DPI

2–3 mm wide, with two distinct upturned spines on the last body segment. They are often confused with grey false wireworm. Pupation occurs during August. The adults are up to 11 mm in length and shiny black with a slight bronze appearance. Over the summer and autumn they shelter in crop residues or tufts of grass. They become active after autumn rains and commence egg laying. Approximately 15 adults per m² can produce more than 1500 larvae, enough to seriously damage most canola crops. Pupation generally starts in August and extends to the end of October.

Check young canola crops regularly for signs of damage. Larvae actively feed during the night and shelter under clods of soil and stubble during the day. A reduction in larval numbers can be achieved by:

- removing crop residues through cutting, burning or grazing;
- cultivating prior to seeding;
- increasing the sowing rate, which may compensate for damage; and
- applying insecticide surface treatment.

Grey false wireworm has a similar lifecycle to bronzed field beetle. The adults are smaller and browner in appearance. The larvae of both species are similar in appearance, except grey false wireworm larvae are slightly smaller, flatter and faster moving. However, they differ in their feeding damage. Grey false wireworm larvae never feed at the surface, rather, they ringbark the hypocotyl and root of the germinating seedlings below ground level. High larval numbers (50/m²) can cause major losses to canola seedlings. Once the damage has become obvious, it is too late to treat the crop.

To detect grey false wireworm larvae prior to sowing, do either one of the following:

- bait using oats or canola grain (200–300 g) pre-soaked for 24 hours. The grain is buried (50 mm deep) and randomly placed (5–10 sites) across the paddock. After seven days examine the baits for presence of larvae; or
- carefully look in the top 20 mm of soil in a 30 cm x 30 cm quadrat, randomly placed (5–10 sites) across the paddock. Count and record the number of larvae.

Vegetable weevil (*Listroderes difficilis*)

The larvae and adults feed on the leaves of the seedlings. They usually feed in the evening and at night and shelter by day in the soil near affected plants. Damage can be severe if the larvae or adults are numerous and seedling growth is impaired by adverse weather.

Check emerging crops in the evening or at night for larvae and adults. Infestation is often confined to the edge of the crop so border spraying may be all that is needed. Treat in the evening or at night.

The legless larvae are about 13 mm long when fully grown with curved green, yellow-green or cream bodies and dark heads. Adult weevils are about 8 mm long and dull greyish-brown with prominent snouts.

They have a V-shaped, pale mark near the middle of the back and a small pointed process towards the rear of each wing case.

Bare following of infested paddocks and eliminating weeds and grasses from headlands can control the vegetable weevil in late spring and summer. The overwintering weevils must eat to live and in the absence of shelter and food plants they either die or disperse to more suitable areas.



Lucerne flea.
PHOTO: SARDI



The grey-coloured
reticulated slug.
PHOTO: G. BAKER, SARDI

Mandalotus weevils (*Mandalotus* spp.)

A complex of native weevil species in the genus *Mandalotus* has been reported causing serious damage to germinating canola in parts of SA and NSW. They are usually associated with lighter soils.

At time of publication no registered insecticide treatments were available. Consult your local agronomist/consultant for control advice.

Brown pasture looper (*Ciampa arietaria*)

The late-stage caterpillars sometimes move into young crops and severely defoliate the plants. Capeweed is a preferred food plant and infestations are likely to be confined to areas around the edges of crops, or within crops, near patches of this weed. Spot or perimeter spraying is usually all that is required.

The caterpillars, which reach 30–40 mm long when fully grown, crawl with a looping motion. They have yellow-brown heads and are grey to dark brown with a pale stripe down each side of the back and a row of reddish spots along each side of the body.

Lucerne flea (*Sminthurus viridis*)

Lucerne fleas are small (2–4 mm), globular, wingless yellow-green insects, which prefer lucerne and clovers, but can attack annual winter crops including canola. They feed on green leaf tissues, leaving a thin transparent 'window'. The growth of seedling canola can be retarded, and in heavy infestations seedling death can occur. From a distance severely affected crop areas can appear to be bleached. Lucerne fleas are usually associated with heavier soils and prefer cool, moist conditions.

Lucerne fleas hatch from overwintering eggs following the first significant autumn rains. Several generations develop over winter.

Monitor crops frequently at germination and in the following weeks. Working on hands and knees, look for fleas, checking the soil surface where they may shelter and the plants for tell-tale signs of their feeding. Unfortunately, there are no specific thresholds for lucerne flea damage in canola. However, if control appears warranted, spray as early as possible because of the risk of damage retarding crop vigour.

Aphids (as vectors of canola viruses)

The common aphid species of canola are cabbage aphid, green peach aphid and turnip aphid. Cowpea aphid also colonises canola at times.

Aphid densities in canola crops during the vegetative phase are generally insufficient to cause crop loss from feeding damage. The exception may occur in dry winters when aphids can be very abundant. Early colonisation by virus-infected aphids, however, can result in canola yield losses due to viral infection.

Beet western yellows virus (BWYV) is the most common virus in WA canola crops. BWYV is persistently transmitted by green peach aphid. Yield losses of up to 50 per cent from the combination of BWYV and green peach aphid have been recorded in WA with infections very early in the growth of the crop. Viruses present in canola crops in NSW, Victoria and South Australia include BWYV, *Cauliflower mosaic virus* (CaMV) and *Turnip mosaic virus* (TuMV). The green peach and cabbage aphids transmit all these viruses. Turnip aphid transmits CaMV and TuMV. Cowpea aphid transmits BWYV. A seed-applied insecticide treatment is available for canola aphid control.

Slugs: reticulated slug (*Deroceras reticulatum*) and black-keeled slug (*Milax gagates*)

The main slug pests of canola crops in southern Australia are the grey-coloured reticulated slug and the black-keeled slug. Other pest slug species found in canola crops include *Deroceras panormitanum*, *Lehmanna nyctelia* and *Arion intermedius*. These slugs can feed both above and below the ground in the emerging canola crop, damaging leaf margins, fully removing cotyledons and chewing through stems.

Slugs prefer heavier soils, particularly those that form cracks or large clods. Slug damage is more common in high rainfall districts and along road verges or fencelines, where slugs enter from an adjacent pasture or stubble, but extensive damage can also occur in drier areas and in the centre of crops. The less tillage and greater stubble retention of conservation farming are allowing more slugs to survive and breed.

Damage often goes undetected when the crop is emerging and resultant poor establishment is incorrectly attributed to agronomic factors. Baiting is often applied too late and crops need to be resown.

The key to controlling slug infestations in canola is monitoring. Inspect crops closely for signs of seedling destruction as most slug activity occurs at night and failure of seedlings to appear may be mistaken as slow germination. If seedling cotyledons are destroyed, the plants will not recover.

Inspect crops after sunset, and/or set baiting stations along fencelines when the soil surface is visibly moist by applying bait under a hessian bag or pot. If slugs are caught at bait points, baiting of the crop is recommended before, or at seeding. Either bait the affected area, which is often along fencelines from adjoining pasture, or bait the whole crop if the bait stations reveal an extensive problem. Treat borders with higher rates of baits when slug numbers are high. Assessing paddocks for the risk of slug damage in the year before a vulnerable crop such as canola will allow early and precise action.

Slug bait pellets may be effective for about a week so successive applications at a lower rate (5 kg/ha) may be more economical than higher rates, especially if rain is

forecast. Broadcast pellets evenly on the surface before the crop emerges, not underground with the seed, where the slugs are less likely to find them. Monitor crops at five to six-day intervals up to fourth true leaf stage and repeat baiting if significant infestations of slugs are detected.

Snails: common white snail (*Cer­nuella virgata*), white Italian snail (*Theba pisana*), conical snail (*Cochlicella acuta*) and small conical snail (*Cochlicella barbara*)

Four snail species are pests in the southern Australian cropping system. Two species are round (the common white and White Italian snails) and the other two are conical. These species differ in behaviour, the damage they cause and their management tactics. Knowledge of the type of snails present (round or conical), the number of each type and the sizes present is necessary before appropriate management can be implemented.

Following sufficient autumn rains, these snails commence egg laying, which may continue from April to September.

Table 9.1 Snail pests in southern Australia

PHOTOS: SARDI

| Snail species | Distribution | Appearance | Food source | Attacks young canola | Grain contaminant | Oversummer site | Management notes [†] |
|---|---|---|---|----------------------|-------------------|------------------------------|--------------------------------------|
|  | SA, VIC, also WA, NSW, east Tas | Round, open, circular umbilicus. | Dead organic matter (plus green plant material) | Yes | Yes | Up on plants, stubble, posts | |
|  | Coastal areas of SA, NSW, VIC, WA and east Tas | Round, semi-circular or partly closed umbilicus | Green plant material and dead organic matter | Yes | Yes | Up, plus on weeds. | Brown-out weeds |
|  | Yorke Pen., SA, also other parts of SA, VIC, NSW and WA | Conical (up to 18 mm length) | Dead organic matter | No | Yes | Up, but often near ground | Cabling and exposing rocks important |
|  | SA, NSW, VIC and WA (mainly higher rainfall areas) | Conical (up to 8–10 mm length) | Dead organic matter and green plant material | No | Yes | Low to ground | Cabling and exposing rocks important |

[†] These are species-specific techniques. Stubble management, burning and baiting are applicable for all four species.



Controlling snails before, or soon after, egg laying commences is essential.

Eggs hatch after about two weeks and round snail hatchlings are up to 1.5 mm in diameter.

Monitoring can help target control to areas of high snail density. Key monitoring times are as follows:

- January/February to assess options for stubble management;
- March/April to assess options for burning and/or baiting;
- May to August to assess options for baiting, particularly along fencelines; and
- three to four weeks prior to harvest to assess the need for header modifications.

Year-round management of snails is required for control of large snail populations. Applying controls before egg laying commences is essential to minimise increases in populations. Monitor live snail numbers per square metre before and after snail control treatments. Use a 30 cm x 30 cm quadrat to estimate numbers per unit area.

Stubble management. Cabling is the most effective treatment when there are surface stones etc. Treatments are most effective at temperatures above 35°C. Repeating stubble treatments will increase snail mortality but overnight moisture, summer weeds and heavy mulch on the soil surface may reduce it.

Burning. Use burning strategically. It may not be required every year and may increase the erosion risk. Summer weeds and stones will reduce the snail kill. Protect burnt and snail-free areas from re-invasion by strip baiting snails.

Baiting. Use summer stubble treatments to lower snail numbers before baiting. Snails must be active and conditions cool and moist for five to seven days. Distribute bait evenly and complete at least eight weeks before harvest due to risk of bait/residue contamination in grain. In emerging canola crops, five snails/m² is the baiting threshold. Baiting is very effective when snail numbers are below 80/m². The following guidelines are recommended:

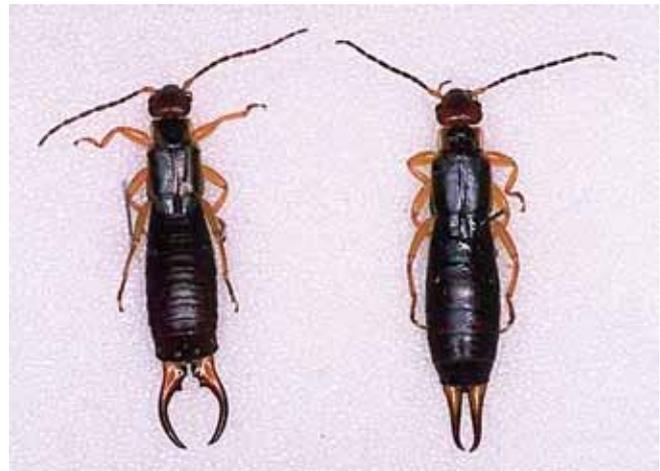
- 5–80 snails/m² – apply bait at 5 kg/ha
- more than 80 snails/m² – apply bait at 10 kg/ha.

European earwig (*Forficula auricularia*)

European earwig is an introduced pest that continues to extend its distribution across southern Australia. It is more prevalent in cool, higher-rainfall districts and appears to be favoured by the lesser tillage and greater stubble retention of conservation farming. Immature and adult earwigs can occur in high densities in germinating canola where they lop young plants off at ground level, making re-seeding necessary.

European earwigs grow to about 16 mm long. Like other earwigs they have a strong pair of terminal, moveable forceps. They are nocturnal, sheltering under clods of soil, stones and other debris during the day. They feed on a wide range of food types including leaf litter and other organic matter, seedling plants, flowers, fruits and other insects, particularly aphids.

If present in high densities they can also damage



Male (left) and female (right) European earwig.

PHOTO: DAFWA



European earwig damage to rosette-stage canola foliage.

PHOTO: A. DORE, DAFWA



Slaters normally feed on decaying organic matter but have been observed feeding on canola seedlings when in very high densities.

PHOTO: A. WEEKS, CESAR CONSULTANTS

mature windrowed canola by feeding on the pods and may contaminate the harvested grain.

No insecticides are registered for the control of European earwigs in canola.

Slaters (*Australiodillo bifrons* and *Porcellio scaber*)

Slaters (including the indigenous *Australiodillo bifrons* and the introduced *Porcellio scaber*) primarily feed on decaying and rotting organic matter but at high densities they can damage seedling canola and cereal crops, leading to reduced yields. Adult slaters (also known as woodlice and flood bugs) are light brown, oval shaped, about 10–15 mm long and 6 mm wide with multiple pairs of legs.

A. bifrons feeding causes ‘windows’ of transparent leaf membrane similar to lucerne flea damage. Damage thought to be caused by *P. scaber* is similar to slug and snail damage, giving leaves a rasped and shredded appearance. Populations of the introduced species *P. scaber* are often initially confined to relatively small areas, having spread from



Cowpea aphid.
PHOTO: G. BAKER, SARDI



previous accidental introductions via external sources such as pot plants, machinery or hay.

They appear to be favoured by moist soil conditions, and by high stubble residues associated with minimum or zero till. During daytime they usually shelter in damp shaded places under stones etc. and hence may be difficult to find on the seedlings.

Where damage to canola has occurred in WA, it is mostly associated with very high slater populations and where there has been at least 4–5 t/ha of straw. Problems have been known to occur even after burning stubbles.

Foliar sprays, bare-earth chemical treatments and snail/slug pellets have been trialled with varying degrees of success.

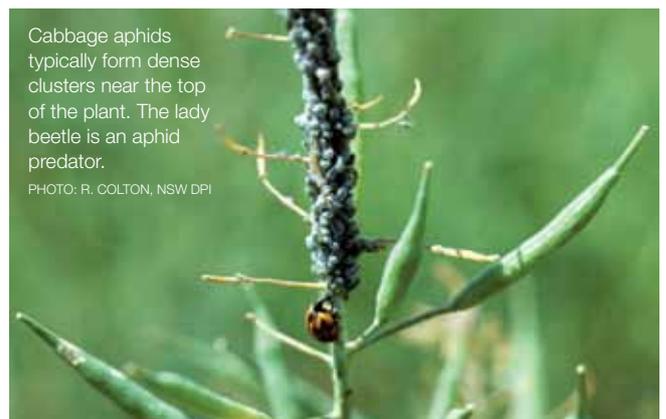


(Top) cabbage aphid, green peach aphid (centre) and turnip aphid (below).
PHOTOS: G. BAKER, SARDI

PESTS AT FLOWERING AND CROP MATURITY

Cabbage aphid (*Brevicoryne brassicae*); turnip aphid (*Lipaphis erysimi*); green peach aphid (*Myzus persicae*) and cowpea aphid (*Aphis craccivora*)

Infestation is most common from flowering to podding. Dense clusters feeding on the upper stems, flower heads and developing seed heads can seriously reduce pod set, pod fill, seed quality and viability. Yield losses of up to 33 per cent have been recorded.



