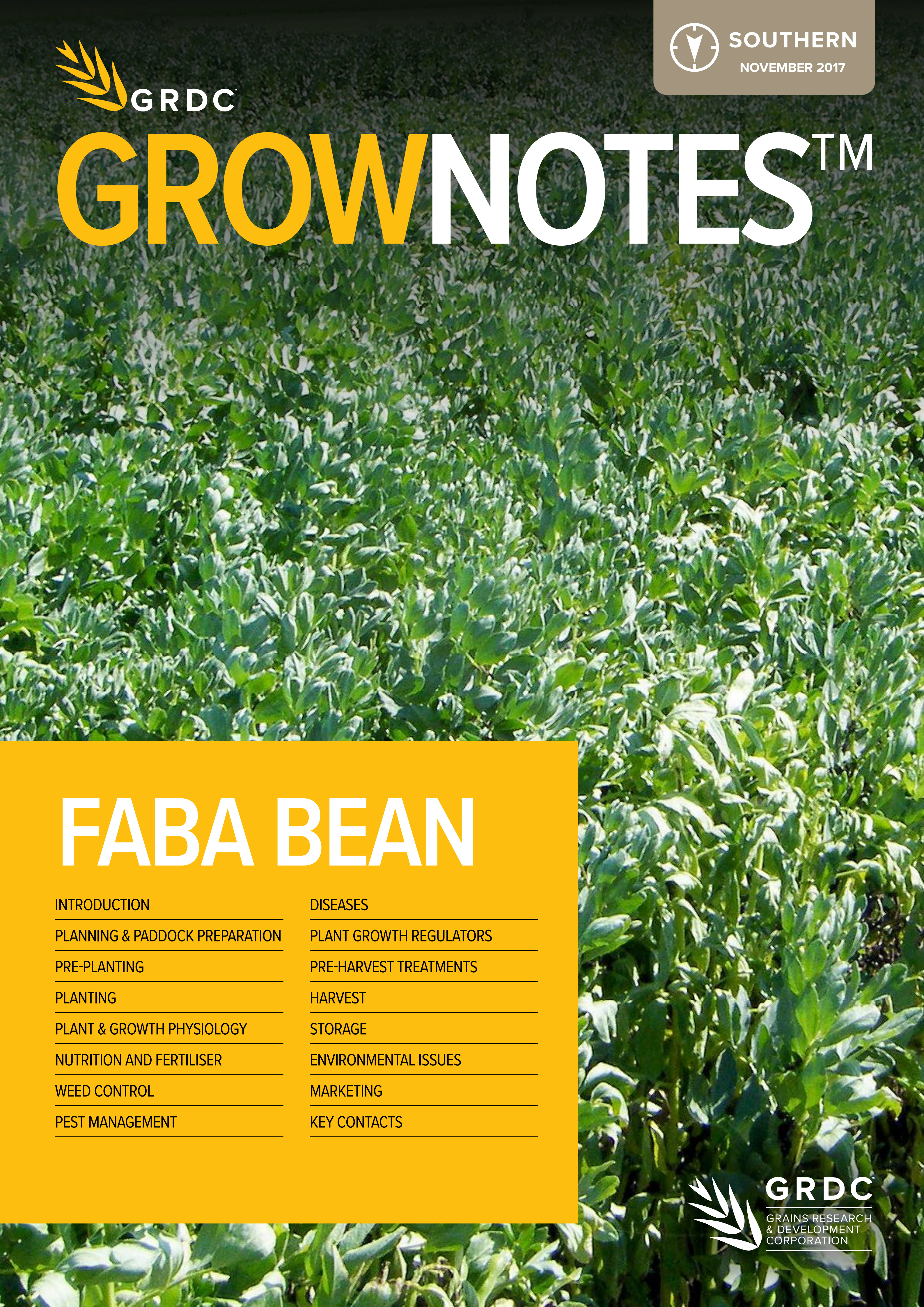


GRDC

SOUTHERN
NOVEMBER 2017

GROWNOTES™

FABA BEAN

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Start here for answers to your immediate faba bean crop management issues

What variety should I grow?

What surface condition is required in the paddock?

What are the key weed issues?

How do I best control diseases of faba bean?

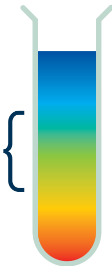
What are the requirements for storing faba and broad bean?

What's the process for marketing faba and broad bean?

Faba bean production

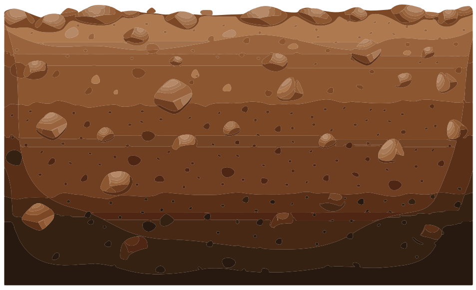
COOL SEASON
>–2°C

RAINFALL
400 – 550 mm



LOW SALINITY, Al
pH 5.5–8 (in $CaCl_2$)

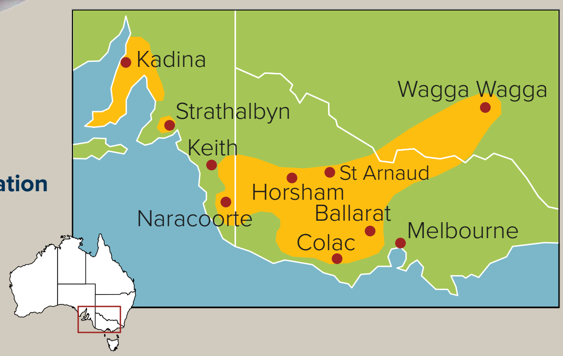
DEEP SOIL
NO HOLLOWS
WELL-DRAINED
LOAM-CLAY



A VARIETY OF
FABA BEAN

BENEFITS

- up to 110 kg N/ha fixed
- good rotation with cereal
- performs well under irrigation
- better cereal yields



Source: Pulse Australia (2015) – Pulse Australia website

ISBN: 978-1-921779-24-4

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3 Pre-planting

6 Nutrition and fertiliser

9 Diseases

13 Storage

14 Environmental issues

Introduction

1.1 Faba bean in Australia

Faba bean and broad bean account for 10–15% of the annual Australian pulse crop, with between 152,000 and 230,000 hectares planted each year.[1] Approximately 370,000 tonnes are produced annually.[2]

The southern region grows 70% of Australia's faba bean by area sown. In the southern region the gross value of faba bean was $105 million (average from 2010-11 to 2016-17).[3] More recently the area planted has increased, with improved varieties with better disease management packages and better market prices. In addition, growers now recognise the contribution of pulses to managing weeds and diseases in the overall rotation. There is also increasing recognition of the fact that faba and broad bean are the better pulses to grow on soils that can become waterlogged for short periods.

Originating in the Middle East in the prehistoric period, faba bean has since been cultivated throughout Europe, North Africa, and Central Asia. It was introduced to China more than 2,000 years ago via traders along the Silk Road, to South America in the Columbian period, and more recently to Canada and Australia.

The Australian faba bean industry commenced in South Australia in 1981 with the release of the variety Fiord and spread to the higher-rainfall cropping regions in Victoria, New South Wales and Western Australia, but with fluctuating areas sown due to the impact of foliar disease. Faba bean production has stabilised in these states following the release of improved varieties and better agronomic management packages. Small areas are now also grown in Tasmania and southern Queensland.

The early varieties had poor foliar disease resistance and some bad experiences with faba bean losses led growers to nickname them 'failure beans'.[4] Today growers have a better understanding of disease management and newer varieties have improved disease resistance and a more consistent grain quality. Better agronomic management packages have also been developed.

1 AEGIC (2015) Australian Grain Note: Pulses. Australian Export Grains Innovation Centre, http://pulseaus.com.au/storage/app/media/using_pulses/AGN_Pulse-Note-LR.pdf

2 ABARES (2016) Australian crop report: February 2016 No.177. Australian Bureau of Agricultural and Resource Economics and Sciences, Department of Agriculture and Water Resources, http://www.agriculture.gov.au/abares/publications/display?url=http://143.188.17.20/anrdl/DAFFService/display.php?fid=pb_aucrpd9aba_20160209_11a.xml

3 DAWR ABARES (2017) Australian Crop Report. ABARES, http://www.agriculture.gov.au/abares/research-topics/agricultural-commodities/australian-crop-report

4 G Onus (2014) Optimising performance and managing risk in faba beans. GRDC Update Paper 26 August 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Optimising-performance-and-managing-risk-in-faba-beans

MORE INFORMATION

GRDC 2011 Choosing break crops Fact Sheet, (southern region) https://grdc.com.au/Resources/Factsheets/2011/03/Choosing-Break-Crops-South

GroundCover™ TV: Value of pulses in the farming system https://youtu.be/ZfbW40oP0SI

1.2 Why grow faba bean?

Faba bean, along with other pulses, are often considered to be a valuable break crop in a rotation dominated by cereals. However, pulses can be the most profitable crop in the rotation, with the human consumption market willing to pay high prices for good-quality grain.

The benefits of including pulses in the rotation are to:

- diversify crop rotation;
- reduce the need for inputs through nitrogen fixation;
- broaden weed control opportunities, particularly for controlling herbicide-resistant weeds;
- provide a pest and disease break;
- fit well into a cereal-based cropping and stubble-retention system;
- spread the timing of farming operations; and
- spread risk across different crop types.[5]

In particular, pulses fit well when grown in the year before canola to provide a two-year break from cereals and, when planted before the canola, increase soil nitrogen and water reserves, therefore reducing the risk associated with growing canola.

There are some advantages to choosing to grow faba bean rather than an alternate pulse. Faba bean:

- Can be sown both early and into dry soil, allowing growers to spread the timing of farming operations. They can also be harvested early compared with cereals.
- Has a shallower root system and shorter growing season, limiting the use of subsoil moisture.
- Tolerates waterlogging better than other pulse crops, making it more suitable for the high-rainfall zone and the heavier soils in the medium-rainfall zone.
- Cattle can pick up larger grain such as faba and broad bean when grazing stubbles after harvest even when the grain is split. Research has shown that bean and lupin stubble produce better weight gain in young Merino sheep than other pulses.

1.2.1 Weeds

Faba bean provides a good opportunity to use different herbicide groups, thus delaying the onset of herbicide resistance. Faba bean allows growers to target grass weeds including herbicide-resistant weeds, particularly annual ryegrass.

However, faba bean is a moderately poor competitor against weeds until canopy closure and there are limited post-emergent broadleaf herbicide control options for use within pulse crops. Effective use of knockdown and pre-emergent herbicides is important.

Faba bean can be sown in wide rows, allowing non-selective weed control between the rows using shielded sprayers.

Pulse crops can be versatile if not used solely for grain harvest. Green or brown manure crops, hay cuts or grazing as standing crops are options that can be useful for managing resistant weeds. While there is no direct income from manuring it can achieve excellent grass-weed control, high nitrogen input, improved residual water carryover and better groundcover (for brown manuring). The large seed of faba and broad bean make them less attractive than smaller-seeded legumes to use as an intentional green or brown manure option.

5 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

1.2.2 Disease

Faba bean provides an important break for cereal root pests and diseases including cereal cyst nematode (CCN), take-all, crown rot and root-lesion nematode.