Cabbage aphids typically form dense clusters near the top of the plant. The lady beetle is an aphid predator.
PHOTO: R. COLTON, NSW DPI



Winged aphids migrate into young canola from autumn weeds. Early control of *Brassica* weeds (for example wild radish, wild turnip) on the property can help limit canola colonisation by aphids. Early sowing can enable the crop to begin flowering before aphid densities peak. However, sowing earlier also creates a risk that crops will be vulnerable to autumn aphid flights, which may result in the early establishment of diseases and increased potential for their spread in spring.

Dry weather favours aphids, which develop more rapidly on drought-stressed plants. Cold, wet winter weather retards their increase. Initially only small groups of plants scattered through the crop may be affected. The rate of increase and spread of aphids within the crop varies greatly, but sometimes occurs very rapidly.

Monitor crops at least twice a week during flowering and podding to observe changes in aphid numbers on flower heads. Check at least five scattered sites in the crop and look for aphids on at least 20 plants at each site. If more than 20 per cent of plants are infested and biological control agents (lacewings, ladybirds, hover fly larvae, tiny parasitic wasps and fungal diseases etc) are not very active, consider control measures.

Early-sown crops often escape infestation because they flower before aphid build-up occurs. However, the frequency of seasonal infestation has increased in recent years. Warm, dry conditions are conducive to aphid build-up. In northern areas, milder winter and spring weather may induce early aphid build-up and necessitate more frequent spraying.

Diamondback moth (cabbage moth) (*Plutella xylostella*)

Diamondback moth (DBM) is the main pest of *Brassica* crops worldwide. It is difficult to control with insecticides because it develops rapidly through an ongoing series of overlapping generations and has great ability to evolve resistance to insecticides.

DBM feed on a wide range of *Brassicaceae*, including vegetable and herb crops, seed crops, fodder crops and weeds. The source of DBM on canola may be local (*Brassica* weeds and volunteer canola), or from other regions.

In canola, the caterpillars make clear, membranous 'windows' and small holes in the leaves and also graze on the stems and pods. Severe defoliation and pod grazing during flowering, pod formation and pod filling reduces seed yield. Sometimes large numbers of caterpillars may develop on the foliage after flowering without causing harm, but then they move to the pods and rapidly cause damage.

The caterpillars are 10–13 mm long when fully grown and have slender, pale-green bodies that taper towards each end. They wriggle violently when disturbed on a plant and may drop to the ground or hang suspended by a silken strand.

Dry warm conditions favour DBM. Rainfall causes direct mortality by dislodging and drowning larvae, and when accompanied by warm temperatures (18–25°C) can induce fungal disease outbreaks that devastate DBM infestations. Drought conditions mobilise nitrogenous compounds in the



Diamondback moth larvae killed by the fungal pathogen *Zoophthora radicans*.
PHOTO: G. BAKER, SARDI



Diamondback moth adult and fourth-instar larvae (above).

PHOTOS: M. KELLER, UNIVERSITY OF ADELAIDE



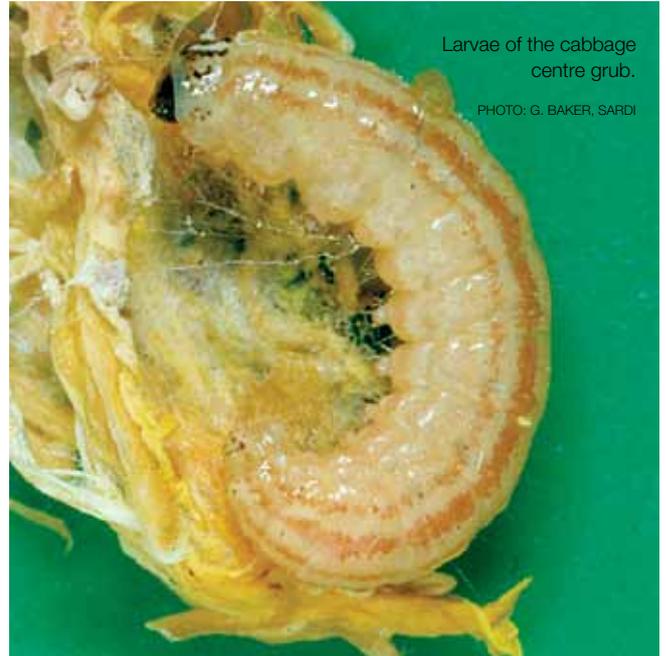
Damage to flower-head (left) and pods (below) from feeding of diamondback moth larvae.

PHOTOS: G. BAKER, SARDI

plants, which may stimulate DBM growth and development.

Monitor crops regularly from flowering and podding until windrowing for caterpillars and their damage. Check by sweep-netting at 5–10 sites in the crop to determine the severity and extent of the infestation. Sometimes damaging populations can develop very rapidly. If 50 or more caterpillars per 10 sweeps are found, WA entomologists recommend increasing the monitoring to every three days. If, over the next week, the density rapidly increases to 80–100 caterpillars per 10 sweeps, spray. If the density remains about 50–70 caterpillars per 10 sweeps, keep monitoring frequently. In this latter circumstance the DBM infestation often stabilises and declines without the need to spray.

Moderate levels of synthetic pyrethroid resistance have been recorded in many DBM populations collected from canola in recent years (1999–2008). The combination of moderate resistance and the sub-optimal spray coverage that is often achieved in dense stands of canola sprayed at around 100 L/ha, often results in poor control.



Larvae of the cabbage centre grub.

PHOTO: G. BAKER, SARDI



Native budworm moth resting with the forewings slightly parted. The outer margin of the hindwing is uniformly dark.

PHOTO: L. TURTON, NSW DPI



Corn earworm moth resting with the forewings slightly parted. The pale patch, or the two spots in the dark outer margin of the hindwing, is exposed.

PHOTO: L. TURTON, NSW DPI

Heliothis caterpillars (family Noctuidae); corn earworm (*Helicoverpa armigera*); native budworm (*H. punctigera*)

Heliothis caterpillars, especially those of the native budworm, can extensively damage canola crops in some seasons. Infestation can occur at any time from flowering and podding until the seedheads have dried off after windrowing, but it is most common during flowering to podding. Caterpillars less than 10 mm long normally feed on the foliage, but larger ones also chew holes in the pods and eat the seeds. Loss of foliage usually does not matter, but heavy damage to the pods severely reduces yield.

Occasionally, heliothis caterpillars are particularly abundant in canola crops during flowering to podding in many areas. This can be due to the combined effect of two or more of the following factors — concurrent drought conditions, concurrent heavy aphid infestation and absence of more attractive nearby crops (for example, grain legumes) to divert the egg-laying moths away from canola.

Heavy aphid infestations and hot dry weather appear to favour heliothis because the egg-laying moths are attracted to the aphid honeydew as a source of food. The aphids also provide an alternative prey for predators that would otherwise feed on heliothis eggs and small caterpillars. The hot dry weather is detrimental to the wasps which parasitise the eggs and young larvae.

Examine crops at regular intervals from flowering to podding for moths and young caterpillars.

Moth activity alone cannot be taken as a guide for spraying. Base spray timing on careful observation of the extent of caterpillar infestation in the crop. Check plants in a large number of sites at random for caterpillars and pod damage. Sweep the borders of dense crops with a butterfly net or shake plants in thinner crops over a white fertiliser





Egg and six larval instars of native budworm.

PHOTO: G. BAKER, SARDI

(Below) *Heliothis* caterpillar and pod damage in canola.

PHOTO: R. COLTON, NSW DPI

Cabbage white butterfly (centre) and looper caterpillar (bottom).

PHOTOS: G. BAKER, SARDI



bag or plastic tray.

Newly hatched *Heliothis* caterpillars are 1–1.5 mm long with dark heads and dark-spotted, whitish bodies. Young caterpillars are 10–20 mm long and pale yellow, greenish or brownish with dark heads, conspicuous upper body hairs and often have narrow, dark stripes along the back and sides of the body.

The threshold for treatment is five or more 10 mm long pod-feeding caterpillars per square metre.

(Below) Rutherglen bugs feed on the pods, reducing the weight and oil content of the seeds.

PHOTO: R. COLTON, NSW DPI



(Above) Rutherglen bug nymphs can cause similar damage to that caused by adults.

PHOTO: R. COLTON, NSW DPI

Cabbage centre grub (*Hellula hydralis*), cabbage white butterfly (*Pieris rapae*), and looper caterpillars (*Chrysodeixis* spp.)

These three caterpillar species may be found in canola crops but generally occur at low, sub-economic densities. Larvae of cabbage centre grub have dark heads and longitudinal reddish-brown stripes. They are usually found on the foliage, especially on the basal leaves, but also attack the young floral parts. Cabbage white butterfly are creamy-white and commonly seen flying in the crop or visiting nearby flowers. Cabbage white butterfly larvae are velvety leaf-green, with a pale-yellow stripe along the middle of the back and each side, and when fully grown are about 3 cm long. They are slow moving and eat ragged holes out of the foliage, but do not attack the floral parts. Looper caterpillars are grass-green, smooth and slender, and move with a characteristic looping action. They feed on foliage and fully grown are about 2.5–3 cm long.

Seed bugs (family Lygaeidae); Rutherglen bug (*Nysius vinitor*) and grey cluster bug (*N. clevelandensis*)

Rutherglen bug is usually the most important pest. It will attack crops at any time from flowering and podding until the seedheads have dried off after windrowing.

The adults and nymphs suck sap from the leaves, stems, flowers and developing and ripening pods and seeds. Heavy or prolonged infestation can severely reduce pod set, pod fill, seed quality and viability.

Regularly check a large number of sites in the crop from the start of flowering until windrowing for adult and nymphal bugs. Infestation is most likely during hot dry weather when damaging populations can build up rapidly. Treatment is warranted if there is an average of 10 or more adults or 20 or more nymphs per plant and the crop is moisture stressed. If necessary, spray before windrowing to prevent damage in windrowed crops.

Adult bugs are about 5 mm long, narrow bodied and grey brown with prominent black eyes. Nymphal bugs are reddish brown, somewhat pear-shaped and wingless.

Plague thrips (*Thrips imaginis*)

The adults and nymphs frequently occur in very large numbers in the flower heads and mainly feed on the stems, flower petals and pollen. They do not affect pollination, pod set or pod fill, but some pods may be distorted.

Adult plague thrips are slender, about 1 mm long and brownish with two pairs of narrow, fringed wings. The nymphs are smaller, yellow or orange-yellow and wingless.

INSECTICIDES

Recommendations change regularly so obtain a copy of your state department's bulletin or chart of current insecticide control recommendations for crop pests.



Canola pods distorted by plague thrips; only the odd plant is affected.

PHOTO: L. TURTON, NSW DPI



Rutherglen bug adult. Length about 5 mm.

PHOTO: L. TURTON, NSW DPI

10. Diseases of canola and their management

Steve Marcroft, MGP; and Tamrika Hind-Lanoiselet, NSW DPI

Canola can be infected by a number of pathogens in Australia, ranging from root rots to leaf disease and crown to stem infections. As with all diseases, their presence and severity depends on plant susceptibility, presence of the pathogen and favourable climatic conditions. Generally, fungal diseases such as blackleg and *Sclerotinia* are more damaging in higher rainfall regions, but if unseasonably high rainfall occurs in lower rainfall regions these areas may also experience high disease levels. Disease control varies for each pathogen but generally variety resistance, crop production practices and fungicides are used, either alone or in combination to reduce economic losses. If growers are aware of the disease risks in their area and follow strategic management plans they should be able to adequately control most canola diseases.

Blackleg caused by the fungus *Leptosphaeria maculans* is the most damaging disease of canola (*Brassica napus*) in Australia and most canola producing countries throughout the world. *Sclerotinia* stem rot and damping-off are other damaging diseases. *Alternaria*, white leaf spot, downy mildew and viruses may be common in some seasons but they do not normally cause significant crop damage. Clubroot has recently been identified in New South Wales and Victoria.

COMMON DISEASES OF CANOLA

Refer to the following sections in this chapter for symptoms and management practices.

| Plant growth stage | Plant part infected | Possible disease |
|--------------------|---------------------|---|
| Seedling | roots | damping-off |
| | hypocotyl | blackleg |
| | leaves | blackleg, white leaf spot, downy mildew |
| Rosette | roots | damping off, blackleg, clubroot |
| | crown | blackleg |
| | leaves | blackleg, white leaf spot, downy mildew, white rust |
| Flowering | roots | blackleg, clubroot |
| | crown | blackleg |
| | leaves | <i>Alternaria</i> , blackleg, white leaf spot, white rust |
| | stem & branches | <i>Alternaria</i> , blackleg |
| Podding | roots | blackleg, clubroot |
| | crown | blackleg |
| | stem & branches | <i>Alternaria</i> , blackleg, <i>Sclerotinia</i> |
| | Pods | <i>Alternaria</i> , blackleg, white rust |

Blackleg

Blackleg, caused by the fungus *Leptosphaeria maculans*, is the most serious disease of canola in Australia. The severity of blackleg has risen in recent years due to increased area and intensity of production. Although not common, yield losses of 50 per cent and greater have been recorded in some seasons with up to 90 per cent yield loss occurring in cases where *L. maculans* has overcome major blackleg resistance genes within certain varieties.

Symptoms and disease cycle

Blackleg survives on canola stubble, producing fruiting bodies that contain large quantities of airborne spores (capable of travelling several kilometres). These dark-coloured raised fruiting bodies (pseudothecia) can be seen easily with the naked eye (see pictures below). Date of spore release from the stubble depends on autumn rainfall. Higher rainfall results in earlier spore release and, consequently, may lead to increased disease severity.

In the autumn and winter, rainfall triggers spore release from the stubble. Within two weeks of spores landing on canola cotyledons and young leaves, clearly visible off-white coloured lesions develop. Within the lesion pycnidial fruiting

Diseases of canola



Stubble with blackleg fruiting bodies that produce wind-borne spores.

PHOTO: B.HOWLETT, UNIVERSITY OF MELBOURNE



Blackleg lesion on leaf, the small black dots are fruiting bodies that produce spores spread by rain-splash.

PHOTO: S. MARCROFT, MGP



Canola plant falling over due to stem canker.

PHOTO: S. MARCROFT, MGP

Root rot form of blackleg (diseased plant on left).

PHOTO: S. SPRAGUE, CSIRO



bodies (dark coloured dots) release rain-splashed spores (see pictures left). Once the lesion has formed, the fungus grows within the plant's vascular system to the crown where it causes the crown of the plant to rot, resulting in a canker. Severe canker will sever the roots from the stem, whereas a less severe infection will result in internal infection of the crown restricting water and nutrient flow within the plant.

In recent years, blackleg symptoms have also been found in the plant roots. This root infection, in severe cases, appears to cause the entire plant to die prematurely. The root rot form of the disease is caused by the same blackleg strains that cause the stem canker. Management practices are the same for both forms of the disease.

Management

Blackleg is the most severe disease of canola but it can be successfully managed by:

- growing resistant varieties;
- avoiding the previous year's stubble; and
- using fungicides in high-risk situations.

Choose a variety with adequate blackleg resistance – the best defence against blackleg is varietal resistance. The Canola Association of Australia (www.canolaaustralia.com) publishes blackleg resistance ratings of all Australian canola varieties in February each year.

Blackleg rating data are collected each year from a number of sites in NSW, Victoria, South Australia and Western Australia. Consult the latest guide as blackleg resistance ratings can change from one year to the next due to changes in the frequency of different blackleg strains).

Isolate this year's crop from last year's canola stubble – varietal resistance alone is not enough to protect your crop from yield loss caused by blackleg. It is also crucial to avoid high levels of disease pressure by reducing exposure to large inoculum loads. In most situations, more than 95 per cent of all blackleg spores in the atmosphere originate from canola stubble that was crop in the previous year. Older stubble does not produce many blackleg spores. Disease pressure falls markedly in the first 200 metres away from last year's stubble and then continues to decline up to 500 m. Therefore, sow crops away from last year's canola stubble. There appears to be little advantage in increasing the isolation distance past 500 m.

Stubble management such as raking and burning or burial can reduce disease pressure by up to 50 per cent. However, it is not known how much stubble must be destroyed to achieve an economic benefit through decreased blackleg severity. Extending the time between canola crops in a paddock rotation does not reduce disease severity due to the wind-borne nature of the spores. Crops that have been sown into two-year-old stubble do not have more disease than crops sown in paddocks with a three-year break from canola.

Some growers have found that planting all their canola crops on one part of the farm in one year and then on the opposite side of the farm in the next year ensures isolation between the crop and the last year's stubble. Anecdotal

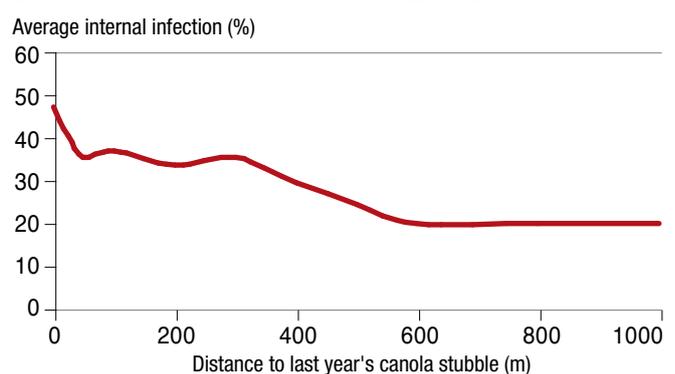
Figure 10.1 2009 CAA blackleg resistance ratings descriptions

| Rating | What do you see? | What do you do |
|---|--|---|
| Resistant (R) | <ul style="list-style-type: none"> Some lesions on cotyledons and leaves. Some internal infection at the base of the plant when cut near maturity. | Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. Fungicide use is unlikely to be economic. |
| Moderately Resistant (R-MR) | <ul style="list-style-type: none"> Lesions on cotyledons and leaves. Some internal infection at the base of the plant when cut near maturity. Some external cankering. | Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. Fungicide use is unlikely to be economic. |
| Resistant to Moderately Resistant (MR) | <ul style="list-style-type: none"> Lesions on cotyledons and leaves. Internal infection at the base of the plant when cut near maturity. Some external cankering. Some plant death in high disease pressure situations. | Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. In high disease risk situations fungicide use may be of economic benefit. |
| Moderately Resistant to Moderately Susceptible (MR-MS) | <ul style="list-style-type: none"> Lesions on cotyledons and leaves. Internal infection at the base of the plant when cut near maturity. External cankering. Plant death will be easily found in high disease pressure situations. | Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. In moderate to high disease risk situations fungicide use may be of economic benefit. |
| Moderately Susceptible (MS) | <ul style="list-style-type: none"> Lesions on cotyledons and leaves. Internal infection at the base of the plant when cut near maturity. External cankering. Plant death will be easily found in moderate to high disease pressure situations. | Avoid high disease pressure. Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. In moderate disease risk situations fungicide use is likely to be of economic benefit. |
| Moderately Susceptible to Susceptible (MS-S) | <ul style="list-style-type: none"> In low disease pressure situations some lesions on cotyledons and leaves may be found. > Low levels of internal infection. > Low levels of external canker. > Occasional plant death. • If sown in moderate disease pressure situations plant death is likely to be severe. | Recommended for low disease pressure regions only (i.e. low rainfall areas). Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. In moderate disease risk situations fungicide use may be of economic benefit. |
| Susceptible (S) | <ul style="list-style-type: none"> In low disease pressure situations some lesions on cotyledons and leaves may be found. > Low levels of internal infection. > Low levels of external canker. > Occasional plant death. • If sown in moderate disease pressure situations plant death is likely to be severe. | Recommended for low disease pressure regions only (i.e. low rainfall areas). Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. Fungicide use is unlikely to be economic at high or low disease risk situations. If blackleg is causing yield loss consider a more resistant variety in future years. |
| Susceptible to Very Susceptible (S-VS) | <ul style="list-style-type: none"> In low disease pressure situations some lesions on cotyledons and leaves may be found. > Low levels of internal infection. > Low levels of external canker. > Occasional plant death. • If sown in moderate disease pressure situations plant death is likely to be very severe. | Recommended for low disease pressure regions only (i.e. low rainfall areas). Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. Fungicide use is unlikely to be economic at high or low disease risk situations. If blackleg is causing yield loss consider a more resistant variety in future years. |
| Very Susceptible (VS) | <ul style="list-style-type: none"> In low disease pressure situations some lesions on cotyledons and leaves may be found. > Low levels of internal infection. > Low levels of external canker. > Occasional plant death. • If sown in moderate disease pressure situations plant death is likely to be extremely severe. | Recommended for low disease pressure regions only (i.e. low rainfall areas). Do not sow into canola stubble from the previous year. Separate your crop by 500 m from the previous year's stubble. Fungicide use is unlikely to be economic at high or low disease risk situations. If blackleg is causing yield loss consider a more resistant variety in future years. |

evidence suggests that this practice has had positive impacts on canola yields.

Consider fungicide use – fungicides applied as a seed dressing (active ingredient fluquinconazol) or on the fertiliser (active ingredient flutriafol) reduce the severity of blackleg. Both fungicides give initial protection to canola seedlings, which is when the plant is most vulnerable to attack from blackleg. However, fungicides do not always give an economic return. Generally, if varieties with low blackleg resistance ratings are sown in higher rainfall areas or if varieties with good resistance are sown into situations of high disease pressure then fungicides are more likely to provide an economic benefit. The economic viability of using fungicides in other situations should be determined

Figure 10.2 Blackleg disease severity reduces as distance to last season's canola stubble increases



by monitoring the number of cankered plants (see previous picture) in the current season's crop. If more than three per cent of plants are cankered then the use of a fungicide may be warranted in future seasons.

Sclerotinia stem rot

Sclerotinia stem rot caused by the fungus *Sclerotinia sclerotiorum* is a disease that attacks many species of broadleaf plants, including canola, peas, beans, sunflowers, pasture species, weeds and lupins. The disease is sporadic, occurring when environmental conditions are favourable for infection. Prolonged humid (wet) conditions during flowering favour disease development, and yield losses as high as 24 per cent have been recorded in Australia. Anecdotal evidence suggests that losses could be greater in the higher rainfall regions of New South Wales.

Symptoms

Disease symptoms appear in the crop from late flowering onwards, two to three weeks after infection. The fungus produces light-brown discoloured patches on stems, branches and pods. These lesions expand and take on a greyish-white colour. Infected canola plants ripen earlier and stand out as bleached or greyish coloured plants among green healthy plants. The bleached stems tend to break and shred at the base. When an infected canola stem is split open, hard black bodies called sclerotia can usually be found inside. Sclerotia are the resting stage of the fungus and resemble rat droppings. They are dark coloured, either round like canola seed, rod, cylindrical or irregular in shape; 2–4 mm in diameter and up to 20 mm long. In wet or humid weather, a white growth resembling cotton wool can develop on lesions and sclerotia may also develop in this white growth.

Disease cycle

Sclerotia remain viable for many years in the soil. When weather conditions are favourable, they germinate to produce small mushroom-shaped structures called apothecia. These apothecia produce thousands of air-borne spores that can be carried several kilometres by the wind. Spores land on canola petals, germinate, and then use the petal as a nutrient source producing a fungal mycelium. When the petals fall at the end of flowering, they often get caught in the lower canopy of the crop allowing the fungus to grow from the petal into the plant. The canola flowering period is therefore the critical time for *Sclerotinia* infection. Wet weather at flowering enhances germination of the spores and infection.

Management

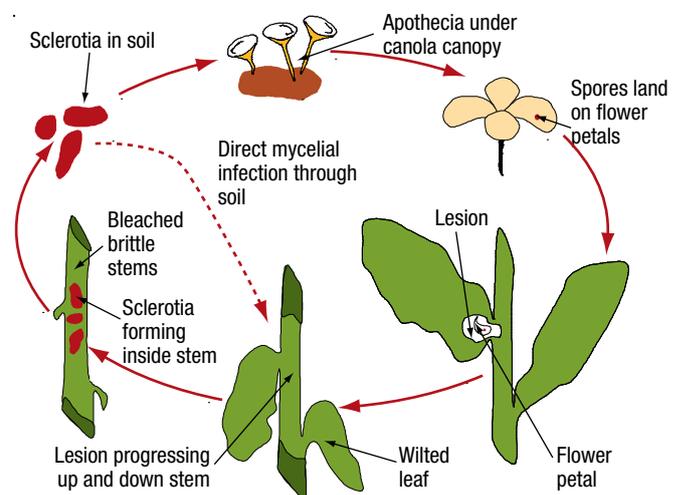
Results from overseas show that the timely application of fungicides during flowering reduces yield losses. In Australia, Rovral® liquid fungicide (active ingredient iprodione) and Sumiscler® broadacre fungicide (active ingredient procymidone) are registered for control of *Sclerotinia* on canola crops.



Sclerotinia stem rot on canola stem.

PHOTO: T. HIND-LAOISELET, NSW DPI

Figure 10.3 Sclerotinia stem rot disease cycle



Use good quality seed that is free of sclerotia. Although there is no canola seed certification for *Sclerotinia* in Australia, careful inspection of seed before sowing will determine if high levels of sclerotia are present.

Sclerotinia does not affect cereals and sclerotia density will decline without a host. A three to four-year break between canola crops and other susceptible crops reduces disease severity.

Control broadleaf weeds to prevent build-up of inoculum and avoid sowing canola next to paddocks that were severely infected with *Sclerotinia* in the previous season.

Alternaria leaf and pod spot (black spot, dark leaf spot, Alternaria blight)

Alternaria is usually caused by the fungal pathogen *Alternaria brassicae* and occasionally by *Alternaria brassicicola*. Canola cultivars are more resistant to *A. brassicicola*. The severity of the disease varies between years and locations depending on seasonal conditions. Warm humid conditions during spring favour the disease. Yield loss is unusual and is normally associated with the shattering of infected pods. If infected seed is sown, seedling blight may occur (refer to damping-off section, page 64).

Symptoms

Alternaria infects all growth stages of canola plants. However, as plants mature from mid flowering onwards they are more susceptible to infection. Alternaria symptoms can occur on all parts of the plant including leaves, stems and pods. Spots on leaves and pods have a concentric or target-like appearance and are brown, black or greyish white with a dark border. Lesions on green leaves are often surrounded by a chlorotic (yellow) halo. Severe pod infections may cause seed to shrivel and the pods to prematurely ripen and shatter. Stem spots are elongated and almost black. Pod symptoms of Alternaria are similar to



Alternaria lesions on the leaf (note target like rings). PHOTO: S. MARCROFT, MGP



Alternaria lesions on pods can lead to premature pod shattering. PHOTO: S. MARCROFT, MGP

those of blackleg and the two can be difficult to distinguish in the field.

Disease cycle

Alternaria spp. survive the intercropping period on infected canola stubble, on cruciferous weeds and, to a lesser extent, on seed. Seed infections can cause seedlings to rot (refer to damping-off section) resulting in a seedling blight that reduces plant establishment. Wind-blown spores cause initial crop infections. Spores remain intact on susceptible plants until moisture from dew or rain allows them to penetrate into the tissue and cause a lesion. These lesions produce further spores and infections can then be spread throughout the crop by either wind or rain. Mild, humid conditions favour disease development and the disease cycle will continue throughout the season under favourable conditions. Hot and dry conditions interrupt epidemics as the absence of moisture greatly reduces spore production. Major outbreaks are not common in Australia as weather conditions are normally warm and dry throughout podding, which is unfavourable for prolonged infection.

Management

- Alternaria is very common in canola crops but is not usually severe enough to warrant control.
- No registered fungicide seed treatments are available for Alternaria in Australia.
- If pods were infected in the previous season, obtain fresh disease-free seed.
- In areas where Alternaria is a problem, select paddocks isolated from last year's canola stubble as Alternaria spores are easily transported in wind and can spread into areas that have not had canola for several years.

Clubroot in canola and juncea canola

Clubroot is caused by the soilborne fungus *Plasmodiophora brassicae*. The disease occurs worldwide and only affects plants in the Cruciferae family including canola, juncea canola (mustard), cabbage, cauliflower, brussels sprouts and broccoli.

In Australian vegetable brassicas, clubroot is widespread and causes significant yield losses. The Australian oilseed industry has been somewhat protected from clubroot as the major production areas for vegetable and oilseed brassicas are usually separated from one another. As well, most Australian pathotypes of clubroot are only able to cause disease in the warmer months and require irrigation water for dispersal, except for Tasmania and some parts of NSW where disease is observed year round.

Symptoms

Swollen, galled roots are the most typical symptom of infected plants. These range from tiny nodules, to large, club-shaped outgrowths. The galls are, at first, firm and white but become soft and greyish-brown as they mature and decay. Affected roots have an impaired ability to transport water and nutrients.

Diseases of canola



Canola roots (above) and mustard roots (below) with severe clubroot infection.



Seedling on left has damping-off symptoms.



Infected seedlings that survive may be stunted and flower prematurely.



PHOTO: S. T. HIND, LANGSELET, NSW DPI

Disease cycle

Resting spores of the fungus can survive in soil for many years, even in the absence of a susceptible host. Infection can occur at any stage of growth and is restricted to the roots. In the presence of susceptible roots, the spores germinate and release tiny motile spores that swim in free water to the surface of the rootlets, penetrate and form a fungal colony (plasmodium) inside the root cells. The fungus causes cells to enlarge and divide rapidly, resulting in the characteristic galls. Late in the season, resting spores develop in the infected roots and are released into the soil as the galls decay. Fields become infested mainly by the movement of soil on cultivation equipment and by seedling transplants.

Management

Several methods of control have been developed in the Australian vegetable *Brassica* industry that may be useful for oilseed *Brassic*as.

- Five-year rotation: infested fields are kept free of susceptible crops and weeds for at least five years to allow sufficient natural decay of the long-lived spores.
- Equipment movement: thoroughly clean cultivating equipment before moving it from infested to non-infested areas.
- Liming: clubroot thrives in acid soils ($\text{pH}_{\text{Ca}} < 7.0$), liming to increase soil pH_{Ca} (7.0–7.5) has been successful for vegetable *Brassic*as but would be cost prohibitive in most areas where oilseed *Brassic*as are grown.

Damping-off (seedling blights and seedling hypocotyl rot)

Damping-off is usually caused by the fungus *Rhizoctonia solani*. However, other fungi including *Fusarium* spp., *Pythium* spp., *Phytophthora* spp., *Alternaria* spp. and the blackleg fungus, *Leptosphaeria maculans*, can also cause damping-off. Symptoms and crop management are similar for all these pathogens so they are grouped together under the term 'damping-off'.

All species are common inhabitants of the soil and cause damage when conditions are not ideal for early seedling growth. Problems are usually seen when seed is sown dry, close to the autumn break (within a couple of weeks of a normal break) or if weather conditions become cool and damp. Yield loss is unusual unless plant numbers are severely reduced or patchy establishment occurs.

Symptoms

Damping-off can produce many symptoms, ranging from pre-emergence rot (failure of plants to emerge) to post-emergence damping-off (plants emerge and collapse at ground level). If affected plants survive, they are normally stunted and may flower and mature prematurely. Once past the seedling stage canola plants are not adversely affected by damping-off. Both pre and post-emergence damping-off occurs in patches and affected areas can spread quickly during cold wet conditions. Leaves of plants affected by post-emergence damping-off may become discoloured, turning orange, purple and/or chlorotic. In some cases, the tap root is dark in colour and shrivelled at ground level. These symptoms should not be confused with insect damage where root or stem tissue has been removed.