Grass weeds need to be controlled for the rotation to be effective. The rotation is one year for take-all and two years for crown rot and CCN. Faba bean is also a suitable rotational crop to reduce the incidence of root-lesion nematode.

1.2.3 Nitrogen

Pulses fix their own nitrogen (N), providing a boost for the following crops. Up to 40% of the nitrogen in a faba bean crop remains in the soil within the root system.

A vigorously growing crop with good nodulation and maximum biomass will fix more nitrogen. Nodulation and nitrogen fixation is suppressed when soil nitrate levels are already high. This means that there will be a greater benefit from pulses when soil nitrate is lacking. Studies in northern NSW showed that each tonne of shoot dry matter produced 19.3 kilograms of N per hectare.[6]

Using faba bean as a manure crop can increase the amount of nitrogen that is retained to benefit subsequent crops.

Faba bean is said to produce more nitrogen than other pulse crops because of its high dry matter production. However, it is more important to consider the soil type, as the pulse crop that will grow well will produce the most nitrogen in a given situation.

6 GRDC (2014) Nitrogen fixation fact sheet (southern and western regions). Grains Research and Development Corporation, http://www.grdc.com.au/GRDC-FS-NFixation-Legumes

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

1.3 Key points for successfully growing faba bean

In the early days faba bean had a reputation for being difficult to grow and highly susceptible to foliar disease. However, an increased confidence in the profitability of this crop has resulted from:

- improved varieties with better regional adaption, higher yield potential and greater disease resistance;
- better disease management packages, including increased sprayer capacity and better short-term weather forecasts for fungicide application planning;
- improved farming systems;
- better crop management; and
- improved irrigation layouts.

Specific variety management packages (VMPs) are available from Pulse Australia to maximise the benefits from new improved pulse varieties.

Some disadvantages of faba bean in a rotation are:

- Unlike canola they do not have a deep root system capable of creating channels through the soil profile.
- They are susceptible to fungal diseases such as Ascochyta blight and chocolate spot. However, newer varieities with some resistance to these diseases now help when used with disease control strategies.
- They are moderately susceptible to hostile subsoils, such as those with high concentrations of boron, aluminium, sodicity and possibly salinity.

The key management practices for successful production of faba and broad bean are as follows:

- Avoid acid soils (or correct with lime) and light, sodic or saline soils, and those with boron toxicity.
- Plan weed management to reduce weed burden while also ensuring no residual herbicide carryover.
- Use good-quality seed with greater than 80% germination that is certified free from seed-borne Ascochyta pathogens.
- Test your sowing equipment with inoculated seed to ensure you can successfully sow the large flat bean.
- Sow into cereal stubble to maximise nitrogen fixation and minimise aphid infestation. Using wide rows can help improve stubble flow.
- Sow within the ideal sowing window. Sowing too early can lead to greater foliar disease incidence. Late-sown faba bean will have limited height and biomass and this will limit yield. Flowers may also be produced closer to the ground, making harvest difficult. Faba bean does not tolerate warm, dry finishes, so the length of the season will be shorter, limiting yield.
- Ensure good nutrition starting with seed inoculation to ensure effective nodulation. Apply phosphorus to deficient soils and, potentially, zinc on alkaline soils or molybdenum on acidic soils.
- Manage disease carefully. Understand the disease risks in your area and conduct a PreDicta®B soil test for nematodes. Choose resistant varieties where possible. Be prepared to apply preventative fungicides during the growing season, typically 2–4 applications at critical timings including post-emergence, prior to canopy closure and early pod-fill. Later sowing is a technique that can be used with caution to limit disease pressure in higher-rainfall areas. Use integrated disease management tools, such as planting more than 500 m from faba bean stubble and managing volunteers over summer.
- Control insects by managing the 'green bridge', using seed dressing and monitoring regularly for *Helicoverpa* caterpillars, which can damage pods during filling, making the seed unsuitable for human consumption markets.

- Harvest on time, with a properly set-up header. Windrowing may assist with even ripening. Start when nearly all pods are black, but before stems become completely dry and black. If the header settings are correct, pods will thresh easily to yield clean, whole seeds with a minimum of splits and cracks.
- Have a marketing plan for on-farm storage or delivery options off-header. This may involve forward contracting if storage, pools or warehousing are not viable options.
- Optimise irrigation set-ups and timing. Faba bean respond well to irrigation in dry areas. Furrow irrigation is successful in southern irrigation areas with either pre-water and sow, or dry-sow and water-up. To maximise yield potential, crops should be watered to produce maximum biomass, and not allowed to stress during flowering and pod-fill.

When assessing the financial performance of bean crops in the rotation take a systems approach over several seasons to see the true benefits to the overall farming system.

1.4 Plant physiology

Faba bean plants are erect and up to 2 m tall at maturity, although most Australian crops are less than 1.5 m tall.

They produce branches stemming from the base. Leaves are compound, with only two leaflets in the early growth stages and up to seven leaflets after flowering begins.

The taproot penetrates to around 60 cm, with a profusion of fibrous roots. Overall, beans produce fewer roots and are shallower rooted than cereals and, given the shorter growing period, use relatively little soil moisture. However, this does make them more vulnerable to dry finishes.

Flowering begins from about the 5th to 7th node (joint) in early-maturing varieties and up to the 15th node or higher in later-maturing varieties. The flowers are in clusters (inflorescences) of 3–8 flowers (depending on the variety) in the axil (angle between leaf and stem) at each node. Inflorescences form in succession up the stem as each new node is produced over a 6–10-week period, or about 15 flowering nodes (Photo 1). Like many legumes, excess flowers are produced and fewer than 15% will develop into viable pods.

Photo 1: *Flowering faba bean.*

Photo: G Cumming, formerly Pulse Australia

Faba bean is predominantly self-pollinating; however, the introduction of honey bee hives has been shown to increase pollination rates and yields.

Flowering will finish when daylight temperatures approach 30°C, after which only a few leaf-bearing nodes are produced.

Pods in a well-grown crop are borne from about 20–30 cm above ground level. Each pod contains 2–4 seeds, which will vary in size depending on variety.

Bottom pods will mature first and turn black, as will the bottom leaves. This will continue gradually upwards as the plant senesces.

1.4.1 Suitable environments

Faba bean is a cool-season crop in Australia, planted in autumn and harvested in late spring to early summer. Faba bean is generally suited to the medium to high-rainfall areas with a minimum of 400 mm average annual rainfall or irrigation. Broad bean have a longer growing season and are more suited to the high-rainfall zone and a minimum of 450 mm.

The ideal soil type is a deep, well-drained loam. Clay soils are also suitable. Soil pH will ideally range from neutral to alkaline (pH in H_20 6.5–9.0, or pH in $CaCl_2$ 5.2–8.0). Faba and broad bean are moderately susceptible to hostile subsoils. Boron toxicity, sodicity and salinity can cause patchiness in affected paddocks. On acid soils, faba bean and broad bean are moderately susceptible to hostile manganese and aluminium toxicity, which can cause patchiness in affected paddocks.

The optimal temperature for plant growth is 15°C–20°C, especially during the reproductive phases of flower and pod development. Faba bean tolerate frost better than other pulses.

1.5 Products and uses

1.5.1 Human consumption

The most profitable use for pulses is the human consumption market. Faba bean and broad bean are a good source of carbohydrate and protein and are low in fat. Carbohydrate is mainly starch. The crude protein content of faba bean and broad bean ranges from 24–31%. They are also high in fibre.[7]

Faba bean and broad bean meet all adult human requirements for essential amino acids except methionine and tryptophan. They also provide the recommended daily allowance of all essential minerals except calcium.

Faba bean is exported as either whole or split product. It is generally consumed whole, canned, split and/or milled into flour. The main uses are:

- Cooked or baked – whole beans are used in soups, purées, baked goods, snack foods and breakfast foods, or can be cooked into a thick gruel.
- Ground – uncooked beans ground with other ingredients make falafel or tameya.
- Sprouts – sprouted for use in salads and stir-fries.
- Fresh – sold fresh in the pod or frozen.

1.5.2 Animal feed

Pulses are a valuable stockfeed due to their high protein levels and palatability, and can be used as part of intensive livestock rations or as supplements for paddock-reared stock.

Faba bean are used in the aquaculture, pig, poultry and horse industries as a source of protein as an alternative to field pea, fishmeal, lupin, soybean meal and other protein supplements.

7 Pulse Australia (2016) Health benefits of pulses. Pulse Australia, http://www.pulseaus.com.au/using-pulses/health-benefits

Faba bean and broad bean are highly digestible and the metabolisable energy for pigs, poultry and ruminants is similar to lupin, field pea and soybean meal. They can correct the deficiencies in cereal stubbles or dry feed better than cereal grains. However, they are not as low in starch or as high in fibre as lupin, so they must be introduced gradually and fed regularly to avoid grain poisoning.

Bean crops may also be grazed where the crop has failed or as part of a strategy to control herbicide-resistant weeds.

Sheep and cattle can graze pulse stubbles, with the residual pulse grain of more value to livestock than cereal stubble. Faba bean produce excellent weight gain in sheep and cattle. Cattle are unable to pick up spilt seed from smaller pulses, but can manage faba and broad bean.

Be aware of any withholding periods or slaughter export intervals for chemicals used. Stocking rates can be estimated by calculating grain losses per hectare (see Section 12 Harvest). However, note that pulse stubbles are prone to erosion and grazing will increase the risk.

1.6 Market

The Australian faba and broad bean industry has grown steadily to now be one of the top five producers in the world. Australia is currently the world's leading exporter of faba bean, supplying one-third of faba bean traded internationally.

1.6.1 Faba bean

All faba bean grown in Australia is targeted at the human consumption markets. Our major buyers are the Middle Eastern countries including Egypt, Saudi Arabia and the United Arab Emirates. Some is split in Australia for human consumption.

International trade in faba bean of food quality is dominated by Egypt as the major importer, with several other countries importing smaller but still significant amounts.

The relatively small global market demand from the Middle East and Northern Africa is consistent and has been for the past 10 years. If there is a surplus of product produced globally prices will fall.

Producing a high-quality product with continuity of supply is important to maintain and increase access to faba bean markets into the future. Maintaining a light-tan seed colour and undamaged seed is essential (Photo 2).

Australia competes with France and the UK as the major exporters. In 2015, with historically high prices being paid globally for faba bean, the Baltic states, eastern Europe and North America entered the international faba bean market for the first time.

In the past, China was a major exporter but it is predicted to become a net importer in the future. Regulations need to be in place for Australian beans to be exported to China.

In addition, several countries are significant importers of faba and broad beans for livestock feed.

Faba bean not sold for human consumption is used by the Australian stockfeed industry, priced on a least-cost ration basis. This is mainly in the aquaculture, pig, poultry and horse industries. This grain is normally of a lower grade (discoloured) and/or damaged by insects or disease. Growers need to be prepared to store grain on-farm prior to selling into the stockfeed market.

Photo 2: *Faba bean products.*

Photo: *Faba beans: The Ute Guide (2009)*

1.6.2 Broad bean

Broad bean grown in Australia target the human consumption markets, as well as export stockfeed markets. Italy, Spain, Indonesia and Taiwan are the main importing countries for larger broad bean, while small broad bean are popular in Middle East countries such as Saudi Arabia, the United Arab Emirates, Jordan and Lebanon where they are used for canning.