Disease cycle

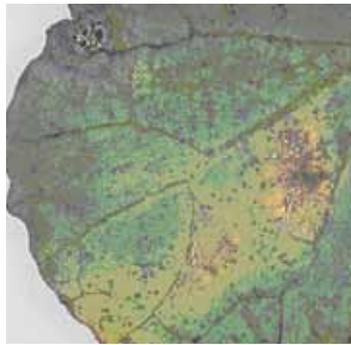
Damping-off fungi are soil-borne and survive in the soil by forming resistant resting structures when no host is present. These resting structures germinate with the break of the season and the fungi grow through the soil until they find a susceptible host plant. Dry seeds become vulnerable to attack as soon as they begin to germinate. Once in the plant, the fungi multiply causing decay that damages or kills the seedling. Damping-off fungi are usually weak pathogens (except blackleg) only able to infect young succulent tissue. At the two to four-leaf stage, below-ground parts of canola plants become woody enough to withstand further infections. Therefore, most damage occurs when wet and cold weather slows plant growth. Temperature and soil moisture affect disease development. Loose, cold and dry soils favour *Rhizoctonia solani*, while cold damp soils favour *Fusarium* spp. and wet, heavy soils favour *Pythium* spp.

Management

- Yields are only affected when plant numbers are severely reduced. If seedling loss is uniform throughout the crop, surrounding plants can often compensate by growing larger. If seedling loss is patchy and large areas die then re-sowing may be required.
- Damping-off fungi will germinate with the opening rains of



Downy mildew on upper side of leaf with chlorotic yellow areas.



Underside of leaf with typical mealy white growth.

PHOTOS: R. COOTTON, NSW DPI

Viruses

The three viruses that infect Australian canola are: *Beet western yellows virus* (BWYV), *Cauliflower mosaic virus* (CaMV) and *Turnip mosaic virus* (TuMV). These viruses are very widespread and surveys have shown that in some situations most crops have some infected plants. As with most viruses, yield loss is very hard to measure so the actual damage to crop production is difficult to determine.

Symptoms

Symptoms vary widely, from no visual indication to stunted red plants and stiffening of leaves for BWYV, chlorotic ring spots and mottling for CaMV and yellow mosaic patterning and tip necrosis for TuMV.

Disease cycle

These viruses are not seed-borne. They survive in weeds or volunteer host plants during the summer and are then spread from these plants into crops by aphids which act as the vector for transmission. BWYV is termed a persistent virus. Persistent viruses are carried in the aphid's body and can be transmitted to healthy plants during feeding. The aphid will often remain infectious throughout its life. CaMV and TuMV are non-persistent viruses, being retained in the aphid mouthparts for less than four hours.

Autumn is the critical infection period, so the earliest-sown crops usually have the highest infection incidence. Yield loss is greater in crops that have been infected as seedlings. Infections can occur past the rosette stage of canola growth but these probably have little effect on yield.

Management

- Control broadleaf weeds (especially over summer) as they can act as reservoirs for viruses.
- Sow at recommended times; earlier sown crops usually have a greater incidence of viral infection.
- Monitor aphid numbers in crops (aphids usually found under leaves) and consider using an insecticide as a foliar (active ingredient primicarb) or seed treatment (active ingredient imidacloprid) to control aphids on seedlings and young canola plants.

White leaf spot

White leaf spot is caused by the fungus *Mycosphaerella capsellae* (also called *Pseudocercospora capsellae*). The disease has a worldwide distribution and a wide host range among cruciferous weeds. In Australia, white leaf spot commonly infects canola seedlings. It is not usually severe enough to cause yield loss.

Symptoms

Leaf, stem and pod lesions are greyish-white to light brown. Unlike blackleg lesions, white leaf spot lesions do not contain pycnidial fruiting bodies (black dots) and usually have a more granular surface. Leaf lesions often have a brown margin when they mature; they can be up to 1 cm in diameter and often join to form large irregular shaped

the season, after which they can be successfully controlled by soil tillage. Dry-sown crops or those sown close to the opening rains may be more severely affected. If crops are re-sown, the sowing tillage will generally control the fungi.

- Application of seed fungicide treatments at sowing can reduce damping-off damage. However, no fungicides are currently registered for damping-off on canola.

Downy mildew

Downy mildew, a common disease of canola throughout the world, is caused by the fungus *Peronospora parasitica*. Infection occurs under cool moist conditions where leaves or cotyledons are in contact with the soil or other leaves. Although the disease can severely attack seedlings, significant yield loss does not usually occur. Downy mildew is rarely found beyond the rosette stage and crops normally grow away from it with the onset of warmer weather.

Symptoms

Chlorotic or yellow areas on the upper leaf surface are the first symptoms to occur. These can be seen on young seedlings when cotyledons or first true leaves are present. A white mealy fungal growth can be seen on the underside of the leaf beneath these spots, if conditions have been moist or if dew periods have been long. Infected cotyledons tend to die prematurely. As the disease develops, individual spots join to form large irregularly shaped blotches. These necrotic lesions may cause a large part of the leaf to dry out and the upper surface to develop a yellow-red colour.

Disease cycle

The fungus, which is both soil and seed-borne, can persist in the soil for a long time. Cool, wet weather favours infection and, under ideal conditions, new infections can develop in as little as three to four days. The fungus is related to white rust with specialised spores (oospores) probably responsible for primary infections. Conidial spores produced on the underside of the infected leaf are then responsible for the secondary spread of the disease.

Management

Downy mildew does not usually affect yield so control is not generally warranted unless plant densities are severely reduced on a regular basis.

- In areas where downy mildew is a severe problem fungicides containing copper as the active ingredient are registered for use in Australia.
- Crop rotation and the control of cruciferous weeds between canola crops can reduce disease severity.

lesions. Nutrient deficient crops have been reported to be more severely affected by the disease. In severe epidemics, infections can defoliate susceptible varieties.

Disease cycle

The fungus survives on canola stubble as thick-walled mycelia. When prolonged wet weather conditions prevail in autumn/winter, wind-borne spores are produced that cause primary leaf lesions on canola. These initial lesions go on to produce new wind-borne spores that cause the rapid spread of the disease throughout the crop. The disease is not usually seed-borne but can be spread by infected seeds or infected debris with the seed.

Management

White leaf spot infection is not usually severe enough to warrant control. Crop rotation and isolation from the previous year's canola stubble will prevent infection from wind-borne spores. Control cruciferous weeds and volunteer canola, and provide adequate nutrition to reduce crop stress.

White rust or staghead

White rust is caused by the fungus *Albugo candida*. The disease is uncommon in Australian canola varieties but does infect *B. juncea* (juncea canola / Indian mustard) and the weed shepherd's purse (*Capsella bursa-pastoris*).

Symptoms

White to cream coloured pustules form on the underside of leaves and on floral parts. These pustules rupture the host epidermis exposing a white chalky dust. On the upper surface of the leaves, the infected areas are bleached and thickened. Systemic infections of the growing tips and flower heads give rise to stagheads. Stagheads are very conspicuous in the crop as swollen, twisted and distorted flower heads that produce little to no seed and become brown and hard as they mature (see photo). Symptoms for white rust should not be confused with symptoms of severe calcium deficiency that cause flowering stalks to collapse, resulting in the withering death of the flower head (see picture).

Disease cycle

Resting spores (oospores) of the fungus can survive in infected plant material or as a seed contaminant for many years when conditions remain dry. When conditions become moist the resting spores are able to directly infect plants. However, they usually produce tiny motile spores that can swim in free water to infect seedlings, causing cream-white pustules to form. Inside the pustules, new swimming spores are formed and then distributed throughout the canopy by rain splash to form secondary infections. They do this by growing through stomata into adjacent cells, causing systemic infections and subsequent stagheads if the growing tips of plants become infected. The resting spores can be formed in any infected tissues but are present in larger numbers in stagheads. When the crop is



White leaf spot infection on a leaf.

PHOTO: M. BARBETTI, DAFWA



Severe white leaf spot infection moving up the plant.



Distinctive white rust staghead on *B. juncea* plant.

PHOTO: S. MARCOFF, MGP



Withertop (calcium deficiency symptom).

PHOTO: P. SAUSBURY, UNIVERSITY OF MELBOURNE

harvested, stagheads break and release resting spores that contaminate harvested seed or blow away to contaminate the soil.

Management

- Obtain seed from disease-free or low-disease crops.
- Control cruciferous weeds.
- Extended rotations will allow crop residues to decompose and reduce the risk of infections.
- Consider growing *B. napus* rather than *B. juncea*.

11. Grazing and fodder conservation

Paul Parker, NSW DPI

In dry seasons, or when spring conditions are poor, growers have a number of options to recoup some or all of their growing costs. Crops can be grazed, made into hay or silage, or left for grain harvest.

The decision will depend on a number of factors, including availability and class of stock, market demand and price of fodder, price of grain, anticipated fodder or grain yield, proximity to markets, and farm operational factors.

Computer software is available on the NSW DPI website (www.dpi.nsw.gov.au) to assist with these decisions.

SOIL CONSERVATION

Grazing or cutting canola usually results in a paddock with minimal ground cover, increasing the risk of soil loss to wind and water erosion. Maintaining some ground cover is advisable otherwise more expensive soil conservation measures such as 'ridging' will be needed if the dry conditions develop into a drought.

GRAZING FAILED CANOLA CROPS

Drought affected or failed canola crops can be grazed by livestock. Experience gained in recent drought years has reduced the risk of stock health problems and stock deaths.

Potential stock health risks

There are some risks to stock health and cases of sickness and sudden death of livestock have occurred, usually when grazing standing crops. However, the number of reported deaths has been very low compared to the area of canola grazed.

Although initially believed to be nitrate poisoning, the more common cause of death has been identified as respiratory distress and failure caused by certain toxic compounds. Other animal health problems recorded in stock fed on a range of *Brassica* crops include:

- respiratory problems from a build-up of fluid on the lungs;
- photosensitisation causing sunburn of exposed skin;
- blindness which can be combined with 'sudden excitability';
- digestive problems including rumen stasis (reduced rate of flow through the rumen) and constipation;
- pulpy kidney; and
- bloat.

Nitrate poisoning can occur when hungry stock are first introduced to canola, usually within the first 48 hours and particularly where they have little or no gut fill. Crops that are

growing on fertile clover paddocks or have had moderate to large amounts of nitrogen fertiliser applied before grazing and then become stressed, pose more of a risk. Over time stock can adapt to high levels of nitrates, but care is needed to minimise potential problems.

Animal deaths due to other toxic compounds are less predictable and could occur after the stock have been on the canola for some days.

Minimising stock health risks

The following management strategies should minimise the risk of health problems for livestock grazing a failed canola crop:

- do not introduce hungry stock into the paddock;
- initially, restrict grazing to short periods or give stock access to another paddock with different feed;
- provide supplementary feed such as hay or grain to dilute the intake of canola;
- introduce a small number of stock and observe them closely for a few days. If there are no problems, introduce the rest of the mob ensuring they have at least partial gut fill;
- monitor the mob regularly and remove them immediately if any unusual behaviour is observed; and
- take special care and inspect the stock more frequently during dull, rainy weather or following heavy frosts. (Also refer to 'Pesticide residue risks', page 69).



Failing canola crops can be grazed, but care must be taken when introducing stock.

PHOTO: J. EDWARDS, NSW DPI

CANOLA HAY AND SILAGE

Canola crops can be cut for hay or silage if the returns are likely to be greater than taking the crop through to grain harvest. This alternative proved profitable for many growers in the poor seasons of 2006 and 2007. However, growers need to weigh up the risk of weather damage to the hay and silage while it is still in the paddock, combined with a volatile market for fodder. Growers without livestock could be holding expensive hay if market demand falls. The dairy industry in Victoria has shown some interest in canola hay in recent years.

Time of cutting

Canola cut for silage is generally of higher quality than canola cut for hay, but because of its higher water content is not economic to transport long distances. Crops that are cut too early in spring for hay take much longer to dry down, so are more at risk of weather damage if not conditioned. Hay cut in early to mid spring and conditioned is usually good quality, whereas crops cut late and baled without conditioning are generally lower and more variable in quality. In these crops water retained in the pods and stems delays baling and results in loss of leaf material.

Cutting canola at early flowering produces the best quality hay but cutting at late flowering to early pod fill is the best compromise between yield and quality — and the most profitable option.

Estimating dry matter yield

Assess the quantity of green material available for hay or silage by taking sample cuts at mowing height from a number of locations within the crop and weighing them. Dry

a sub-sample to determine moisture content and calculate hay yield, making allowances for losses in the hay or silage making operation. Below 2000 kg/ha standing crop dry matter the loss percentage increases significantly as more handling of the green material is required to bale or produce silage. Quality is also reduced as the most nutritive parts of the plant (such as leaf and young pods) are lost first. Hybrids produce more dry matter than open pollinated canola types so will produce the most hay or silage for a given cutting time.

Quality testing

Canola crops can produce high-quality fodder, but livestock owners or hay producers need to be aware of the variability in the quality and should test feed samples before buying to help develop a feed plan for the animals (Table 11.1).

The two main laboratories for testing feed samples are NSW DPI Feed Quality Service (Wagga Wagga) and the Victorian FeedTest Laboratory (Hamilton).

The quality of the final product will depend on the nutrition of the crop (especially nitrogen nutrition), the stage of growth at which it is cut and, for hay, whether it has been conditioned. Silage is likely to produce higher quality feed than hay. However, any differences in the cost between producing hay and silage need to be considered when comparing the value of the two, especially when compared with the grazing of a standing crop.

Nutrient export in hay crops can be very high and this needs to be considered when planning the following crop. A soil test in autumn is essential in paddocks where crops were cut for hay the previous season.

Feeding canola hay and silage

Canola hay or silage can be fed to any class of livestock, provided necessary precautions are taken when introducing these feeds to the diet. Feeding canola hay and silage is

Table 11.1 Canola hay and silage quality (2006 and 2007)

| NSW DPI Feed Quality Service | | | | |
|-------------------------------|---------|-------------------|------------------------------|---|
| Baled canola hay (samples) | | Crude protein (%) | Dry matter digestibility (%) | Metabolisable energy (MJ per kg dry matter) |
| 2007 (257) | Average | 17.7 | 63.4 | 9.1 |
| | Range | 8.6–33.6 | 45.0–83.0 | 5.8–11.9 |
| 2006 (106) | Average | 21.0 | 69.4 | 10.0 |
| | Range | 12.0–31.0 | 57.2–76 | 7.9–11.6 |
| Victorian FeedTest Laboratory | | | | |
| 2007 (708) | Average | 15.1 | 64.5 | 9.5 |
| | Range | 5.9–27.7 | 31.9–85.3 | 3.9–13.1 |
| 2006 (579) | Average | 15.9 | 66.4 | 9.8 |
| | Range | 4.0–27.2 | 33.0–85.3 | 4.1–13.1 |
| Victorian FeedTest Laboratory | | | | |
| 2007 (135) | Average | 17.9 | 67.3 | 10.2 |
| | Range | 8.8–33.4 | 42.9–83.6 | 6.9–12.4 |
| 2006 (219) | Average | 17.7 | 65.2 | 9.9 |
| | Range | 7.3–28.4 | 42.0–81.7 | 6.8–12.4 |

SOURCE: NSW DPI Feed Quality Service, Victorian FeedTest Laboratory



Growers can recoup some of their costs or even make a profit in dry springs by cutting for hay or silage.

PHOTO: D. McCAFFERY, NSW DPI

considered safer than grazing a standing crop.

Care must be exercised at all times to minimise any potential risks to livestock. Generally animals find canola hay and silage palatable and they waste very little.

In many cases stock have been fed canola hay as the sole maintenance ration, with no significant ill effects. However, it is preferable to use another fodder source, such as cereal hay, as part of the ration.

Canola silage is made in traditional soil pits or bunkers or wrapped in plastic as round bales. A problem which can occur with plastic wrapping is puncture holes or deterioration of the wrapping, which allows moulds or bacteria to grow. These organisms can be deadly to animals.

To safely introduce animals to canola hay or silage, similar guidelines to grazing apply, but also consider the following:

- test the hay or silage for nitrate nitrogen level. If care is taken when introducing the feed, stock can adapt to many types of feed, even those with raised nitrate levels;
- do not offer large amounts of canola hay or silage to hungry stock. Introduce it slowly by replacing part of the more recent diet, increasing the proportion of canola hay

over a period of days. For contained stock, try to offer a mixture of fodder types, at least for the first two weeks of using canola; or

- alternatively, introduce the feed to only a few animals, as described above, monitoring them closely for several days before introducing the canola hay to remaining animals.

Pesticide residue risks

Failing to comply with a chemical withholding period for grazing or cutting for fodder can lead to unacceptable levels of chemical residues in livestock products such as milk, meat and eggs. This could have serious implications for the marketing of these products.

Before grazing or cutting a crop for hay or silage, check to ensure that it has not been sprayed with chemicals that carry specific label warnings that treated crops are not to be grazed or fed to livestock.

Many fungicides, herbicides and insecticides used on field crops have the following label statement: "Do not graze or cut for stockfeed for 'x' days after application" as well as the normal harvest withholding period. The withholding



Canola hay needs a ready market to be a cost effective operation.

PHOTO: D. McCAFFERY, NSW DPI

period varies with the product and can even vary with the timing of use of a single product. For example, atrazine has a 15-week withholding period for grazing or cutting canola where it is applied pre-emergence but only six weeks when applied post-emergence, while simazine has a 15-week withholding period used either pre or post-emergence.

Not all chemical labels list withholding periods for the grazing of livestock on every crop listed as approved for treatment. However, the label may have a section headed 'Protection of livestock' under which other warnings can be issued.

If the hay or silage is either offered for sale or is purchased, a signed commodity vendor declaration (CVD) can be requested. An industry accepted CVD form can be found on the Meat and Livestock Australia website (www.mla.com.au). This form will then become part of the vendor declaration required to on-sell the livestock.

A commodity vendor declaration form requires the following information:

- the date the crop was cut for fodder;
- a list of chemicals used on the crop, rates and application dates;

- the appropriate withholding and/or export interval for cutting for fodder for all chemicals;
- chemicals applied to adjacent crops and neighbours crops that may pose a spray drift risk; and
- the property's chemical residue status classification.

12. Irrigation management

Don McCaffery, NSW DPI

Canola is an important irrigation crop, grown in rotation with a range of winter and summer crops. While rice is the major break crop in continuous crop rotations involving winter cereals, canola and faba beans have gained in popularity in recent years. Irrigated production is mostly confined to the inland river valleys of central and southern NSW and the irrigation districts of northern Victoria. The largest area of production is in the Murrumbidgee and Murray Valleys of southern NSW, where yields are typically 2–2.5 t/ha. However, yields of 3.0–3.5 t/ha and higher are achievable with high levels of management, paying particular attention to paddock selection and soil type, irrigation method and establishment technique, sowing time, nutrition management, and spring irrigation scheduling.

An achievable water use efficiency (WUE) target for canola on a good flood irrigated layout is 8–10 kg/ha/mm, that is, for each millimetre of growing season water (rainfall plus irrigation). Note that starting soil water is not included in the calculation of WUE as it is presumed to be negligible in most years in southern Australia. A water budget undertaken at the start of the irrigation season, or before sowing, will help with decisions on crop inputs and yield targets. The water budget should be reviewed on a monthly basis. The planted area must be matched to the supply rate by calculating peak water requirements during flowering and pod filling.

SALINITY

Canola has a similar salinity tolerance to wheat and much better than soybeans and maize. Overseas research indicates that canola has a soil salinity threshold of around 6.5 deci Siemens per metre (dS/m) averaged in the rootzone. The impact of soil salinity is highly dependent on soil texture. To ensure salinity does not affect yields, avoid paddocks with high watertables (within 1 metre of the soil surface) which are also saline. Canola can also tolerate more saline irrigation water than some other crops, but specialist advice should be sought from an experienced irrigation agronomist or irrigation officer. The published threshold for irrigation water salinity for canola is about 2 dS/m for a slow draining soil. However, without a leaching component, irrigation water of this salinity will make the soil more saline over time.

IRRIGATION SYSTEMS

Canola yields best in moderate to highly fertile self-mulching grey or brown soils. These soils are generally the best for irrigated cropping.

Raised beds

Raised beds are ideal for irrigated canola, especially where the slope is 1:1500 or flatter. The optimum slope depends on the soil type and structure which dictate the water movement from the furrow into the bed (subbing ability). Raised beds are the preferred flood irrigation method in the

Raised beds are the preferred method for growing canola under flood irrigation.

PHOTO: D. McCAFFERY, NSW DPI





Border check irrigation can be successful with good irrigation management.

PHOTO: D. McCAFFERY, NSW DPI



Overhead spray irrigation offers improved water-use efficiency and greater flexibility than flood irrigation methods.

PHOTO: M. GRABHAM, NSW DPI

Murrumbidgee Valley. They allow the crop to be watered up without soil crusting problems, and to be fully irrigated in the spring without the risk of waterlogging the crop.

Raised bed farming is a system where the crop zone and the traffic lanes (wheel tracks or furrows) are distinctly and permanently separated. Paddocks are laser levelled before bed construction, with the beds running down the slope. Some growers in southern NSW are trialling raised beds within bankless channel terraced contour systems. In these systems the beds are formed on a zero or near zero grade.

Soil suitability needs to be carefully assessed for the raised bed system. Self-mulching clay soils are well suited to raised bed irrigation. Other soils may be suitable with appropriate management, for example, the addition of gypsum and organic matter. Soils should be free of any compaction layers, have good soil structure to allow water infiltration into and drainage out of the beds, be non-slaking and non-sodic, have a soil pH_{Ca} greater than 5.0 and be at low risk of developing shallow watertables and salinity. Hard setting and crusting soils will impede water infiltration. The selection of bed width will depend on the soil's subbing ability. Farming equipment may need to be modified to suit the proposed bed width, for example, tractor or seeder wheel spacings.

After the beds are formed, all traffic should be restricted

to the furrows where possible, to avoid compaction and, over time, allow better water absorption (subbing) as soil structure improves. In practice, most harvesters will run on the beds, hence the timing of the final irrigation should consider crop development so that the soil profile is sufficiently dry to carry the header and minimise soil compaction. Tyre pressures can be lowered to reduce compaction.

Bed width varies according to soil type and is typically in the range of 1.5–2 m. Bed widths for red-brown earths or non self-mulching clays should be narrower, about 1–1.5 m, as moisture may not sub to the centre of the bed if the beds are too wide. Some growers sow twin rows closer to the irrigation furrow, leaving an unsown gap in the middle of the bed.

Beds are usually formed by setting listers at the desired furrow spacing to pull the beds up in a rough condition from a cultivated surface and then using a bed shaper to form a flat-top bed.

Ring rollers have been used to complement bed-shaping equipment. These are made of heavy cast iron rings independent of a main axle to allow them to adjust to the curve of the bed. The implement is cheap to use and principally breaks down clods and firms up the bed. Heavy rice rollers are also used for the same purpose, but the soil must be dry. Depending on soil conditions, these implements are used before chemical spraying and sowing.

Disc seeders or tined seeders with narrow points are used to sow canola on beds. Row spacing can be flexible.

Border check (flat) system

The need for adequate slope and surface drainage will dictate the soil type used for border check layouts. Heavier soil types, which generally do not have the desired slope, can be successfully irrigated using the lasered terraced contour system. In both systems, watering and drainage need to occur in 12–15 hours. High flows of 15–20 ML/day will be needed to achieve these relatively quick watering/drainage times, especially on the lasered terraced contour system. Without high flows, traditional border check in small bays is a better option.

Flood irrigated layouts must allow the crop to be irrigated and drained within 12–15 hours. Border check is the most common flood irrigation method in the Murray Valley and the Goulburn-Murray Valley of northern Victoria. Border check irrigation is acceptable when paddock slopes are 1:1000 or steeper – preferably between 1:750 and 1:1000. Lesser slopes, for example, 1:1500 can be used if bays are short, so long as the crop can be irrigated and drained within the 12–15 hour timeframe.

Border check bays should have uniform slope to allow an even rate of water advance and infiltration.

Border check systems are not suitable for sandy soils as the top of the bay will be overwatered by the time the water reaches the drainage end, resulting in waterlogging at the top end, and potentially excessive deep drainage to the watertable.

Terraced contours

Lasered terraced contour systems (with bankless supply channels contained within the contour bay) are being adopted in the Murrumbidgee Valley to suit both rice and winter crop production. Significant cost savings can be made by not changing the contour irrigation layout to a more conventional border check layout for winter crops. Because the contours are terraced and are designed for very high flow rates, the waterlogging risk is greatly reduced compared to a traditional contour layout.

Spray irrigation

Spray irrigation using centre pivots and lateral moves is suitable for canola, provided the irrigation system is designed to meet demand during spring and provided there is sufficient output to match evapo-transpiration (ET) levels of around 8 mm per day. In practice, most centre pivots will be designed for a summer crop of 12 mm ET per day or better so when planning multiple circles do not overstretch the capacity of the irrigation system. Water application rates and application frequency need to match the crop requirements and the infiltration characteristics of the soil to ensure there is no waterlogging or moisture stress.

Soils that disperse on wetting are generally not suited to spray irrigation systems because the water output of the irrigator exceeds the soil's capacity to take that water in. Stubble retention has enabled much improved water infiltration rates under centre pivots, particularly where soils are prone to dispersion.

Water quality is important with spray systems, as salty water applied direct to foliage can damage plant tissues.

The management of irrigated canola crops is similar to that of canola grown under high rainfall conditions in many ways (see earlier chapters). The following information applies specifically to irrigated canola.

SOWING, ESTABLISHMENT AND IRRIGATION

Sowing time is a major factor in achieving high-yielding irrigated canola crops. Sowing time needs to take account of the maturity of the variety as it relates to flowering time and pod filling; the irrigation layout and establishment method; the soil type and plant height at flowering, which generally indicates lodging potential.

A second critical factor is sowing depth. Most soils used for irrigation in south-eastern Australia are medium to heavy clays or varying soil surface structure. The objective of sowing at a shallow, uniform depth cannot be overstated. The small canola seedling will find it difficult to push through a clay from depth.

On raised beds, shallow sowing and watering-up is the preferred method of establishing the crop. Aim to sow and water-up between 20 April and 10 May. Good drainage is

essential. This sowing time, when soil temperatures are generally higher, ensures establishment prior to the onset of cooler, wetter winter conditions. Sowing in the first two weeks of April is not recommended as it can lead to crops flowering too early and lodging.

On border check (flat) layouts, the preferred method is to sow dry and water up on soils that have good structure and are not likely to slake or crust. In this situation, sow seed shallow, only 5–10 mm deep, onto a firm seedbed base to reduce the risk of seed sinking and not establishing. Heavy rollers can be used to break down large clods and produce a firm, level seedbed. Always sow up and down in the direction of the border check as this will aid drainage throughout the year. Canola is slower to establish when watered up on flat layouts than on raised beds. Therefore, aim to sow slightly earlier, 15–30 April in the Murrumbidgee valley of NSW and 20 April–15 May in northern Victoria.

For soils that are not suitable for watering-up (commonly red soil types), the preferred method on border check layouts is to pre-irrigate in late March/early April and sow the seed at 15–20 mm into moisture as soon as the soil is trafficable. Press wheels or rollers will improve seed-soil contact and assist germination. Medium-term weather forecasts, whilst not completely reliable, will give some indication of the potential for rain during the time the paddock will be drying out awaiting sowing. In some seasons, it may be prudent to delay pre-irrigation for a number of days, for example, if no rain is forecast for April. Aim to sow the crop from 20 April and finish by 15 May.

Expect to use 1–2 ML/ha to establish the crop in a dry autumn. Considerably less water will be required to establish a crop using spray irrigation. About 30–40 mm is sufficient, and will provide some additional stored moisture going into winter.

Spring irrigation

Timing of the first spring irrigation is critical.

Canola's peak water use is from stem elongation until the end of pod filling (about 25 days after the end of flowering) when any stress will result in yield loss. However, its quick early root development allows for a more efficient use of water early in spring. Because of its more advanced growth stage, canola should be irrigated before wheat as it will have used more soil moisture through late winter. Canola is less tolerant of waterlogging (often caused by a combination of irrigation and rain) than wheat in the period from flowering to maturity.

Adequate soil moisture at flowering is crucial, particularly at early flowering. The first irrigation should be applied at 60 per cent plant available water (PAW). This ensures there will be no moisture stress at the critical flowering time. A missed irrigation during flowering can halve yields. In crops with lower yield potential and where irrigation water is limited, one timely irrigation at early flowering will give the greatest yield and financial response. Early spring irrigation will maximise the number of pods which set seed and later irrigations will maximise seed size.

Three years of demonstration work on a border check layout in the Murray Valley of NSW showed a 0.75 t/ha response to irrigating at early flowering, which reduced to 0.3 t/ha by waiting until mid flowering.

If there has not been substantial winter rainfall (soil profile is dry to 60–80 cm) and the crop is showing early signs of moisture stress, irrigate in early August if water is available. Growers with access to a bore or river allocation have a distinct advantage over irrigators on company schemes. From these water sources crops can be watered before August in very dry years with relatively low risk on raised bed layouts or spray irrigation.

Be prepared to irrigate for the target yield. Between two and four spring irrigations are usually needed to finish the crop but this depends on soil water holding capacity. These irrigations will normally require 1.5–3 ML/ha in total depending on the efficiency of the irrigation layout and the amount of spring rainfall.

In fully irrigated crops the final irrigation needs to be applied to supply enough soil moisture for the crop up until physiological maturity as seed is still filling and gaining weight. Physiological maturity usually occurs about 25–30 days after the end of flowering (end of flowering date is recorded when five per cent of plants still have flowers). So, the last irrigation in a crop with high yield potential crop needs to be applied about 10–15 days after the end of flowering date.

Crops grown under spray irrigation need to be irrigated earlier in the spring than those under flood irrigation, mainly because smaller amounts of water are applied at each irrigation and the time it takes to get to a full soil profile is longer. Starting irrigation earlier will provide a soil moisture buffer in the event of hot, dry weather. Spray irrigated crops need to be irrigated even closer to maturity as smaller amounts are applied in each irrigation. About 30–40 mm applied in each of three or four irrigations is usually required. The total irrigation requirement (establishment plus spring) for a spray irrigation system will vary from 1.2–2 ML/ha.

Irrigation scheduling

To time irrigations precisely, the irrigation supply system must have the capacity to deliver sufficient water. Growers should use a locally developed and tested irrigation scheduling system to aid their irrigation management decisions. Two practical systems are available for canola, based on either the measurement of weather conditions or the measurement of soil water. The NSW Department of Primary Industries provides a weather-based water use information service called Water Watch in some irrigation areas of NSW. Water Watch evapo-transpiration values can be related to any type of crop and used in a manual water balance calculation system.

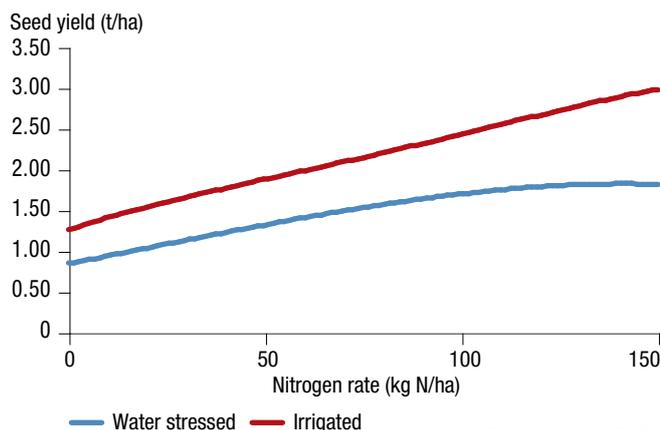
Soil moisture monitoring equipment is in demand as irrigators strive for maximum efficiency with limited water. Technology to meet this demand is developing rapidly. Neutron probes perform well when used with a consultant.

Newer technology using four to six gypsum blocks connected to data loggers is proving very popular. They are relatively cheap, easy to install and interpret. The Hansen logger allows data to be viewed in the field, while the GBug operates on a wireless connection to download data, which can then be uploaded into computer software for analysis. Other similar devices are commercially available.