Broad bean go into the whole-seed edible market, as well as stockfeed markets. Either way, there is a need for broad bean to be light and bright in colour and without weather damage. Size is critical and determines price.

Broad bean marketing is different to that of faba bean. There are few, if any, delivery points direct off-header, so on-farm storage is essential. Movement off-farm may not occur until spring, so there is often a long wait for sales, with cashflow implications for growers. Small broad bean can be hard to sell.

MORE INFORMATION

GroundCover™ TV: Pulse Breeding Australia retrospective: https://youtu.be/TMmloC9gsm0

1.7 Faba bean research

The Australian faba bean breeding program aims to develop varieties that add value to the Australian cropping industry and meet the quality requirements of international markets. The program targets new varieties for either the southern region or the northern region (mainly northern NSW).

The breeding program began by introducing overseas varieties, but is now focused mainly on local crossing and selection, with a much reduced reliance on the introduction of new germplasm.

The early generations of the breeding cycle are undertaken at the University of Adelaide's Waite Campus, for the southern region, and the NSW Department of Primary Industries' Australian Cotton Research Institute (ACRI) in Narrabri for the northern region.

The main objectives of the breeding program are:

- to combine disease resistance and high yield potential in well-adapted backgrounds; and
- to introduce new sources of disease resistance, or other new traits of interest, to locally adapted material.

The breeding program is part of Pulse Breeding Australia (PBA), a world-class Australian breeding program delivering highly adapted chickpea, field pea, lentil, faba bean and lupin varieties to growers across Australia.

PBA has operated since 2006 and its vision is to see pulses expand to more than 15% of the cropping area so as to underpin the productivity, profitability and sustainability of Australian grain farming systems.

PBA's nationally coordinated breeding programs aim to deliver superior varieties to all Australian growing regions. PBA is an unincorporated joint venture between:

- Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR)
- South Australian Research and Development Institute (SARDI)
- Queensland Department of Agriculture and Fisheries (DAF)
- New South Wales Department of Primary Industries (DPI)
- Department of Agriculture and Food, Western Australia (DPIRD)
- University of Adelaide
- University of Sydney
- Pulse Australia
- Grains Research and Development Corporation (GRDC)

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Planning and paddock preparation

Key points

- **Faba bean is a pulse crop most suited to the high and medium-rainfall zones of the southern region. Research is underway to expand the area of faba bean into the low-rainfall zone.**
- **The crop provides residual nitrogen, residual water and, when free of grass weeds, a disease break to boost yields of subsequent cereal crops.**
- **Faba bean prefers alkaline to slightly acid soils and cannot tolerate exchangeable aluminium in the soil, which is more common in acid soils. Do not grow faba bean in paddocks with Group B herbicide residues.**
- **Faba bean is typically sown with no-till into retained stubble but can be grown using a range of farming systems.**
- **The crop responds well to irrigation. Layout is one of the most important factors affecting irrigated faba bean yield.**
- **Several tools are available to estimate potential yield of faba bean to manage inputs effectively.**
- **Faba bean stubble can be grazed and is of high nutritional value to livestock, mainly due to spilt grain.**

2.1 Paddock selection

Faba bean is best suited to the medium and high-rainfall zones (400–550 mm annual average rainfall) as well as irrigated areas (Figure 1).[1 2]

Faba bean can be grown in drier areas or in dry seasons, but early sowing with suitable varieties may be needed to mitigate yield loss.[3]

Several new, early-flowering and maturing faba bean breeding lines are showing promise, with improved drought resistance. A faba bean variety trial in the Victorian Mallee focused on drought tolerance in the very dry season of 2015. A gross margin of $150/ha was achieved for the top-yielding breeding line, with $230/ha production costs at $450/t grain price, while modern commercial varieties gave very low or negative net returns.[4]

2.1.1 Paddock selection: key points

Assess the best paddock for faba bean based on past rotation, weed types, weed population, disease risk, herbicide use and soil type.[5]

The crop requires mild weather conditions during flowering to maximise yields.[6]

Faba bean is best suited to well-drained, deep and level soils with slightly acid or neutral to alkaline pH. The crop can be grown on more acidic soils where there is no exchangeable aluminium in the soil.[7] Soils should also have low levels of sodicity, salinity and boron, which can cause patchiness.[8]

Rough, rocky and uneven paddocks are not ideal for faba bean as harvest losses will be much higher where headers cannot cut at a low height.

Ideally, paddocks should be chosen well in advance to ensure good broadleaf weed control in the preceding crop and, if possible, the standing stubble left after harvest.[9] Paddocks with high weed burdens should be avoided as faba bean is only moderately competitive with weeds and broadleaf herbicide options are limited.

Be careful to avoid damage from herbicides used in the previous 24 months when planning to sow faba bean.

Faba bean is suited to paddocks that are likely to have a low nitrogen status, such as those with a longer cropping history. This will maximise the amount of nitrogen fixed by the plants.[10]

Faba bean crops should be sown at least 500 m from faba bean stubble to reduce the spread of Ascochyta blight. This recommendation extends to 1 km in areas where old stubble is prone to movement such as down slopes and flood plains.

Pay particular attention to controlling broadleaf weeds in the preceding crop.

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1 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

2 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

3 M Lines, L McMurray, J Paull, C Jeisman (2013) Faba bean varieties and management, 2012, Trials Results Book, MacKillop Farm Management Group, www.mackillopgroup.com.au/media/2012TrialBook/faba_beans.pdf

4 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

5 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

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7 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

8 K Lindbeck (2014) Faba bean and chickpea disease management. GRDC Update Paper, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Faba-bean-and-chickpea-disease-management

9 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

10 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

Faba bean yields can be improved by direct-drilling into standing cereal stubble.[11 12 13 14]

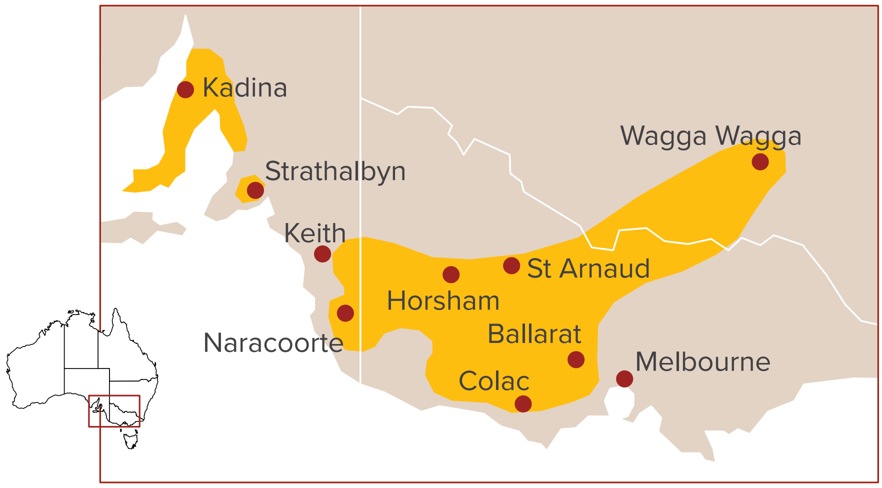

Figure 1: *Key requirements for faba bean in southern Australia.*

Source: Pulse Australia

2.1.2 Soil types

Soil structure

The ideal soil for faba bean is deep, well-structured loam to clay loam.

As faba bean tend to have shallow roots, the crop may suffer moisture stress in sandy soils that dry quickly (Photo 1). Faba bean are also not suited to sands (Photo 2) or infertile soils. Deep loams are considered the best soil for faba bean.[15 16 17]

Photo 1: *Faba bean suffers moisture stress in sandy soils that dry quickly.*

Photo: Felicity Pritchard

11 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

12 G Onus (2014) Optimising performance and managing risk in faba beans. GRDC Update Paper 26 August 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Optimising-performance-and-managing-risk-in-faba-beans

13 Pulse Australia (2014) Northern faba bean best management practices training course – 2014. Pulse Australia.

14 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

15 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

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17 C Mullen (2004) The right pulse in the right paddock at the right time, Agnote DPI 446. W Noad (ed.). NSW Agriculture, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/general-information/right-pulse

Photo 2: *Faba bean (centre) does not grow well on deep sands, in contrast to narrowleaf lupin.*

Photo: Alan Robson, Grain Legume Handbook (2008)

Although faba bean is very tolerant of waterlogging compared with other pulses,[18] a well-drained soil is preferred. Plant growth will be affected by prolonged waterlogging and foliar disease becomes more severe. Faba bean need good nodulation and disease control to survive extended waterlogging.[19 20]

Compacted soil layers, particularly on duplex soils, should be avoided.[21] Hard-setting soils also cause problems. Shallow, calcareous soils – particularly those on exposed limestone reef – can restrict growth (Table 1).

Table 1: Soil type effects on faba bean and broad bean growth.

Soil structure	Faba bean	Broad bean
Clay	Excellent	Excellent
Loam	Excellent	Excellent
Sand	Poor	Poor
Light sand	Very poor	Very poor
Clayed sand low lime)	Average	Poor
Clayed sand (free lime)	Average	Poor

Source: Grain Legume Handbook

Paddocks with a uniform soil type make management easier, as major variations in soil type can lead to uneven ripening of the crop. This can delay harvest, which increases the risk of weather damage and losses from cracking and split grain.

18 M Lines, L McMurray, J Paull, C Jeisman (2013) Faba bean varieties and management, 2012, Trials Results Book, MacKillop Farm Management Group, www.mackillopgroup.com.au/media/2012TrialBook/faba_beans.pdf

19 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

20 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

21 Topcrop Australia (undated) Checklist for a successful faba bean crop. Topcrop Australia and Victoria Department of Natural Resources and Environment.

Uneven ripening also complicates the timing of insecticides, desiccants and fungicides (see Section 11 Pre-harvest treatments for more information).[22]

Faba bean may fail to nodulate on acidic soils with high aluminium, particularly if they are hard-setting or waterlogged.[23] Inoculation with granular inoculum can assist faba bean nodulation on some acid soils (see Section 4 Planting for more information).

Soil pH

Faba bean prefers slightly acid to alkaline soils but can tolerate acid soils with no exchangeable aluminium. Faba bean prefers slightly acid to alkaline soils ranging in pH ($CaCl_2$) from 5.2 to 8.0, with no exchangeable aluminium.

Consider applying lime if pH in the topsoil is less than 5.2 ($CaCl_2$) Avoid growing faba bean on paddocks with acid soil at depth, that is with pH ($CaCl_2$) less than 5.2 at 20–30 cm.[24 25 26]

Hostile soils

Growers considering faba bean on acidic soil should check aluminium and manganese levels are not within the toxic range for faba bean; the crop has low tolerance for soil aluminium.[27]

Faba and broad bean are moderately susceptible to hostile subsoils. Boron toxicity and possibly salinity can cause plants in affected areas to die.[28]

Sodic soils should be avoided.[29] A soil with an exchangeable sodium percentage (ESP) of >5% exchangeable sodium is considered sodic. Faba bean is suited to soils with an ESP below 5 in the top soil and 10 in the subsoil (see Section 6 Nutrition and Fertiliser for more information).[30]

Evenness of soil surface

An even soil surface is important to make harvesting easier (see Section 2.5 Seedbed requirements for more information).