Some irrigation companies are establishing data handling services for growers to help manage the advanced soil moisture systems where new capacitance probes are completely sealed and buried below the cultivation depth.

Soil moisture monitoring equipment is proving its worth, especially for timing the critical first spring irrigation, when growers are hesitant to irrigate if rain is forecast in the near future.

Figure 12.1 Relationship between moisture stress during flowering and applied nitrogen on canola seed yield at Condobolin, NSW



13. Bees and pollination



Take care when applying insecticides on crops with nearby beehives.

PHOTO: F. McRAE, NSW DPI

Trent Potter, SARDI and Don McCaffery, NSW DPI

All canola varieties grown in Australia are of the *Brassica napus* type and, as such, are self-pollinated and generally do not need pollinating agents such as bees. While the crop is very attractive to bees, their presence is unlikely to have any direct effect on yield. Research on the benefits of honey bees to canola yield is inconclusive. Wind and feral bees usually make the use of honey bees unnecessary. However, canola is one of the earliest flowering crops in south-eastern Australia in spring and so is quite important to commercial beekeepers. Seed companies use honey bees to produce valuable hybrid seed.

Insecticides and bees

Honey bees find canola very attractive and will travel several kilometres to forage on the flowers of a canola crop. It is often necessary to apply an insecticide to control pests during flowering when the bees are most active. Insecticides can kill bees and special precautions are necessary to avoid serious bee losses. Bees are generally inactive in cold, overcast weather

Insecticides can be less damaging to bees if the correct chemical is chosen and applied correctly. Some insecticides have a fairly short residual toxicity to bees (10 hours or less) and can be safely applied at sunset after most of the bees have returned to the hive for the day, ensuring it will be safe for them to return to the crop the following morning.

Some other insecticides remain toxic to bees for several days after application and are never safe to apply to a flowering crop. If one of these chemicals must be used,

Bees and pollination

ensure the hives are removed from the area and are not returned until the crop is safe again. If there is a choice of chemicals, select the one least damaging to bees. Also remove hives if an insecticide with a short residual toxicity has to be applied at a time other than late in the evening.

Communication between the grower, the beekeeper, the spray contractor and neighbours will avoid most potential problems. As much notice as possible needs to be given before spraying to allow hives to be moved if necessary, to minimise potential bee losses.



Canola flowers are very attractive to honey bees.

PHOTO: R. COLTON, NSW DPI



14. Windrowing and harvesting

Paul Carmody, DAFWA

THE BENEFITS OF WINDROWING

Canola is an indeterminate plant, which means it flowers until limited by temperature, water stress or nutrients. 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 all pods are mature at harvest.

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 a shorter flowering and pod maturity period. 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 type of varieties being grown, soil types, seasonal conditions, availability of windrowers and the size and variability of the crop. Canola crops which 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 needs to be windrowed before the lower pods approach shattering stage.

Like hay cutting, windrowing 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 to wind, rain and hail damage than a standing crop. In the windrow, seeds will reach a uniform harvest moisture content of eight per cent within 6–10 days of being cut.

A number of 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, the advantages of windrowing are that it:

- allows earlier harvest (8–10 days) because seed matures more evenly;
- hastens maturity in higher rainfall areas;
- evens maturity where soil types are variable in individual paddocks;
- reduces losses from hail and excessive winds;
- provides more flexibility for the grower with large areas, as the timing of harvest is not as critical;
- reduces shattering losses during harvest;
- can be done around the clock to help with covering large areas; and
- in some cases can help control escaped or herbicide resistant weeds.

WHEN TO WINDROW

Windrowing normally starts 20–30 days after the end of flowering. Carrying it out on time is important to maximise yield and oil content.

The crop is physiologically mature and ready for windrowing when most seeds reach 35–45 per cent moisture. The timing of windrowing is determined by estimating the level of seed colour change. Consulting experienced local growers or agronomists is also invaluable when determining timing. Begin checking canola about 14 days after the end of flowering (end of flowering is when 10 per cent of plants still have flowers). For triazine-tolerant varieties this can be slightly longer than for conventional varieties or hybrids of similar flowering maturity.

Randomly collect 30–40 pods from the primary stem of a number of plants and from different positions in the plant canopy. Select both brown and green pods and shell them in a white container.

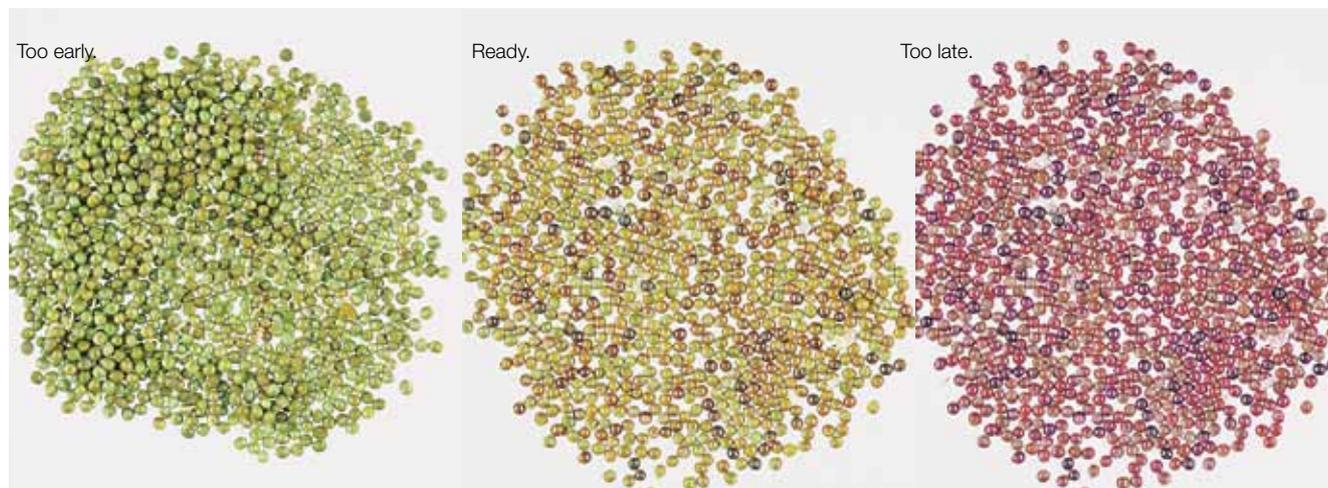
Assess what percentage of the seeds show sign of colour change. Part of the seed may have turned from green to red, brown or black. This is known as the percentage seed colour change.

The optimum time is when 40–60 per cent of seeds have changed colour from green to red, brown or black, and lasts only 4–6 days. In warmer, drier areas windrowing is better done when seed reaches 50–60 per cent seed colour change. Under higher temperatures the windrowed plant dries too rapidly to allow seeds to fully mature in the pods and oil content can be lower. 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 per cent of seed

Seed colour changes determines the optimum time for windrow timing.

PHOTOS: DAFWA



green or green-red and be very firm but pliable. The other 20 per cent 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 they are booked well in advance. Making a note of the end of flowering will help the grower and the contractor to determine roughly when the crop will be ready to windrow. The most important part of any decision to windrow is to make the assessment in a representative area of the paddock.

The optimal windrowing stage for canola lasts about four to six days, depending on temperature and humidity. For each day windrowing is delayed past the optimum time, the more susceptible the crop is to shattering losses. These can be minimised by operating at night or when humidity is high

after dew or rain. However, where shattering losses during windrowing are obvious, growers are best advised to change strategy to either direct harvesting or desiccation followed by direct harvesting.

Windrowing too early, for example by four or five days, can lead to yield losses of up to 10 per cent and reduced oil content. Never windrow a canola crop before seed colour has changed, as this will result in significant yield loss.

Rollers can also 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 harvest if windrowing operations occur.

Key points

- Physiological maturity occurs when the seed moisture content reaches 35–45 per cent.
- Check the crop regularly from 14 days after the end of flowering (10 per cent of plants with flowers).
- Look for seed colour change from 40–60 per cent on the main stem from pods at all levels.
- Sample from representative areas of the paddock;
- Check all varieties for seed colour change, they 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 four to six 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 well advised to organise a contractor or an experienced neighbour to carry out the windrowing.



Crops windrowed too late have higher shatter losses. In this situation direct heading can be a better option.

PHOTO: PAUL PARKER, NSW DPI

Windrowing is a crucial part of the harvest operation in most regions. Pictured is a self-propelled draper style windrower fitted with a vertical knife.

PHOTO: F. PRITCHARD, ICF



WINDROWER TYPES

The three types of windrowers are:

- tractor-drawn (PTO windrower), delivers off-centre windrow;
- self-propelled windrower, typically delivers a centre windrow; and
- harvester belt or draper front (for example, MacDon), can deliver the windrow either side.

Tractor-drawn machines involve a relatively low capital outlay and suit most medium farms (less than 1000 ha total crop). Self-propelled machines are more manoeuvrable and suited to a wider range of applications, for example undulating paddocks, irrigated rows, raised beds and controlled traffic paddocks. They are also better suited to high-yielding crops (over 3 t/ha) which are too big for tractor-drawn machines.

The draper or belt-front harvesters work like a self-propelled windrower but are less manoeuvrable. They are more suited to lower yielding crops (less than 1.5 t/ha). As a dual-purpose front they tend to be too wide for large crops but this can be partially overcome by having less of the machine front in the crop where necessary. An advantage over a self-propelled windrower is that there is one less machine to maintain on the farm.

A draper front can deliver the windrow to either side of the machine and so in very light crops can be used to put two windrows together.

WINDROWER ESSENTIAL FEATURES

- Platform table deep enough (at least 1.1 m) to handle the cut crop.
- A large opening (intake area or 'throat') 1.2–1.5 m wide and at least 1m high above the belt.
- Throat opening free of projections that could hinder the flow of cut material through the opening.
- Good range of adjustments for the table and reel to handle different crop situations.
- Finger tine reels rather than batten reels, as they are gentler on canola crops and help feed the crop onto the belt.

- Vertical knives to minimise drag and entanglement of cut material.
- Mixer belts used for cereals need to be removed.
- A good operator to balance the reel speed, platform table speed and ground speed with the conditions of the crop they are windrowing.

Over the years a number of modifications have been made to imported windrowers to suit Australian conditions.

Australian canola crops are taller than the spring Canadian canola crops and a common local modification is to enlarge the 'throat' of imported windrowers.

A blockage during windrowing can translate to a major problem at harvest. These very large clumps in the windrow, known as 'haystacks', will take longer to dry and can also stall some smaller harvesters.

WINDROWER SIZE

The ideal width of a windrower depends on the expected yield of the crop and the size of the harvester; wider windrowers are better for lower yielding crops and short varieties as less material will be passing through the machine. Tractor-drawn 10-metre-wide PTO windrowers are sufficient where crop yields are expected to be 1.5–2 t/ha. MacDon draper fronts (12 m wide), which are attached to the front of the header work well where crop yields are expected to be below 1.5 t/ha.

A larger windrow will take slightly longer to reach the correct harvest moisture content (eight per cent). Small or light windrows are more prone to being wind-blown or lifted by whirlwinds, which can make harvest very difficult.

The rule of thumb is that a good sized windrow is about 1.5 m wide and 1 m high.

How a windrow sits on the stubble will determine if air is able to pass under it to help in drying. Most large capacity harvesters can generally handle big windrows but in high yielding areas (> 2.5 t/ha) they will require modification – such as raising and switching to a larger diameter table auger. These are best set up by the dealer.

It is important to match the harvesting capacity of the header with the size of the windrow; smaller capacity means

Windrowing and harvesting

A well-laid windrow drying down ready for harvest.

PHOTO: P. BOWDEN, NSW DPI



smaller windrows in most conditions.

Large headers, particularly those with hydrostatic drives and axial flow machines, can handle large windrows with suitably large pickup or draper fronts.

OWNER OR CONTRACTOR

The choice between owning a windrower and hiring a contract windrower depends on attitude to risk and managing the risk of shattering loss in canola. It can be as much a personal choice as an economic one.

The availability of contractors and their timeliness needs to be weighed against windrower ownership and a grower's ability to manage the windrowing operation themselves. Costs include both direct costs, such as interest, maintenance and insurance, the hidden cost of depreciation and the opportunity cost of capital. Ownership would often factor in the opportunity to offer contracting services to neighbouring farmers. The advantage of owning a windrower is that each paddock can be windrowed at the optimal time. Farmers with variable soil types and undulating country may find it easier to get the timing right by windrowing crops themselves.

Dual-purpose fronts like the MacDon or Honey Bee draper fronts provide growers with more options on whether to windrow or direct harvest their own crops.

A draper front can be justified on farms cropping more than 2000–3000 ha. A draper front offers increased flexibility at a critical time of year as it can be used as a windrower or for direct harvesting. The benefits are further enhanced if barley is a significant part of the farming operation. A draper header front can safely pick up lodged crops of malting barley without head losses.

Larger grain farms (> 4000 ha cropping) can justify a self-propelled windrower given that it can be used for hay cutting and windrowing other crops, which therefore spreads costs over a number of operations on the farm.

WINDROWING OPERATION

An even crop establishment makes windrowing and harvest easier. Stems with an average diameter of < 10–15 mm are preferred for harvest machinery. Too few stems per square metre (< 5/m²) will result in the windrow sitting on the ground making it difficult to pick up, even with crop lifters. Also, the very large plants can cause uneven feeding into the harvester and are difficult to thresh. Planted row spacings of up to 50 cm do not usually present a problem. Using standard cereal width knife guards, the knife needs to be in good condition to cut the larger stems of canola (see harvest section for more detail on knife guards).

The most common cutting height for canola is 30–60 cm, depending on the crop density and height. Cutting crops too high can lead to lower oil content and result in yield loss as short branches fall to the ground.

Some growers place a chain or steel bar beneath the windrower exit to push tall stubble down before the windrow lays on it. This can help the windrow to sit lower in the stubble and minimise the risk of movement by wind.

A well-laid windrow is gathered evenly from both sides and interlocked with the stems angled down at 45–60° to provide good strength against the wind and allow for even drying.

Low yielding crops (< 0.7 t/ha) can be more susceptible to wind damage. In this case it is advisable to lay two windrows together by using an end delivery windrower system like that on a harvester draper front. This will halve the time to harvest the crop as two windrows are picked up simultaneously.

Harvesting in the same direction as the windrower will mean the pods enter first on to the harvester platform, reducing losses as well as the risk of crop stubble 'spearing' the tyres on the harvester.

Key windrow settings are:

- set the reel as high as possible so that it lightly pushes the plants onto the windrower;
- reel speed only slightly faster than ground speed;
- draper speed at a medium pace so that plants are evenly mixed from both sides;

Severe winds can still cause damage to windrowed crops.

PHOTO: P. PARKER, NSW DPI



- knife guard fingers about 130 mm apart (standard as for cereals); and
- minimise blocking or bunching of the windrow to allow for easier harvest.

Where windy conditions are common, a windrow roller can help push the windrow into the stubble to anchor it. Purpose built windrow rollers can be attached behind the windrower and are used successfully to push light windrows into the stubble for protection against wind.

HARVESTING WINDROWED CROPS

When to harvest

The timing of harvest for a windrowed canola crop is less critical than for a standing crop. A windrowed canola crop can be ready to harvest within 7–10 days after cutting when the seed moisture has dropped to eight per cent. Begin sampling the windrow within 7 days and thresh out a small sample with the harvester to check the moisture content. By taking a sample from a typical part of the crop, growers can be confident that, once it has reached a moisture content of eight per cent, most of the windrows will be ready for harvest.

In drier regions, when seed moisture content has dropped

Belt pickup front

PHOTO: F. PRITCHARD, ICF



well below eight per cent, it is advisable to harvest canola early in the day to minimise losses. In higher rainfall districts, temperatures are not usually high enough for pod shattering to be an issue when picking up windrows.

Canola can remain in the windrow for up to six weeks if it has been windrowed at the correct stage. Canola that is windrowed late will be more susceptible to shattering if left for more than three to four weeks.

Harvester type

All modern combine harvesters are suitable for harvesting canola. Closed fronts were used on earlier harvesters for cereals but these were never suitable for harvesting canola crops. Today most harvesters have open auger fronts or draper (belt) fronts and are equally capable of harvesting windrowed canola with some minor modifications such as crop lifters. However, it is the belt pickup front which is considered the best for harvesting windrowed crops like canola.

Belt pickup fronts

In traditional growing regions many growers have dedicated pickup fronts they attach to their harvesters. These consist of rubber or canvas belts fitted with small fingers to gently pick up and feed the windrow into the harvester (see picture). Pickup fronts have a modified platform auger that allows plenty of clearance for the windrows to pass under before being pushed up into the front elevators of the harvester. As well as their gentle action, pickups can reduce contamination by green material in the harvest sample. They also reduce the amount of stubble material going through the harvester. A popular modification is the addition of a roller down across the top of the belt front. This presses the windrow down as it is fed on the platform and helps prevent the windrow from bunching up against the table auger or being pushed over the top of the front above the elevator.

Auger or draper fronts

Growers who do not grow canola every year could use either an open auger front or a draper front with crop lifters attached to pick up windrowed canola. Depending on the crop situation they are less likely to pick up the windrow as quickly and as cleanly as a belt pickup front. Auger and draper fronts will require some minor modification before they can pick up windrows.

Modifications to auger fronts

- Replace cereal augers with a narrower diameter auger to help handle the bulkiness of canola windrows.
- Raise the auger off the table to the second highest possible position to allow good clearance. If a blockage occurs there is at least some room to adjust further.
- Lupin breakers attached to the centre flights of the table auger can help feed the windrow into the elevators.
- Use finger tine reels rather than batten reels to help feed the windrow into the front gently.

Windrowing and harvesting



Draper fronts with some modifications are well suited to harvesting windrowed crops as well as for direct harvesting. PHOTO: P. CARMODY, DAFWA

Modifications to draper fronts

- Bring the auger at the elevator forward to help feed the windrow into the elevator.
 - Maintain a belt speed slightly faster than the ground speed.
 - Ensure the belt is tight, especially in heavy windrows.
 - A short overhead auger across the mid section of the front helps feed bulk into the elevator.
 - The reel need only just touch the windrow onto the belt.
- Consult your local machinery dealer to determine the most suitable modifications to the harvester.

Crop lifters

Where a belt pickup front is not available, attaching crop lifters to an open front harvester is a good alternative to pick up windrows. The simplest way to attach crop lifters is to the knife guards at 300 mm spacing, at least across the centre of the front. Some growers place them across the entire front to handle all crop situations but it is advisable to pick up the windrow at the centre of the front to minimise seed losses.

The most suitable lifters for canola are usually 300–400 mm long and can lift the windrow cleanly over the knife and on to the front's platform. Most growers leave the knife cutting when picking up the windrows, which second cuts stems to shorten the stubble length for an easier seeding operation the following season.

The only manufacturer of crop lifters in Australia is Harvestaire, which has a range of crop lifters to suit either open fronts or belt fronts of most harvesters. Crop lifters are simply attached to the knife guards and will help pick up down or tangled crops as well as windrows.

CHEMICAL DESICCATION

Chemical desiccation is an alternative to windrowing and very effective where crops have lodged or where weeds have emerged in maturing crops. The most commonly used desiccant is diquat (Reglone®), which is registered for aerial application on canola crops (refer to product label for application rates).

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 high moisture problems. 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 per cent 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 four to seven days after the desiccant is applied, depending on the size and density of the crop. Only desiccate the area of crop that can be harvested over a period of one or two days.

The harvester must be ready within three days of a desiccant being applied to minimise potential losses due to shattering – withholding periods should be adhered to.

Desiccation is generally considered a special purpose management aid for when problems with windrowing, weeds or harvesting are anticipated. Specialist agronomic advice should be sought.

DIRECT HARVESTED CROPS

Most canola in Australia is windrowed but an increasing number of growers in medium and low rainfall districts are switching to direct harvesting. Advances in harvest machinery and improvements in varieties are making direct harvesting of canola more of an option. The new varieties can have a shorter pod maturation phase and are less prone to shattering.

In lower yielding regions, crops tend to be direct harvested. Harvesting is usually a better option than windrowing for very low yielding crops (< 0.5 t/ha) due to the extra costs involved in windrowing and the difficulty in laying and picking up windrows with the harvester. There is some risk of pod shatter and for large areas (> 500 ha) it is advisable to desiccate to bring forward harvest for some of the crop. Earlier maturing crops ripen quickly without concerns of high seed moisture in most seasons.

Benefits of direct harvesting

- One less operation on the farm (no windrowing).
- Direct harvesting can give cleaner samples with lower admixture.
- Suits rocky areas or where sticks can be a problem when windrowing.
- Reduces the risk of harvester blockage that can occur with windrows.
- Can harvest the paddock according to tramlines.
- Possible to harvest sections of the crop as it matures.

Timing of direct harvesting

- When all the pods are dry and rattle when shaken.
Although tops of plants may contain a few green pods, do not wait for them to ripen as the rest of the crop will begin to shatter.
- Only begin harvest when the moisture content has fallen to eight per cent. Ensure moisture meter is properly calibrated before harvest.
- Do not use the general colour of the crop as a guide, use seed moisture content.

Direct harvesting is best done in the early hours of the day to minimise seed losses. However, at the start of the harvest period the moisture content may be too high to permit harvesting in the early hours of the day. Draper fronts are preferred for direct harvesting canola.

Properly adjusted open auger front machines are reasonably effective at directing the harvesting of canola and much of it depends on the patience and skill of the operator.

Harvester settings

Canola is easily threshed but capacity is limited by the sieves, so pay special attention to them, particularly the top sieve. Harvesters with larger sieve capacity will be able to harvest canola the fastest but, because of the bulkiness, canola harvesting can only proceed at about 80 per cent of the speed of cereal harvesting.

Regularly check for harvest losses at the start of the season. Calibrate losses with a square 2 litre ice-cream container placed under and beside the windrows before harvest. In undulating country steep slopes can significantly change the angle and therefore the load on the sieves. It is best to harvest on the contour if possible to minimise losses.

Reel

A reel fitted with finger tines is preferable to a batten reel, whether direct harvesting or picking up windrowed canola. Tine reels are able to feed the crop onto the platform with minimal shattering. The reel speed and height should be set to gently assist the crop into the machine. A reel set too low or too fast will cause excessive shattering at the cutter bar.

Vertical knife

A vertical knife rather than crop dividers will reduce shattering losses at the crop end of the front when direct harvesting canola. Knives can be attached at either or both ends of a front to help the harvester pass through the crop. Vertical knives are a standard feature on most windrowers and usually operate off the reel's hydraulic drive on harvester fronts with some minor modifications.

Front auger and elevator

Adjust the table auger as high as possible. If the adjustment is insufficient to give 8–10 mm clearance, it may be necessary to change the adjustment hole slots. Alternatively, change the front auger to a smaller diameter one which increases the clearance up to 20 cm depending on the size of the crop.

The front elevator carries a much larger volume compared to cereals and should be checked for tension and freedom of float. Check that the reverse drive mechanism is working well just in case blockages need to be cleared.

Some draper fronts can have a cross auger above the entrance to the elevators to help feed the bulky windrows into the harvester.

Drum and concave

Canola is not a difficult crop to thresh. Under normal conditions most of the seed threshes out on the front or on the elevators. Any little holes or gaps in the harvester need to be sealed or closed to reduce losses.

Drum speed should be about 60 per cent of that used for cereals. Set at 650–700 rpm for small diameter (46 cm) cylinders, and 450–600 rpm for large diameter (61 cm) cylinders. Axial flow machines should be set to a lower speed (20 per cent lower) compared to cereals to reduce excessive damage to the seed.

Too high a drum speed and too narrow a concave will cause seed cracking, skinning and excessive smashing of pods and stems, which could be difficult to remove from the sample. The concave should be nearly wide open, allowing for some further adjustment, so that any blockages can be cleared.

In many districts, canola is harvested in very dry conditions compared to Australia's northern hemisphere counterparts and consequently imported harvesters can easily over-thresh canola if not set up correctly. In some cases it may be necessary to switch to concaves with



Direct harvesting is an option on some crops.
PHOTO: F. McRAE, NSW DPI

fewer wires or bars in dry conditions or remove wires from concaves in a conventional harvester. This can also improve the capacity of some machines in canola.

Wind

Allow about half an opening for direct harvesting but this may need to be increased to two-thirds for large windrows. Set the fan at half to three-quarter speed. Where wind is controlled by shutters, these should be open less than halfway.

Direct the air as uniformly as possible under the entire length of the sieves. This will ensure that stems, pods and canola do not move across the sieve as a mat, which will result in high seed losses out the back of the header.

Start with a low fan speed and gradually increase it until chaff and seed separate with no canola being blown over the top sieve.

Sieve settings

The proper adjustment of the fan and the sieves is vital, since the canola seeds are light and can easily be blown out of the harvester or ride out on the chaff on the bottom sieve. The top sieve does most of the separation in canola and this also minimises the returns off the lower sieve if set up correctly.

Top sieve – air foil louvre sieve, 3–6 mm open or 3–4 mm punch hole or expanded mesh sieve.

Bottom sieve – adjustable louvre sieve, 2–4 mm open.

Check the sample in the bin to adjust the lower sieve. If it contains a large quantity of trash, it is likely the sieve is open too far. This should not be a problem with a punch hole sieve. The returns to the drum should be almost minimal with a well set up harvester. If returns are too large, seed will be 'skinned', releasing oil which leads to a build up of gum throughout the threshing, cleaning and grain tank areas. High speed drum settings and a concave set too close can lead to similar problems.

While adjustable sieves are suitable they can take longer to set up but this can be necessary in districts where the crop condition varies a lot throughout harvest.

Walkers

If straw baffles are fitted over the walkers these should be lifted as high as possible to allow a free flow of material.

Sample

The best sample will be taken when the humidity is high, for example at night or after rain. During high day temperatures (above 30°C) smashed pod pieces tend to contaminate the sample but, because of its light weight, a small percentage of such admixture is acceptable. It may be necessary to stop harvesting during the heat of the day. Some receival sites will not accept seed samples which have a temperature above 30°C.

Speed of travel

The speed at which the harvester moves is the most critical part of the operation. Ground speed is determined by the ease with which the windrow can be picked up and is normally the limiting factor for modern harvesters. This highlights the importance of laying a good windrow.

Canola seed and trash are relatively light when mixed, therefore it is difficult to separate them quickly. Yield varies even though windrows look even. Set the loss monitor carefully and drive to it.

GRAIN LOSSES

The longer harvest is delayed, the greater grain losses will be and this is especially true in canola. Losses can occur from windrowing up until harvest, due to pod shattering. Harvest losses can occur at the front and back of the harvester if it has been set up incorrectly. Grain losses will also vary depending on the time of day if the machine is not adjusted throughout the day and according to conditions.

Do not rely on grain loss meters for determining losses over the sieves when harvesting canola. The easiest method to assess losses for the entire machine during canola harvest is to use a square 2 L ice-cream container (0.022 m² equivalent). Put containers in the uncut section of crop in front of the harvester, four either side of where the harvester will go, to measure the front losses, and four in the middle of the machine, to measure the front plus machine losses. Then harvest the crop over the top of where the containers are and count the number of seeds in each container. Remember the concentrating factor when calculating machine losses. For canola, approximately 60 seeds captured in a square 2 L ice-cream container is equivalent to 100 kg/ha of lost yield.

Insidious losses can occur from small holes in the harvester, field bins and trucks as canola seed 'runs' so easily. For older harvesters it is essential to seal all holes and cracks with duct tape or silicon, especially on the table, front elevators, returns auger and grain tank. On some machines losses can occur from the outloading auger if unchecked. To check if the machine is leaking, stop harvesting and run it for three minutes then reverse and inspect the ground for seed loss.

When harvesting canola, tolerance thresholds are lower than for cereals and therefore harvesters need to be well prepared before harvest. Harvesting windrowed canola can be about 20 per cent slower than direct harvesting cereals or canola, especially to minimise losses. Draper front harvesters have significantly lowered losses in direct harvested canola compared to conventional fronts.

Generally, up to 10–20 kg/ha is considered an acceptable loss in canola grown on reasonably uniform paddocks. If a contractor is being used, reach an agreement on acceptable losses before the crop is harvested and check losses at the start of harvest.

15. Post-harvest management

Paul Parker, NSW DPI

Retaining crop residues is central to most modern farming systems in south-east Australia. Retained stubble has many benefits, with soil moisture conservation a top priority in Australia's highly variable climate. Canola harvest residue spread across the header harvesting width will maximise the amount of soil moisture conserved and may help protect the soil against wind and water erosion. In some instances stubble removal, partial removal or burning may be necessary to reduce disease levels and weed seed numbers or to overcome difficulties with establishing the following crop.

FEED QUALITY OF CANOLA STUBBLE

Canola stubble has little grazing value due to its poor feed quality. Tests of stubble show that metabolisable energy and crude protein are well below the minimum survival requirements for livestock. However, volunteer canola germinating after harvest can provide worthwhile summer or autumn feed.

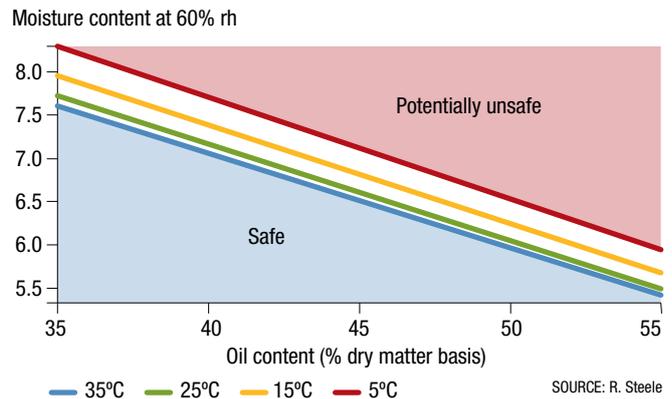
DISEASE MANAGEMENT

Burning canola stubble will typically remove about half of the available stubble. As blackleg spores originate from canola stubble, burning will reduce blackleg severity but generally there will still be enough spores to initiate the annual disease cycle. After the severe bushfires on the Eyre Peninsula of South Australia in 2005, which burnt all canola stubble, canola crops in the following year still suffered yield losses from blackleg in susceptible varieties (see chapter 10).

Research has also shown that a good hot burn can be effective in destroying many of the sclerotia (fungal fruiting bodies) of the disease sclerotinia. However, it will not eliminate the problem as most burns will not destroy all sclerotia and sclerotinia spores are airborne, meaning they can travel a considerable distance from neighbouring paddocks.

Canola stubble does not burn as readily or completely as cereals; usually the standing stubble between the header trash windrows remains unburnt and is left to stand if a cereal crop is to follow. This standing material rarely presents a problem at sowing or for the germination and establishment of cereals. If there are no disease or weed seed issues harvest residue should be spread across the harvest width.

Figure 15.1 Storability of canola as a function of temperature, moisture content and oil content



GRAIN STORAGE AND DRYING

Don McCaffery, NSW DPI and Neil Barker, GrainCorp

Grain storage

Most harvested canola is not stored on-farm in south-east Australia but is transported direct from the paddock to a major grain bulk handler or centralised storage. However, a small proportion is stored on-farm for a short time (two to four months) for logistical reasons such as delayed delivery arrangements with crushers.

Canola is much more difficult to store than cereals. It requires a lower storage temperature and must be aerated to preserve its quality and prevent insect infestations.

To maintain its market value canola must:

- have a high oil content of good colour;
- be low in free fatty acids;
- contain no residues of unregistered chemicals or residues above permitted limits;
- be relatively low in moisture and temperature; and
- be free of stored product insect pests, moulds and mycotoxins.