2.1.3 Paddock selection to reduce disease risk

Paddock selection can reduce the risk of faba bean diseases.[31]

A 4-year, or more, break between faba bean crops is recommended. Avoid sowing the crop adjacent to faba bean stubble, particularly downwind. If possible, separate the faba bean crop from the previous year's faba bean stubble by at least 500 m.[32]

Avoid, where possible, sowing faba bean adjacent to vetch crops or stubble, which may harbour the fungus *Botrytis fabae*, the primary cause of chocolate spot in faba bean (see Section 9 Diseases for more information).

22 Pulse Australia (2014) Northern faba bean best management practices training course – 2014. Pulse Australia.

23 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

24 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

25 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

26 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

27 Pulse Australia (2014) Northern faba bean best management practices training course – 2014. Pulse Australia.

28 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

29 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

30 C Mullen (2004) The right pulse in the right paddock at the right time, Agnote DPI 446. W Noad (ed.). NSW Agriculture, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/general-information/right-pulse

31 K Lindbeck (2014) Faba bean and chickpea disease management. GRDC Update Paper, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Faba-bean-and-chickpea-disease-management

32 Pulse Australia (2014) Northern faba bean best management practices training course – 2014. Pulse Australia.

Ensure that the maximum plant-back periods for herbicides are adhered to, particularly for sulfonylurea herbicides and clopyralid; herbicide residuse may cause significant crop damage and weaken plant's ability to resist disease (see Section 2.4 Herbicide residue management for more information).

2.1.4 Paddock selection based on weed status

Faba bean should not be sown in paddocks with moderate to high levels of broadleaf weeds, as there are few chemical control options. Generally, grass weeds can be readily controlled in faba bean crops.[33] Australian faba bean breeding lines with Group B herbicide tolerance are being assessed.[34 35]

Herbicide-resistant grass weeds can cause major problems in faba bean. A careful management strategy of resistant weeds must be in place well in advance of sowing.

While it may be possible to reduce the weed burden in the season and summer before sowing faba bean, it is best to avoid paddocks with specific weeds that cannot be controlled by herbicides.[36]

2.2 Paddock history and rotation

Pulses play an important, complementary role in crop rotations/sequences[37] by enabling better management of weeds, diseases, herbicide residues and soil nitrogen.

While the most suitable rotation requires careful planning, there are no set rules and a separate rotation should be devised for each cropping paddock. The main aims should be sustainability and the highest possible long-term profit.

To achieve these, the rotation must be flexible enough to cope with key strategies such as maintaining soil fertility and structure, controlling crop diseases, and controlling weeds and their seedset.

Recent research in Victoria and southern New South Wales showed that canola and pulse crops were frequently as profitable and, in some cases, considerably more profitable, than wheat. Further, wheat following break crops was consistently more profitable than wheat on wheat.[38]

Faba bean is usually grown after a winter cereal.[39] Growers are frequently adopting a continuous pulse/cereal/oilseed/cereal sequence, such as faba bean/wheat/canola/barley.[40] Alternatively, an increasing number of growers are now using a double-break rotation of a pulse followed by canola to provide an additional weed and disease break before returning to a cereal crop.

Successive cropping with the same pulse is likely to result in a rapid build-up of root and foliar diseases and weeds. Take extreme care if growing the same crop in the same paddock without a break of at least 3 years. Where possible, alternate different pulse crops in a continuous rotation with cereals.

33 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

34 M Lines, L McMurray, J Brand, A Ware, J Davidson, R Kimber, J Paull, K Hobson (2014) Pulse varieties and agronomy update (Adelaide). GRDC Update Paper 25 February 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Pulse-varieties-and-agronomy-update-Adelaide

35 D Mao, J Paull, C Preston, S Ying Yang, T Sutton, L McMurray (2016) Developing improved herbicide tolerance in pulse crops. GRDC Update Paper 9 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Developing-improved-herbicide-tolerance-in-pulse-crops

36 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

37 Grain Legume Handbook Committee (2004) The role of pulses. Grain Legume Handbook. J Lamb, A Poddar (eds.) Grain Legume Handbook Committee.

38 M Peoples, T Swan, L Goward, J Hunt, A Glover, I Trevethan, A Pratt (2015) Key outcomes arising from the crop sequence project. GRDC Grains Research Update Paper 19 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Key-outcomes-arising-from-the-crop-sequence-project

39 G Onus (2014) Optimising performance and managing risk in faba beans. GRDC Update Paper 26 August 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Optimising-performance-and-managing-risk-in-faba-beans

40 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Faba bean fits well into stubble-retention systems. Compared with wheat, the sowing window for faba bean is relatively early, which can assist in spreading out operations and labour requirements, particularly if the crop is dry-sown (see Section 2.3 Stubble and summer weed management for more information).

Growing faba bean within a cereal-based rotation requires minimal additional machinery, although slight machinery adjustments may be required to handle the larger seed size.

In high-rainfall areas, faba bean provide a new rotation option and opportunity to generate income from paddocks where wet conditions rule out other winter grain crops.

Faba bean may also be sown as an opportunity crop in low-rainfall areas and still produce economic yields; summer rainfall must be sufficient to provide a full moisture profile before planting. Stubble retention is highly beneficial in this situation.[41]

2.2.1 Rotational benefits of pulses

A survey of scientific research from across the world has revealed that the average yield increase of wheat after a break crop is about 20%.

The reasons for this include:

- improved weed control;
- improved residual water and nitrogen supply;
- cereal root disease control;
- effects on soil biology and structure; and possibly
- allelopathy (the chemical inhibition of one plant by another).[42]

Importantly, the benefits of pulses and other break crops/pastures can only be captured if break crops are managed well.

A weedy, low-yielding pulse or canola crop is not really a 'break' crop, as weeds will host cereal diseases and set seeds that emerge in subsequent cereal crops. Nitrogen fixation by the legumes will also be poor.[43]

Yield gains in subsequent crops

A recent review of more than 900 experiments has quantified the yield benefits delivered by break crops.

When compared with wheat on wheat, wheat yields after a break crop increased on average by:

- 1.0 t/ha following pulses (ranging from 0.7–1.6 t/ha);
- 0.8 t/ha following canola; and
- 0.5 t/ha following oats.

Although the yield benefit was variable, yield was rarely reduced. The average yield benefit was also constant across the full range of wheat yield, whether 1.0 t/ha or 6.0 t/ha.

This 'break-crop effect' often extended to a second wheat crop in the sequence, especially following legumes (a benefit of 0.2–0.3 t/ha), but rarely to a third crop, except under dry conditions.[44]

41 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

42 J Kirkegaard, O Christen, J Krupinsky, D Layzell (2008). Break crop benefits in temperate wheat production. Field Crops Research 107. pp 185–195.

43 J Kirkegaard (2015) Grain legumes can deliver an extra 1t/ha yield to wheat crops. GroundCover Supplement Issue 115 March–April 2015. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Grain-legumes-can-delivery-an-extra-1tha-yield-to-wheat-crops

44 J Kirkegaard (2015) Grain legumes can deliver an extra 1t/ha yield to wheat crops. GroundCover Supplement Issue 115 March–April 2015. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Grain-legumes-can-delivery-an-extra-1tha-yield-to-wheat-crops

The individual factors contributing to the yield gains in cereal crops after break crops have been assessed. The most important components were found to be the suppression of the cereal disease take-all and the contribution of soil nitrogen by legume crops. These two factors were each estimated to increase the yield of a 4 t/ha wheat crop by 0.5 t/ha.

Financial benefits over the rotation

The financial benefit of well-managed break crops to subsequent cereal crops is an important reason for growers to choose to sow pulses or other break crops, especially where break crops are considered more risky or less profitable than the main cereal crop.

Consider the economic benefits of break crops over a full 2–3-year cropping sequence, rather than just the year in which it is grown.

Another important benefit of break crops is having a diversified grains income to manage price variations.[45] [46]

Managing weeds including herbicide-resistant weeds

Break crops form part of the integrated management of weeds, including herbicide-resistant weeds.

The prevalence of herbicide-resistant weeds (especially annual ryegrass) due to intensive cereal production with selective herbicides now dictates crop sequence decisions for many growers.[47] One of the main reasons for southern region growers to switch from a cereal to a break crop is the availability of more herbicide options to manage difficult weeds.[48]

Random sampling of paddocks in southern NSW, South Australia and Victoria has revealed widespread resistance or partial resistance to a broad range of herbicide groups (up to 70–80% of samples in some areas).[49] [50]

Faba bean is moderately competitive against weeds in its early stages, depending on plant population and row spacing. Crop-topping to prevent weed seedset is possible in many situations – except in long growing seasons and in late-maturing varieties.[51]

Nitrogen fixation

Faba bean plants fix their own nitrogen and may contribute a significant amount of additional soil nitrogen, which is available for following crops to use.[52] However, normally high soil nitrogen following a pulse crop is a result of residual nitrogen carrying over, rather than a net gain from the pulse crop.

While pulses can usually fix sufficient nitrogen from the air for their own needs, a large amount is removed in the grain during harvest.

MORE INFORMATION

Inoculating legumes: A practical guide, https://grdc.com.au/GRDC-Booklet-InoculatingLegumes

45 J Kirkegaard (2015) Grain legumes can deliver an extra 1t/ha yield to wheat crops. GroundCover Supplement: Profitable pulses and pastures (issue 115), https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Grain-legumes-can-delivery-an-extra-1tha-yield-to-wheat-crops

46 J Angus, M Peoples, J Kirkegaard, M Ryan, L Ohlander (2008) The value of break crops for wheat. Proceedings 14th Conference, Australian Society of Agronomy, Adelaide, SA. Australian Society of Agronomy, www.regional.org.au/au/asa/2008/concurrent/rotations/5786_angusjf.htm

47 J Sabburg, G Allen (2013) Seasonal climate outlook improvements changes from historical to real time data. GRDC Update Paper 18 July 2013, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Seasonal-climate-outlook-improvements-changes-from-historical-to-real-time-data

48 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

49 J Broster, E Koetz, H Wu (2011) Herbicide resistance levels in annual ryegrass (Lolium rigidum Gaud.) in southern New South Wales. Plant Protection Quarterly 26 (1). pp 22–28.

50 C Preston, P Boutsalis, S Kleeman, R Saini, G Gill (2013) Maintaining the best options with herbicides Maintaining the best options with herbicides. GRDC Update Paper, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/08/Maintaining-the-best-options-with-herbicides

51 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

52 M Lines, L McMurray, J Paull, C Jeisman (2013) Faba bean varieties and management, 2012, Trials Results Book, MacKillop Farm Management Group, www.mackillopgroup.com.au/media/2012TrialBook/faba_beans.pdf

A well-grown pulse crop that yields poorly due to a harsh seasonal finish can provide a net increase in soil nitrogen levels. In low-yielding cereal/pulse rotations, the pulse may provide enough nitrogen for the following crop.

In contrast, an average or high-yielding pulse crop often removes at least as much nitrogen in the grain as it produces through fixation. After a pulse crop, the soil nitrogen level is not usually depleted.[53]

A field trial comparing faba bean, chickpea and wheat revealed that faba bean is more dependent on fixed nitrogen than chickpea in its early stages; faba bean needs early and effective nodulation.