The storage conditions and processes affect many quality parameters. The most appropriate storage conditions are to maintain temperature of the seed below 20°C and seed moisture below seven per cent. Figure 15.1 is the best guide to determine if a load of canola of known moisture content and oil content is safely storable under Australian conditions. It shows the relationship between moisture content, oil



Aeration is important in the storage of canola.

PHOTO: J. SLEE, RIVERLAND OILSEEDS

content and temperature of canola in storage.

Storage conditions will affect:

- free fatty acid (FFA) development – high levels of FFA will cause off-flavours and reduce processing yield and quality. FFA levels are typically less than 0.5 per cent soon after harvest but can rise above two per cent in storage if temperatures are above 25°C;
- mould growth and mycotoxin development – can occur in any part of the storage where temperatures and moisture conditions favour the growth of storage fungi;
- heating and spontaneous combustion – high moisture and/or high temperature of canola seed may lead to moisture migration, mould, heating of the seed and, eventually, spontaneous combustion; and
- stored product insect attack – the same grain insect pests that attack stored cereal grains can also attack canola. Aeration systems used to regulate temperature are very effective against stored insect pests.

Temperatures below 18°C will limit population increases and below 14°C will effectively control all beetle pests. Alternatively, fumigate with phosphine gas, which is the only registered chemical for stored canola. To work effectively, the silo must be completely sealed and gas-tight. A number of delivery systems are available including the SIROFLO® system. Tablet and pellet formulations

may leave un-reacted residue which, if detected, could seriously damage export markets. It is preferable to use the sachet and blanket forms where appropriate, with all fumigation products removed at the end of fumigation.

Grain drying

Grain drying is not normally necessary. However, where seed is harvested above 10 per cent moisture it should be dried as soon as possible to avoid seed heating and possible spontaneous combustion. Depending on the seed moisture content, canola grain can be dried using either aeration or with a heated air grain dryer. Seek specialist advice when considering grain drying.

16. Marketing

Dick Benson, Dick Benson and Associates;
and Penne Kehl, Cargill

Market opportunities for canola have increased significantly since the late 1980s because of the significant gains made in breeding new varieties with improved oil and meal quality and increased production leading to access to important export markets.

Australian canola competes mostly with Canadian product on the international stage.

Canola is sold into a deregulated domestic market and, consequently, the responsibility of finding an acceptable price and arranging a buyer rests with the grower.

DOMESTIC DEMAND

Canola oil was originally used only in vegetable oil blends. However, it is now recognised as a product very low in saturated fats with additional health properties due to its monounsaturated fatty acid composition. This has improved the demand for canola for bottled oil and margarine, which are promoted for their health benefits in Australia and overseas.

The use of canola meal has increased considerably since the introduction of low glucosinolate varieties. Canola meal competes with other sources of protein, particularly imported soy meal. It is considered to be superior to sunflower meal and pulses and a premium is paid for meal above its nominal protein level, due mainly to higher lysine and energy levels and improved digestibility. However, it is not competitive with imported soy meal in terms of quality and variability.

Meal consumption, largely for pig and poultry feeds, has increased in parallel with domestic production of canola and growth in the livestock sector. Maintenance of high protein levels, low glucosinolates and a more consistent product will be essential to ensure further growth in demand for canola meal.

Australia's domestic demand for canola seed in 2008 was about 600,000 tonnes.

EXPORT

Japan is a major importer of canola seed, with annual imports of more than two million metric tonnes. This product is supplied almost exclusively by Canada, the world's major exporter, and Australia. Australia's exports to Japan have steadily increased due to improved supply and the demand by Japanese crushers for an alternative source of supply. Australia has advantages over Canada of lower sea freight, different harvest timing and a product of at least equal quality.

Australia exported an average of 741,680 metric tonnes

of canola around the world over the five-year period ending 2007-08. During this period the major markets were Japan (46.5 per cent), Pakistan (25.9 per cent), and Bangladesh (6.2 per cent). To maintain or increase market share, Australia must be recognised as a consistent supplier of quality product. Due to drought-induced supply disruptions Australia has lost market share in Japan to Canadian canola in recent years.

PRICING

Australia's oilseed production is insignificant in global terms so the prices paid to Australian farmers for oilseeds are determined very largely by world supply and demand factors. While Australia is a net exporter of oilseeds, it still imports a range of oilseeds and products – mainly soy meal and palm oil.

Different oilseeds substitute for one another to some extent but, because they each have different oil and meal quality and different proportions of oil and meal, complete substitutions are often not possible. These factors complicate the market and make comparisons difficult. Soybeans, which comprise about 70 per cent of world oilseed trade, are considered the benchmark for trading and prices internationally.

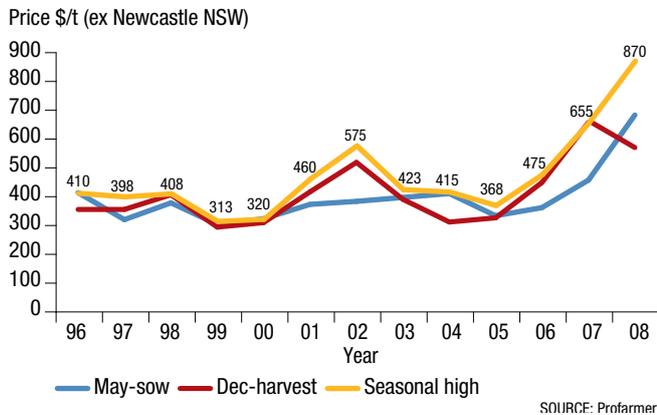
Import parity price will set the ceiling on domestic prices just as export parity will establish the floor.

Domestic prices are set by reference to three variables: the se are Winnipeg Commodity Exchange (WCE) futures, usually November or January which covers the Australian harvest period; the forward AUD/CAD exchange rate and the basis. The basis is the premium or discount that Australian prices trade at compared to WCE futures, expressed in CAD/t. A drought in Australia resulting in a small canola crop and a shortfall to meet domestic demand will see a strong basis. Conversely, a large crop will usually see a weak basis. Basis varies considerably over the year and between years as seasonal prospects change.

DEVELOPING A MARKETING STRATEGY

Growers must pay some attention to the long-term forecasts being offered by market analysts before canola is sown each year. However, canola prices are very hard to predict early in the season as global and domestic oilseed supply mainly depends on the weather over the growing season. Also, there are about 10 competing soft vegetable oilseeds and demand and supply factors vary for the oilseed, the oil and meal, complicating the ability to forecast prices. Growers

Figure 16.1 Comparison of the canola price, delivered Newcastle NSW, at sowing (early May) and harvest (early December) and the seasonal high 1996–2008



need to look at pricing opportunities available well before sowing and during the growing period of the crop, taking into account the performance of their own crop, risks of forward selling and domestic and global marketing factors.

It is necessary to know what is a high and low price so that you can set realistic target prices for selling. Growers will not normally sell more than 40–50 per cent before harvest on a conservative yield basis as disease, frosts, drought and a host of other factors can destroy crops and cause shortfalls in meeting contracted tonnage, which can incur large penalties. A good approach is to aim to sell certain percentages of the crop at specific times. So, for example, you could sell 10 per cent pre-sowing, 10 per cent on full ground cover, 10 per cent at flowering and another 10 per cent just prior to harvest. The timing of sales will depend on how the crop is performing as well as price.

From well before sowing it is advisable to monitor the price of canola closely and on a daily basis when market prices are rising strongly. It is a good idea to have one or two sources of independent market advice:

- this will ensure you are sent alerts or are aware when market action may be appropriate; and
- you will receive regular newsletters with information on market trends.

You should also organise to receive daily prices from the main traders and buyers via internet and fax. Inform whoever is likely to be selling your grain about your cropping intentions and ask for their field representative or agent to contact you if there are pricing opportunities.

OPTIONS FOR SELLING GRAIN

Canola is a high-value crop and so should not be stored on-farm for long after harvest as the holding cost in terms of interest lost can soon mount up. Also, oilseeds stored for extended periods must be subjected to carefully controlled aeration to prevent the possibility of quality deterioration due to heating and to prevent stored product insect attack. Canola is usually sold off the header and stored at local delivery silos or trucked directly to the crushing plant.

One useful option is to warehouse canola at the local silo as soon after harvest as possible. This eliminates concerns relating to any storage problems which may arise in the future, and can provide growers with more flexible marketing options after the harvest has been completed

The number of ways of forward selling has increased considerably, a major reason being to reduce the risk to growers.

A fixed price fixed tonnage contract – the traditional way of forward selling before harvest – entails some risk if used when crop outcome is uncertain. If the grower cannot deliver against the contract the buyer will usually ‘wash the contract out’ which may involve a penalty to the grower. The buyer will usually have the right to replace the failed contract tonnage by buying on the open market and the price needed to purchase the canola may be well above the market price bid to growers generally. The buyer may also give the grower the option to roll the contract over to the following year, but whether this is desirable largely depends on the difference between the contracted price and the market price when the contract is declared non-deliverable.

Other variations of the fixed price, fixed tonnage contract include target price orders and no price established contracts where the pricing decision can be made at a date after contracting or delivery. A number of marketing pools are also available to growers.

Over the Counter (OTC) products including basis contracts are now offered by most major traders, however, grower participation to date has been small. The products allow the grower to set the futures and exchange rate legs while leaving the basis leg unfixed. If the crop fails, as long as the basis is not fixed, the contract is non-deliverable. While the futures and currency hedges have to be closed out, any loss or profit is limited to these transactions and there is no washout penalty. A more recent development is the introduction of Bank Swaps. A grower hedges the futures and currency with the bank. It is a cash settled (non-deliverable) contract so the basis is established when the grower sells his canola. This contract gives the grower the choice of when and to whom to sell his canola.

With any market strategy the grower must feel comfortable with the risks taken. Each grower must develop their own strategy, but it is important that marketing is given the same status as other technical decisions.

The aim is to ensure the farming business does not suffer

because of a sudden collapse in prices late in the season and is able to take advantage of any spike in prices, so that the average price achieved is in the top one-third of prices for the season. All growers will have a different attitude to risk. Farmers who have expanded the farm enterprise to provide employment for children and have incurred significant debt as a result are more inclined to hedge prices to ensure debt repayments are able to be made. For a farm operator who is well established with close to 100 per cent equity it may be less important.

Delivery standards are as follows:

- **Moisture content.** Eight per cent maximum. If accepted over the maximum then a two per cent deduction in price applies for each one per cent moisture above eight per cent. Growers normally have little trouble achieving a moisture level of eight per cent; in fact many crops are as low as six per cent moisture when harvested. High moisture seed should not be stored as severe heating is likely.
- **Oil content.** Forty-two per cent is the base level, with 1.5 per cent premium or deduction for each one per cent above or below 42 per cent.
- **Impurities.** Seed is rejectable at over three per cent (by weight) impurity. If accepted, a one-for-one penalty operates up to four per cent, and two-for-one penalty operates above four per cent. Impurities include weed seeds, stem and seed pieces, and very small shrivelled canola seeds. Most growers achieve a fairly clean sample and few are penalised for impurities.
- **Test weight.** A minimum test weight of 62 kg/hectolitre applies. Seed is rejectable under this limit.
- **Broken seed.** Seed is rejectable if it contains over seven per cent broken seed. There is a 0.5 per cent price penalty for each one per cent broken seed above this level. Broken seed consists of hulls, kernels and seed pieces normally resulting from mechanical damage.
- **Damaged seed.** Up to three per cent of seed may be damaged without penalty. A 0.5 per cent price penalty applies for each one per cent broken seed above this level. Seed is 'damaged' if it is affected by heat, frost, sprouting or other weather damage.
- **Field insects.** Up to 10 large field insects per 0.5 L are allowed (grasshoppers, woodbugs, ladybirds and Rutherglen bug) and 100 small field insects (thrips/aphids/mites) but loads may be rejected if they contain higher levels of these insects.
- **Green seed.** Up to two per cent without penalty. Loads may be rejected above two per cent using the ruler method or determined as chlorophyll, up to a maximum of 12 parts per million, and rejectable above this level. A full copy of the Canola Standards can be obtained from the Grain Trade Australia (formerly NACMA) website (www.nacma.com.au).

Further information

Grain cropping information is available in either hard copy or electronic format from a wide range of sources including state departments, grower-based farming systems groups, research providers, seed companies and industry organisations.

Publication

Canola: The Ute Guide

email: ground-cover-direct@canprint.com.au

Websites

NSW Department of Primary Industries
www.dpi.nsw.gov.au

South Australian Research and Development Institute
www.sardi.sa.gov.au

Victorian Department of Primary Industries
<http://new.dpi.vic.gov.au>

National Variety Trials
www.nvtonline.com.au

Australian Oilseeds Federation
www.australianoilseeds.com

Grains Research and Development Corporation
www.grdc.com.au

Canola Council of Canada
www.canola-council.org

Grain Trade Australia (formerly NACMA)
www.nacma.com.au

Australian Pesticides and Veterinary Medicines Authority
www.apvma.gov.au/index.asp



Acknowledgements

The contributions of the following people who provided technical information or acted as expert reviewers are gratefully acknowledged.

Charles Aldersey, Goodman Fielder, Sydney NSW
 Peter Allen, 'Carumbi', Temora NSW
 Jonathan Banks, formerly CSIRO Entomology, Canberra ACT
 Dr Chris Bourke, formerly NSW DPI, Orange NSW
 Neil Barker, Grain Corp Melbourne VIC
 Geoff Beecher, NSW DPI, Yanco NSW
 Greg Condon, Grass Roots Agronomy, Junee NSW
 Tim Condon, Delta Agribusiness, Harden NSW
 Chris Duff, Delta Agribusiness, Young NSW
 John Francis, Holmes Sackett, Wagga Wagga NSW
 Mark Harris, Rural Management Strategies, Wagga Wagga NSW
 Bernard Hart, 'Waerawi', Junee NSW
 Peter Hocking, CSIRO, Canberra ACT
 Dr Joanne Holloway, NSW DPI, Wagga Wagga NSW
 Robert Hoogers NSW DPI, Yanco NSW
 Damian Jones, Vic. DPI, Kerang VIC
 John Lacy, NSW DPI, Yanco NSW
 John Lamont, Sedgefield, Old Junee NSW
 Dr Deidre Lemerle, EH Graham Centre, Wagga Wagga NSW
 Peter Matthews, NSW DPI, Temora NSW
 Janet MacDonald, Unilever, Sydney NSW
 Peter Mangana DAFWA, Perth WA
 Dr Svetlana Micic, DAFWA, Perth WA
 Dr Gordon Murray, formerly NSW DPI, Wagga Wagga NSW
 Dr Adrian Nicholas, NSW DPI, Tamworth NSW
 Dr Rob Norton, University of Melbourne, Horsham VIC
 Kieran O'Keefe, NSW DPI, Griffith NSW
 John Piltz, NSW DPI, Wagga Wagga NSW
 Bruce Ramsey, Incitec/Pivot, Wagga Wagga NSW
 Rosemary Richards, AOF, Sydney NSW
 Dr Phil Salisbury, University of Melbourne, Melbourne VIC
 Dr Steven Simpfendorfer, NSW DPI, Tamworth NSW
 Dr Doug Sommerville, NSW DPI, Goulburn NSW
 Mark Stanley, PIRSA, Port Lincoln SA
 Rob Taylor, 'Glenalla', Grenfell NSW
 John Tompson, formerly NSW DPI, Deniliquin NSW
 Dr Paul Umina, CESAR, Melbourne VIC
 Peter Watt, Elders, Cowra NSW
 Rachael Whitworth, NSW DPI, Griffith NSW
 Rob Wilson, CAA, Wagga Wagga NSW
 Neil Wratten, NSW DPI, Wagga Wagga NSW

The base document used to produce this publication was the NSW DPI Agfact P5.2.1 Canola. The authors of that Agfact, Bob Colton and John Sykes are duly acknowledged.



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