Faba bean fixed 3.5 times more nitrogen than chickpea (57 kg/ha compared with 16 kg/ha) and used almost half the soil nitrogen (69 kg/ha compared with 118 kg/ha) (Figure 4). Soil nitrogen balance (combined crop-fixed nitrogen as inputs and grain nitrogen as outputs), was positive for the pulses (79 to 157 kg/ha for faba bean) but negative for wheat (–22 to –66 kg/ha). Despite this, soil nitrate levels in the wheat, faba bean and chickpea plots did not differ at the end of the season.[54]

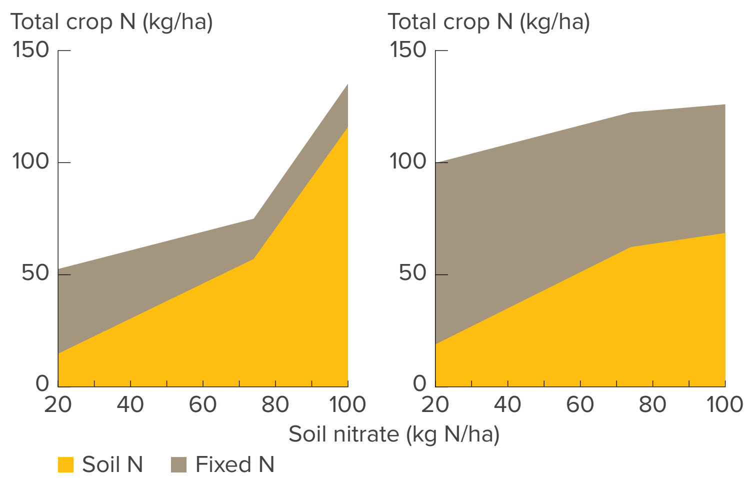

Figure 2: *Faba bean fixed 3.5 times more nitrogen than chickpea (left) (57 kg/ha compared with 16 kg/ha) and used almost half the soil nitrogen (69 kg/ha compared with 118 kg/ha).*

Source: J Turpin, D Herridge, M and Robertson (2002)

Various studies undertaken in SA, Victoria and southern NSW have compared inputs of fixed nitrogen by pulses grown for grain or brown manure and pure legume pastures either cut for hay or grazed. Brown-manured crops and forage legumes generally provided higher net returns of fixed nitrogen to soils than grain crops, since large amounts of nitrogen were removed in the pulse grain at harvest. Different legume species also have different potential for growth and nitrogen fixation, regardless of their end use.[55]

After a pulse crop, the nitrogen-rich residues break down rapidly. Most of this organic nitrogen is readily available to the following crop.

Residual water

The shallow root system, combined with a shorter growing season, means that soil moisture at depth is not fully extracted, potentially providing residual available water for subsequent crops.

53 Grain Legume Handbook Committee (2004) The role of pulses. Grain Legume Handbook. J Lamb, A Poddar (eds.) Grain Legume Handbook Committee.

54 J Turpin, D Herridge, M and Robertson (2002) Nitrogen fixation and soil nitrate interactions in field-grown chickpea (*Cicer arieinum*) and faba bean (*Vicia faba*). Crop and Pasture Science 55(5). pp 599–608.

55 J Kirkegaard, O Christen, J Krupinsky, D Layzell (2008). Break crop benefits in temperate wheat production. Field Crops Research 107. pp 185–195.

Cereal disease management

Grass-free pulse crops are generally effective disease breaks, usually more so than pastures due to the potential of grasses to provide alternate hosts for diseases.[56]

Faba bean is a pulse break crop that can be used in rotations to effectively break the life cycle of cereal root diseases such as take-all, crown rot, root-lesion nematode and cereal cyst nematode.[57]

Take-all

In southern Australia, much of the yield benefit in well-fertilised dryland wheat crops as a result of including break crops has been attributed to control of take-all.[58 59]

All grass-free pulse and oilseed crops can provide a disease break from take-all. Remove grass weeds from faba bean before the end of July (or the end of June in the Mallee) to prevent the fungus multiplying and being carried into the next crop.[60]

Crown rot

For crown rot, a 2-year break with a non-susceptible crop such as faba bean can reduce the severity of crown rot on subsequent wheat or barley crops. Break crops allow for the natural decomposition of cereal residues, which harbour the crown rot fungus.

Root-lesion nematode

Root-lesion nematode (RLN) is another important cereal disease that can be managed with the inclusion of faba bean in the rotation. At least 1 in 5 cropping paddocks in south-eastern Australia have enough RLN to reduce yield.

Faba bean, field pea and lentil are useful in crop rotations as they are poor hosts of the two important species that are common in southern region cropping soils: *Pratylenchus thornei* and *P. neglectus* (Table 2). The two species often occur together (see Section 9 Diseases for more information).

Rotations are the best way of controlling RLN. Resistant crops can potentially halve nematode populations each year. A 2-year break (or longer) from susceptible crops may be necessary to minimise yield loss if nematode numbers were high to begin with.[61] (See Section 2.8 Nematode status for more information).

Table 2: Hosting abilitty of various crops of two important RLN species. Faba bean is a poor host of the two important root-lesion nematode species, making it a particularly useful crop in rotations.

Crop	*P. thornei*	*P. neglectus*
Faba bean	Poor	Poor
Barley	Poor to intermediate	Poor to intermediate
Canola	Intermediate	Good
Field pea	Poor	Poor
Lentil	Poor	Poor
Vetch	Good	-

Note: In some crops the hosting ability varies between varieties.
Source: G Hollaway (2013) Cereal root diseases, Agnote AG0562. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases

56 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

57 G Hollaway (2013) Cereal root diseases, Agnote AG0562. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases

58 J Kirkegaard, O Christen, J Krupinsky, D Layzell (2008). Break crop benefits in temperate wheat production. Field Crops Research 107. pp 185–195.

59 J Kollmorgen, J Griffiths, D Walsgott (1983) The effects of various crops on the survival and carry-over of the wheat take-all fungus *Gaeumannomyces graminis* var. *tritici*. Plant Pathology 32. pp 73–77.

60 G Hollaway (2013) Cereal root diseases, Agnote AG0562. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases

61 G Hollaway (2013) Cereal root diseases, Agnote AG0562. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases

Cereal foliar disease

Break crops can also play a role in cereal foliar disease management. None of the main leaf or stem diseases of wheat can be hosted by grass-free faba bean or other pulse crops or oilseeds.[62]

Fusarium head blight can also be reduced with a 1–2-year non-host crop, such as faba bean.[63]

2.2.2 Rotational disadvantages of pulses

Faba bean is susceptible to fungal diseases such as Ascochyta blight and chocolate spot and will require several fungicide applications during the season.

While the crop has few disadvantages, a tall faba bean crop usually needs to be sprayed with a high-rise, self-propelled boom sprayer or aerial sprayer late in the season.[64]

Unlike canola or safflower, faba bean does not have an extensive, deep root system to break up hardpans and create channels in the soil profile to facilitate air and water movement.

Faba bean and broad bean are moderately susceptible to hostile subsoils. Boron toxicity, sodicity and possibly salinity can cause plants in affected areas to die. Faba bean and broad bean have a low tolerance for exchangeable aluminium.[65]

While faba bean has sometimes struggled to provide a financial return as a 'stand-alone' crop, relative to other crops, new varieties, better disease control and modern agronomic practices have improved this situation. Growers also need to consider the beneficial impact of faba bean on subsequent cereal yields and weed control options even if the faba bean crop performs poorly.[66]

Faba bean, like other pulses, provides limited stubble cover, increasing the risk of soil erosion.[67] This is especially so if stubble had not been retained at sowing.

VIDEO

Watch a video from SANTFA about burning snails and weed seeds: https://youtu.be/zqQKFFqndKQ

2.3 Stubble and summer weed management

Direct-drilling and stubble retention, GPS guidance and controlled-traffic farming are some of the factors supporting more intense crop production with the inclusion of pulses, compared with traditional pasture/cereal farming systems.[68]

Case studies of southern NSW growers highlight how faba bean crops and other pulses can be successful using a range of farming systems.[69]

Traditionally, faba bean paddocks are prepared using conventional or minimum cultivation, similar to other winter crops. Faba bean paddocks are typically sown using no-till methods into retained stubble, although some soils may require cultivation before sowing to remove hardpans.

Maintaining stubble will maximise yield potential. It makes harvesting faba bean easier, as pod height is increased.[70]

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62 GRDC (2011) Break crop benefits fact sheet. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2011/03/break-crop-benefits-west

63 D Herridge (2011) Managing legume and fertiliser N for northern grains. Grains Research and Development Corporation.

64 GRDC (2014) Planning/Paddock preparation., GrowNotes™: Faba Beans (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

65 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

66 Grain Legume Handbook Committee (2004) The role of pulses. Grain Legume Handbook. J Lamb, A Poddar (eds.) Grain Legume Handbook Committee.

67 GRDC (2014) Planning/Paddock preparation., GrowNotes™: Faba Beans (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

68

69 E Armstrong, D Holding (2015) Pulses Putting life into the farming system: An insight from growers who are making pulses work. NSW Department of Primary Industries, www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/general/pulses-farming-system

70 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

Harrowing, slashing or burning are options where stubble loads are too heavy, or where the stubble has been disturbed by grazing and stubble-handling equipment is unavailable[71]. Strategic burning of some cereal stubbles may allow hassle-free sowing and some control of weed seeds and stubble-borne cereal diseases.[72] Disc seeders are now more commonly being used for sowing into retained cereal stubble.

MORE INFORMATION

GRDC 2011 Stubble management Fact Sheet https://grdc.com.au/Resources/Factsheets/2011/03/Stubble-Management

VIDEO

SANTFA video: Stubble management https://youtu.be/hjJ5HtyLluU

2.3.1 Stubble management

Photo 3: *Faba bean crops sown into cereal stubble establish well and may have lower soil evaporation than when sown into bare soil.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Managing stubble after cereals should start during the cereal harvest, making sure that straw is left about 30 cm in height. Ideally, damage to stubble should be minimised by restricting all traffic, including chaser bins and boom sprays, to tramlines or permanent wheel tracks.[73]

Retaining stubble can provide many benefits, particularly in drier climates. These include better water infiltration and slower moisture loss from evaporation, potentially ensuring that more moisture is captured and stored in the soil. It can also help to retain some deep soil moisture left from summer rains, if weeds are controlled.

Retaining stubble may provide the opportunity for earlier sowing compared with burning stubble, due to preservation of soil moisture near the surface. Some pulse growers have been able to produce a pulse crop in drought years by retaining stubble, allowing earlier sowing, sometimes with wider rows spacing. These have led to crops that are taller at harvest with less lodging.[74]

In the low-rainfall zone, moisture conservation techniques, including stubble retention, will allow faba bean to be included in farming systems in the future (Photo 5). Potential breeding lines with early flowering and early maturity are achieving much higher yields than modern varieties in very dry conditions.[75]

71 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

72 E Armstrong, D Holding (2015) Pulses Putting life into the farming system: An insight from growers who are making pulses work. NSW Department of Primary Industries, www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/general/pulses-farming-system

73 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

74 GRDC (2011) Break crop benefits fact sheet. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2011/03/break-crop-benefits-west

75 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

Sowing directly into standing cereal stubbles can be a part of an integrated pest management strategy against aphids. Bare soil is more attractive to some aphid species, which transmit viruses to pulse crops (see Section 8 Pest management for more information).

Table 3: Effect of stubble retention and fungicide treatments on faba bean grain yield (t/ha) at Rupanyup and Lake Bolac, Victoria, in 2011.

	Grain yield (t/ha)			
	Rupanyup, Wimmera, Victoria (medium-rainfall zone)		Lake Bolac, Western District, Victoria (high-rainfall zone)	
	Standing stubble*	Burnt stubble*	Slashed stubble*	Burnt stubble*
Total disease control, (fortnightly carbendazim + chlorothalonil)	4.7	3.9	3.2	3.4
Carbendazim x 3 (early, mid, late flowering)	4.5	3.7	3.1	3.2
Carbendazim x 2 (early and late flowering)	4.1	3.4	2.85	3.05
Nil fungicide	3.5	3.0	2.5	2.65
Least significant difference (same site, same stubble treatment)	0.21	0.22	0.21	0.23

* Separate but adjacent trials for stubble treatments.

Source: Jason Brand, Agriculture Victoria, Southern Pulse Agronomy

Trials held in the Wimmera and Western District of Victoria compared faba bean disease treatments on separate trials with burnt stubble and standing stubble or burnt and slashed stubble (Table 3).

Results at Rupanyup (Wimmera) suggest large yield differences between stubble treatments. Maturity of the plots in the standing stubble was up to 2 weeks later than the burnt stubble. Response to fungicide regimes across varieties was relatively similar in both trials at the Wimmera site. The average height to the lowest pod in standing stubble (32.3 cm) was more than in the burnt stubble (26.1 cm).

In contrast, at Lake Bolac, the high-rainfall site, summer rainfall provided a full soil moisture profile at sowing. Consequently, stubble retention appeared to have little effect on faba bean yield. While faba bean yields were slightly higher on burnt stubble, disease levels were also higher than on slashed stubble. Disease, predominantly rust, resulted in grain yield losses of between 5% and 35%, depending on variety.[76]

2.3.2 Wide rows with retained stubble

Row spacing in faba bean – and any other crop – is about the whole farming system, and row spacing per se cannot be looked at in isolation.

Faba bean growers in southern Australia are finding success with wide row and skip row sowing (30–54 cm), particularly in low-yielding seasons. Retaining stubble (preferably standing) and good weed control is essential with wide rows.[77 78]

For faba bean, wide row cropping with stubble retention may provide several benefits:

- confidence to sow earlier with less problems with disease and podset;
- better stubble clearance and easier sowing;
- management of weeds by minimal soil disturbance;

76 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

77 W Hawthorne (2015) Wide row pulses and stubble systems. Australian Pulse Bulletin. Pulse Australia, www.pulseaus.com.au/growing-pulses/publications/wide-rows-and-stubble-retention

78 S Kleeman, G Gill (2008) Wide row cropping for weed management opportunities. GRDC Update Paper 20 June 2008, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/Widerow-cropping-for-weed-management-opportunities

MORE INFORMATION

GRDC 2011 Crop placement and row spacing Fact Sheet https://grdc.com.au/Resources/Factsheets/2011/02/Crop-Placement-and-Row-Spacing-Southern-Fact-Sheet

Australian Pulse Bulletin: Wide row pulses and stubble retention www.pulseaus.com.au/growing-pulses/publications/wide-rows-and-stubble-retention

- less rain-splash diseases (Cercospora and Ascochyta) early in the season, when the crop is sown into stubble;
- delayed canopy closure, allowing later initial fungicide application;
- better early podset in lush growth conditions;
- easier access for pollinators (such as native bees);
- early erectness if sowing inter-row into standing stubble, even at 50 or 60 cm row spacing (note the crop may lodge later if the crop is dense and the stubble is tall);
- lowest pods are higher, so they are easier to harvest; and
- improved water use efficiency.

A trial at Roseworthy, SA, in 2006 showed that increasing row spacing from 18 to 36 cm significantly increased Fiesta VF faba bean yields by 24% in a low-yielding (drought) season (Table 4). Yields at the 54 cm spacing were also 20% higher than at 18 cm. In this low-yielding trial, yields significantly improved with wider rows, compared with 18 cm spacing ($P < 0.05$). Good weed control is imperative with wide rows. With wider rows, water use was deferred from the vegetative to the reproductive phase, contributing to better pod retention and yield.[79 80]

Table 4: Faba bean yield response to row spacing, Roseworthy, South Australia, 2006.

Row spacing (cm)	Yield (t/ha)
18	0.79
36	0.98
54	0.95

Note: coefficient of variation (CV) and least significant difference (LSD) not available. Good weed control is imperative.

Sources: S Kleeman, G Gill (2008) Wide row cropping for weed management opportunities, GRDC Update Paper 20 June 2008; GRDC Crop placement and row spacing fact sheet

In contrast to the Roseworthy trial, faba bean at a higher-yielding site at Hart, SA, in 2009 produced much higher yields with 22 cm spacing compared with 45 cm spacing, with or without standing stubble (Table 5). Faba bean on wide rows performed better with standing stubble than without, whereas stubble made no difference to yields of faba bean on narrow rows (note that there was only light stubble present in the trial). Loss of soil moisture through evaporation where there is insufficient groundcover is an important issue to consider in wide-row faba bean.[81]

Table 5: Grain yield of Farah⁽ᴰ⁾ faba bean with two row spacing and stubble treatments, Hart, South Australia, 2009.

Row spacing (cm)	Stubble removed (slashed)	Stubble standing
22.5	3.31 ab*	3.42 a
45	2.23 f	2.64 cde

*Different letters indicate significantly different yields. CV and LSD not available.
Source: Hart Field Site, South Australia, 2009

Weed control is imperative with wide-row cropping. A second trial at Roseworthy revealed that, without weed control, faba bean grown on wide rows could not compete with annual ryegrass (189 plants/m^2) and produced extremely low yield (0.16 kg/ha) (see Section 7 Weed Control for more information).

In the second Roseworthy trial, faba bean sown in 54 cm rows yielded 1.05 t/ha, compared with 0.68 t/ha with 18 cm rows, when weeds were controlled post-sowing,

79 S Kleeman, G Gill (2008) Wide row cropping for weed management opportunities. GRDC Update Paper 20 June 2008, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/Widerow-cropping-for-weed-management-opportunities

80 GRDC (2011) Crop placement and row spacing fact sheet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2011/02/Crop-Placement-and-Row-Spacing-Southern-Fact-Sheet

81 Hart (2010) Pulse row spacing and standing stubble. Hart Trials Results 2009. Hart Field Site, http://www.hartfieldsite.org.au/media/TRIALS%20RESULTS%20BOOKS/HART2009TrialsResultsBook.pdf

pre-emergence and in-crop. In the trial, higher faba bean yields with wide rows could partly be explained by much lower annual ryegrass density (50 plants/m^2) than in the conventional 18 cm spacing (140 plants/m^2). Such large differences in ryegrass populations may have been due to differences in soil disturbance. With no weed control, however, the 54 cm row spacing yielded only 0.16 t/ha.[82]

When dealing with row spacings in faba bean and any other crop, it is about the whole farming system. Row spacing per se cannot be looked at in isolation.

2.4 Herbicide residue management

More information about herbicide damage and plant-back periods for pulses is available in Section 7 Weed Control.

Residues of several herbicides can affect crop rotation choices or cause damage to faba bean crops, particularly after low rainfall.

Avoid use of the long-term residual Group B sulfonylurea (SU) herbicides in wheat when re-cropping with faba bean, including sulfosulfuron, chlorsulfuron and triasulfuron.[83]

Avoid also using the following fallow and in-crop residual herbicides in wheat/faba bean rotations:

- Group B sulfonamides;
- Group B imidazolinones;
- triclopyr/picloram (e.g. Grazon® DS)
- clopyralid (e.g. Lontrel®); and
- shorter-residual Group B sulfonylurea, metsulfuron and metsulfuron/thifensulfuron, particularly during summer (after November).

2.4.1 Management of SU residues in faba bean

Follow plant-back periods (minimum re-cropping intervals) as indicated on label (see Section 7 Weed Control for more information).

If Group B herbicide residues already exist, do not use another Group B herbicide in crop to avoid further crop damage.

2.4.2 Management of 'IMI' residues in faba bean

Be wary of using imidazolinone (IMI) products in a low-rainfall area if you intend to grow faba bean the following year.[84] Soil pH and required rainfall may interact for some IMIs.

Reassess the risk of herbicide-residue damage if IMI products have been used and drought conditions have been experienced during the previous wheat, canola or fallow.

Be wary of using IMI products in short-term chemical fallows or for summer weed control in paddocks planned for faba bean. For example, imazapic (e.g. Flame®) requires 200 mm rainfall in the 3 months before sowing faba bean.[85]

82 S Kleeman, G Gill (2008) Wide row cropping for weed management opportunities. GRDC Update Paper 20 June 2008, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/Widerow-cropping-for-weed-management-opportunities

83 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

84 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

85 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

The South Australian Research and Development Institute (SARDI) and Southern Pulse Agronomy are screening faba bean lines for IMI tolerance (Photo 6). However, herbicide-tolerant faba bean varieties are several years away.[86]

Photo 4: *SARDI and Southern Pulse Agronomy are screening faba bean lines for IMI tolerance. Herbicide-tolerant faba bean varieties are several years away.*

Photo: Felicity Pritchard

2.4.3 Management of triazine residues in faba bean

In southern Australia, avoid high rates of atrazine to avoid triazine carrying over from triazine-tolerant (TT) canola. That is, do not use more than 1.7 L/ha of triazine herbicides for alkaline acid soils (pH >6.5) or 3.3 L/ha for acid soils (pH <6.5) where the active ingredient (a.i.) is 600 g/L. This equates to a limit of 1.1 kg/ha triazine herbicides for alkaline soils or 2.2 kg/ha for acid soils when using 900 g/kg a.i. The herbicide label does not specify if soil pH is measured in $CaCl_2$ or water.

Consider using lower rates if double-cropping faba bean after a summer forage or grain crop of sorghum or maize in irrigated areas. Revise the strategy completely on highly alkaline clay soils if high rates have been used in summer crops followed by dry conditions.

Post-emergent applications of atrazine should not exceed 1.7 L/ha (for 600 g/L a.i.) or 1.1 kg/ha (for 900 g/kg a.i.).

Do not apply triazines to consecutive crops.

Crop damage is most likely caused by herbicide leaching into seed furrows after heavy rainfall in ridged soils and with shallow sowing.

The risk of crop damage increases where there are low levels of subsoil moisture. Crops in this situation are predominantly surface-rooted and vulnerable to damage from herbicide recharge after each rainfall event.[87]

86 E Leonard (2016) Strong interest in herbicide tolerant pulses. GroundCover issue 121 March–April 2016. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-121-Mar-Apr-2016/Strong-interest-in-herbicide-tolerant-pulses

87 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

2.4.4 Management of Group I foliar herbicide residues

Do not sow faba bean if residues from pre-sowing application of a group I herbicide are a possibility.

Be aware that for some 2,4-D and dicamba products the minimum re-cropping interval only begins once 15 mm of rain has fallen.

Avoid using Lontrel® or Grazon® DS in the fallow period before sowing faba bean and closely adhere to plant-back periods.[88]

2.4.5 Testing for herbicide carryover

Growers can test soils for herbicide residues via test strips in paddocks, a pot test or by laboratory testing. Testing for herbicide residues is not an exact science as conditions vary considerably across a paddock. Table 6 highlights some of the advantages and disadvantages associated with three methods of testing herbicide residues

Table 6: Advantages and disadvantages associated with three methods of testing herbicide residues.

Test	Method	Advantages	Disadvantages
Field test	Sow a test strip and observe emerging plants after a rain to note any herbicide symptoms	Inexpensive Very rough guide	Need to wait for a rain Possible sowing delay = yield penalty Herbicide may be at depth Time-consuming
Pot test	Take some soil from the affected paddock and grow a susceptible plant in a pot next to a pot without any suspected herbicide carryover, noticing the differences	Inexpensive Very rough guide	Takes time Sampling errors Over-watering may influence results Herbicide may be at depth
Laboratory test	Soil test affected paddock and send to laboratory for analysis of the grams of active ingredient per hectare	Exact value	Expensive Only as good as the representation of the soil test Takes time for analysis and interpretation of results

Source: G Bardell (2007)

88 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

2.5 Seedbed requirements

Unlevelled paddocks and obstacles such as sticks and stones can cause problems with managing and harvesting faba bean (Photo 5).

The soil surface should be levelled as much as possible, as low-set pods on plants may cause harvest difficulties.[89] Cloddy or badly ridged paddocks and sticks and stones can contaminate the harvested grain and downgrade quality. The harvester may also be damaged.[90]

Consider rolling after sowing on stony or extremely cloddy soils to create a flat seedbed, particularly if dry sowing with a tyne seeder.[91]

Photo 5: *Harvest losses can increase where sticks, stones, soil clods and a ridged surface are present close to low-set pods.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Soils with hardpans may require cultivation before sowing to allow healthy root development.[92]

For stubble-retained farming systems, cereal straw should be left standing at about 30 cm height (see Section 2.3 Stubble and summer weed management for more information).

Sowing into retained stubble can cause blockages and result in stubble piles remaining in the paddock. If not broken down during the season, the piles can be picked up by the header front, causing mechanical blockages and potentially contaminating the grain if they contain excess soil.[93]

Several options are available to manage stubble bunching (see Section 2.3 Stubble and summer weed management).

Many dryland faba bean crops require the header front to be set close to ground level. Small variations in paddock topography, including undulating paddocks and gilgai (crab holes), can lead to differences in cutting height across the header, creating significant harvest losses.

Flex fronts, which follow the contour, are an alternative in these situations. It is hard to avoid contaminating harvested grain with dirt in undulating, gilgai paddocks. This can increase grading losses and add to costs. (See Section 12 Harvest for more information.)

89 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

90 Pulse Australia (2014) Northern faba bean best management practices training course – 2014. Pulse Australia.

91 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

92 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

93 Pulse Australia (2014) Northern faba bean best management practices training course – 2014. Pulse Australia.

2.6 Irrigation layout and planning

Faba bean respond well to irrigation in dry areas. Full or supplementary irrigation is practised in Australia where it is economical, when grown in rotation with other winter and summer crops.

2.6.1 Paddocks and irrigation layout

Irrigation layout is one of the most important factors for successful spring irrigation.

Select paddocks for faba bean with good irrigation layout such as beds or hills and relatively good grades for adequate drainage.[94] Faba bean performs best on bed layouts, as waterlogging in spring is a significant issue on contour layouts (Table 7).[95]

A border-check layout can also be successful with grades steeper than 1:800, or with short runs with water on and off in less than 8 hours. The runs need to be short with free-draining soils that can be irrigated quickly and do not remain saturated.[96]

Furrow irrigation is successful in southern Australian irrigation areas. Crops can be established by either pre-watering and sowing, or dry-sowing and then watering-up. A faba bean crop may not need to be watered again until early spring if winter rainfall is adequate.[97]

Table 7: Trends of possible effect of irrigation layout on average irrigated faba bean yield (t/ha) from Faba Check report data, southern NSW.

Year	Beds	Border-check	Contour	Sprinkler
2000	4.57	3.87	3.29	–
2001	4.37	4.04	3.72	3.70
2002	N/A	N/A	N/A	N/A
2003	5.16	3.77	–	N/A
Average	4.70	3.89	3.51	

Note: Faba bean grown on beds consistently out-performed faba bean grown on any other layout. Water use efficiency of faba beans grown on beds is higher than faba beans grown on border check.
Source: Faba Check report data, southern NSW

When growing irrigated faba bean, avoid heavy clay or dense soil types (bulk density more than 1.5) or those that do not drain freely and are subject to waterlogging.

Do not grow faba bean on freshly land-formed paddocks, particularly if there are large cut-and-fill areas.

2.6.2 Sowing irrigated faba bean

Rolling may be required to flatten the ridges left by press-wheel furrows or to flatten clods.

Do not sow too early as irrigated faba bean crops can suffer from lodging.

For irrigated beds, sowing can become extremely difficult once beds with heavy stubble become moist. Firm beds are often easier to sow than soft, fluffy beds[98] (see Section 4 Planting for more information).

94 Pulse Australia (2016) Best management guide .Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

95 R Whitworth (2005) Faba Check in Southern NSW – what have we learned? Faba Bean Symposium: The Performance Pulse, Darlington Point, NSW. Pulse Southern NSW. pp 17–21.

96 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

97 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

98 M Kirkman, S Kirkman (2005) Land preparation and seeding issues. Faba Bean Symposium: The Performance Pulse, Darlington Point, NSW. Pulse Southern NSW. pp 45–47.

2.6.3 Irrigated faba bean crop management

Irrigation can be used in activating and incorporating several pre-emergent herbicides.

Faba bean is more sensitive to foliar diseases under irrigation, compared with dryland crops. Waterlogging for a short time during flowering and podding may result in severe losses, particularly if the crop is stressed from factors such as herbicides and disease. Aim to prevent a build-up of disease[99] during winter. Protect faba bean crops in spring before each watering while the canopy humidity and disease risk are high.

Lodging can be an issue at harvest for irrigated faba bean crops. This can be worse on beds, as plants are harder to pick up from furrows. In this case it is important to harvest in one direction.[100]

2.6.4 Irrigation management

Monitor soil moisture for good irrigation scheduling, for higher yields and grain quality while supporting a more sustainable irrigated farm.[101]

Pre-irrigate to fill the moisture profile prior to sowing all faba bean crops, unless this has already been achieved by rainfall.

Water-up on beds, rows and under sprinkler irrigation. This is not recommended for border-check layouts unless moisture is insufficient to achieve a uniform germination.

Generally, start to in-crop irrigate early, when there is a deficit of between 30–40 mm and about 60–70% field capacity. Moisture scheduling is more important than growth stage.

Timely spring irrigations are important. Aim to minimise moisture stress by using optimum irrigation layouts. Irrigate before flowering to prevent moisture stress and high temperatures, which limit yield, quality and grain size. Hot conditions during September and October can affect yield, especially in dry seasons. Crops on beds may require two to three spring irrigations, after being watered up. A survey of 57 faba bean crops in 1991 in southern NSW revealed that half of these crops (29) yielded at least 3.0 t/ha; some above 5.0 t/ha. Nearly two in three of these top-yielding crops were watered three times in the spring.[102]

If furrow irrigating, water every second row to avoid waterlogging. Doubling siphons can increase water flow and reduce irrigation time.

Aim to complete watering in less than eight hours and have good tail-water drainage to avoid any waterlogging. Do not irrigate if crops are at risk of waterlogging and avoid irrigating if there is likelihood of rain soon after.

Faba bean is more sensitive to waterlogging during its reproductive stage (flowering and podding). When grown on beds or rows, this usually does not pose a risk with spring irrigation.[103] However, if crops are grown on border-check layouts and with heavy soil types or long runs, this can be a problem. If in doubt, do not water.

Sprinkler irrigating is ideally suited to growing pulses as there is very little risk of waterlogging, even during flowering and pod-fill. However, there may be a need for greater disease control against chocolate spot, rust or Ascochyta blight due to more frequent wet conditions. In 2014, faba bean crops yielded 4.9 t/ha in southern NSW under sprinkler irrigation.

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99 Pulse Australia (2016) Best management guide .Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

100 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

101 R Hoogers (2005) Soil moisture monitoring. Faba Bean Symposium: The Performance Pulse, Darlington Point, NSW, Pulse Southern NSW. pp 37–44

102 R Hoogers (2005) Soil moisture monitoring. Faba Bean Symposium: The Performance Pulse, Darlington Point, NSW, Pulse Southern NSW. pp 37–44.

103 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia

Faba bean is one of the field crops more sensitive to salinity (Table 8). Yield reductions can occur when irrigated with saline water.[104 105]

Table 8: Field crops' water salinity (ECw) tolerance. Faba bean is one of the most sensitive crops to salinity. During the early seedling stage of the most tolerant crops, ECw should not exceed 3.0 dS/m.

Field crop	Nil reduction (dS/m)	10% yield reduction (dS/m)
Barley	5.3	6.7
Canola	4.3	7.3
Wheat	4.0	4.9
Oats	3.3	4.2
Faba bean	1.1	1.8

Source: Salinity tolerance in irrigated crops (2014)

Photo 6: *Irrigated faba bean grown on beds.*

Photo: Trevor Bray, formerly Pulse Australia

104 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

105 J Lacy (2015) Finley irrigated wheat, canola and faba bean systems results 2014. GRDC Update paper 12 March 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Finley-irrigated-wheat-canola-and-faba-bean-systems-results-2014

2.7 Yields and yield targets

2.7.1 Seasonal outlook

Seasonal outlooks may assist growers in making crop choices and managing crops. They may aid in assessing potential yield of crops before sowing and throughout the growing season.

The Break newsletter (Victoria)

Agriculture Victoria provides seasonal climate risk information to grain growers in 'The Break' newsletter. The newsletter describes credible seasonal outlooks, generates potential crop yields from digital decision-support tools, provides links and highlights topical climate risk information. The Break summarises rainfall, crop condition and potential yield for cropping regions across Victoria.

Another newsletter is 'The Fast Break', which details oceanic and atmospheric climate driver activity over the past month and summarises 3-month model predictions for the Pacific and Indian oceans, rainfall and temperature for Victoria.

'The Very Fast Break' is a 2-minute video summarising oceanic and atmospheric climate drivers and the summarised model predictions for rainfall and temperature for Victoria. The Break newsletters and videos are available on the Agriculture Victoria website (http://agriculture.vic.gov.au/agriculture/weather-and-climate/newsletters).

Understanding weather and climate drivers

For tips on understanding weather and climate drivers, including the Southern Oscillation Index (SOI), visit the Climate Kelpie website (http://www.climatekelpie.com.au/) or watch Agriculture Victoria's Climatedogs video (http://agriculture.vic.gov.au/agriculture/farm-management/weather-and-climate/understanding-weather-and-climate/the-climatedogs-the-four-drivers-that-influence-victorias-climate).

CliMate

Australian CliMate (http://www.australianclimate.net.au/) is a suite of climate-analysis tools delivered online, and on iPhone, iPad and iPod Touch devices. CliMate allows you to review climate records relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, as well as El Niño–Southern Oscillation status. It is designed for decision-makers such as growers, whose businesses rely on the weather. It is available for download from the Apple iTunes (https://itunes.apple.com/au/app/australianclimate/id582572607?mt=8).

One of the CliMate tools, 'Season's progress?', uses long-term weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years. It explores the readily available weather data, compares the current season with the long-term average and graphically presents the spread of experience from previous seasons.

Crop progress and expectations are influenced by rainfall, temperature and radiation since planting. 'Season's progress?' provides an objective assessment based on long-term records.

Bureau of Meteorology

The Bureau of Meteorology (http://www.bom.gov.au/) has recently moved from a statistics-based to a physics-based model for its seasonal climate outlooks. The new system has better overall skill, is more reliable, allows for incremental improvements in skill over time, and provides a framework for new outlook services including multi-week/monthly outlooks and the forecasting of additional climate variables.

MORE INFORMATION

GroundCover™ TV: Managing summer fallow https://www.youtube.com/watch?v=5Kp5woTOo7c

HowWet?

HowWet? (http://www.australianclimate.net.au/About/HowWetN) is a program that uses records from a nearby weather station to estimate how much plant-available water (PAW) has accumulated in the soil and the amount of organic nitrogen that has been converted to an available nitrate during a fallow.

HowWet? tracks soil moisture, evaporation, run-off and drainage on a daily time-step.

2.7.2 Stored soil moisture

Measure stored soil moisture

Deep soil tests can provide soil moisture measurements in the lead-up to sowing. Growers can also measure soil water at sowing and estimate plant-available water.

Soil moisture probes can help people confirm decisions or assist decision-making.

Agriculture Victoria provides live deep soil moisture data from 11 sites to help dryland growers and advisers/managers validate the technology, and delivers training to interpret the data for crop decision-making.[106]

Plant-available water capacity

Plant-available water capacity (PAWC) is a measure of the ability of a soil to store water for crop production.

The two most important parameters are the drained upper limit (DUL) and the crop lower limit (CLL) of the soil.

Knowledge of PAWC, and in particular CLL, is necessary to calculate plant-available soil water at sowing – required for Agricultural Production Systems sIMulator (APSIM) models – from soil test results (see Section 2.7.4 Setting target yields for more information).

Information on 500 different soil types and their PAWC is available from the APSoil database (www.apsim.info) and the Australian Soil Resource Information System (ASRIS) website (www.asris.csiro.au).[107]

Retaining stubbles and controlling summer weeds may help to reduce water loss between winter crops. Control of summer weeds is a major contributor to improved water use efficiency in crops in southern Australia[108 109] (see Section 7 Weed Control for more information).

The ability to store summer rainfall may also depend on the size of the rainfall events, with the potential benefit of stubble retention being greatest where moderate rainfall is received during the fallow period. Small amounts of rain may evaporate quickly irrespective of the presence of stubble, whereas high rainfall may allow soil moisture to accumulate irrespective of the presence or absence of stubble.[110]

106 Agriculture Victoria (2016) Soil Moisture Monitoring in Dryland Cropping Areas. Risk management through soil moisture monitoring project. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/soil-moisture-monitoring-in-dryland-cropping-areas

107 GRDC (2009) Water use efficiency fact sheet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2010/02/Water-Use-Efficiency-SouthWest

108 GRDC (2015) GrowNotes™: Field Pea (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

109 J Hunt (2013) Control summer weeds to reap yield benefits. GroundCover Supplement Issue 103 March–April 2013. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS103/Control-summer-weeds-to-reap-yield-benefits

110 V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. Grains Research and Development Corporation, www.grdc.com.au/GRDC-Booklet-WUE

MORE INFORMATION

GRDC 2009 Water use efficiency Fact Sheet www.grdc.com.au/GRDC-FS-WaterUseEfficiencySouthWest

2.7.3 Water use efficiency

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

WUE relies on:

- the soil's ability to capture and store water;
- the crop's ability to access water stored in the soil and rainfall during the season;
- the crop's ability to convert water into biomass; and
- the crop's ability to convert biomass into grain (harvest index).[111]

2.7.4 Setting target yields

French-Schultz model

Rainfall is the main driver of potential yield in the dryland cropping environment of Australia.

A simple model to estimate water-limited potential yield was developed by scientists French and Schultz in South Australian for cereals, and is widely used in Australia.

The model is:

potential yield (kg/ha) = (crop water supply (mm) – 110 mm) x 20 kg/ha/mm.[112]

The 110 mm is the estimated soil evaporation and 20 kg/ha/mm is the potential WUE for wheat. Crop water supply (mm) in the medium and low-rainfall zones of the southern region are growing-season rainfall plus stored moisture.

For pulses and canola, the typical parameters used are 15 kg/ha/mm for WUE, and 130 mm for soil evaporation (Figure 3). Of note, for pulses this could now be less than the original 130 mm given modern stubble-retention systems retain more soil moisture.

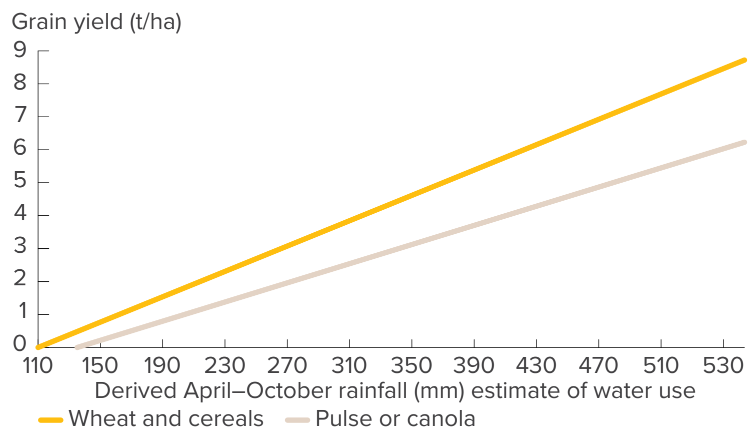

Figure 3: *Relationship of grain yield (t/ha) to estimated water use April–October. Pulses, 15 kg/ha.mm water available over 130 mm; cereals, 20 kg/ha.mm available over 110 mm.*

Source: Grain Legume Handbook (2008), from French and Schultz model

111 GRDC (2009) Water use efficiency fact sheet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2010/02/Water-Use-Efficiency-SouthWest

112 R French, J Schultz (1984) Water use efficiency of wheat in a Mediterranean type environment: I. The relation between yield, water use and climate. Australian Journal of Agricultural Research 35. pp 743–764. W Hawthorne, pers. comm.

In practice, growers typically use a variation of the French–Schultz method, such as:

Potential yield (kg/ha) = (available rainfall* – 110 mm) x WUE*****

where

* available rainfall = GSR + 25% summer rainfall

** or 60 mm evaporation for stubble-retained systems

*** WUE = 8 to 10 kg/ha/mm for faba bean

WUE of faba bean grain in Western Australia has been measured as 10.4 kg/ha/mm, ranging from 7.7–12.5 kg/ha/mm[113]. Soil evaporation was 100–125 mm, similar to cereals.[114]

While the French–Schultz model can be used to determine an upper limit of water-limited potential yield, it often overestimates actual yield as it does not account for rainfall distribution, run-off, drainage or stored soil water.[115]

The different pulses and their systems do differ though in their water-limited yield potential (Figure 4). Faba bean has the highest yield potential of the pulses at high-yielding locations, whereas field pea has the highest yield potential at low-yielding, water-restricted locations.[116]

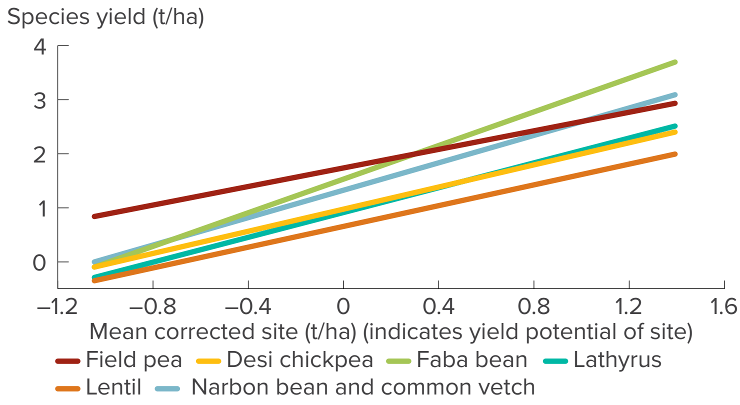

Figure 4: *Variation in grain yield of different grain legume species across sites with different yield potential in Western Australia.*

Source: Kadambot Siddique (2016)

113 V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. Grains Research and Development Corporation, www.grdc.com.au/GRDC-Booklet-WUE

114 K Siddique, K Regan, D Tennant, B Thompson (2001) Water use and water use efficiency of cool season grain legumes in low rainfall Mediterranean-type environments. European Journal of Agronomy 15 (4). pp 267–280, http://www.sciencedirect.com/science/article/pii/S116103010100106X

115 Y Oliver, M Robertson, P Stone, A Whitbread (2009) Improving estimates of water-limited yield of wheat by accounting for soil type and within-season rainfall. Crop and Pasture Science 60. pp 1137–1146.

116 W Hawthorne, pers. comm.

MORE INFORMATION

GRDC 2009 Plant parasitic nematodes Fact Sheet
www.grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW

APSIM

Sophisticated crop simulation models such as the Agricultural Production Systems sIMulator (APSIM) – and its commercial interfaces Yield Prophet® and WhopperCropper® – can combine detailed data about soil water-holding capacity, soil moisture at sowing, long-term climate data, weather data, potential crop responses to available moisture and additional inputs, in order to estimate potential yield.[117]

APSIM is internationally recognised as a highly advanced simulator of agricultural systems.

For a comprehensive description of the processes simulated by APSIM for faba bean, refer to Turpin *et al* (2003).[118]

For faba bean, the APSIM model was tested over diverse conditions in Australia, using experimental data. APSIM was based on the old variety Fiord, which has a reasonably high thermal time relative to photoperiod response for flowering. It probably would not work as well with varieties that have a greater photoperiod response, such as Nura$^{\phi}$ and PBA Rana$^{\phi}$.

Simulated grain yield explained 87% of the variance in actual yields.

Issues that still need to be accounted for in APSIM include:

- lodging;
- variation in harvest index under wet or cold conditions;
- variation within genetic material in their photoperiod response; and
- accurate simulation of the response of leaf area expansion under mild levels of water deficit.[119]

2.8 Nematode status

Knowing which root-lesion nematode (RLN) species are present is critical for best management because each species can build up on different crops[120] (see Section 9 Diseases for more information).

117 GRDC (2009) Water use efficiency fact sheet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2010/02/Water-Use-Efficiency-SouthWest

118 J Turpin, M Robertson, C Haire, I Rose (2003) Simulating fababean development, growth, and yield in Australia. Crop and Pasture Science 54 (1). pp 39–52, https://www.researchgate.net/publication/263003662_Simulating_fababean_development_growth_and_yield_in_Australia

119 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

120 GRDC (2009) Plant parasitic nematodes fact sheet (southern and western regions). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW

2.9 Post-harvest grazing of faba bean crops

2.9.1 Nutritional value of faba bean

Faba bean stubble and particularly the unharvested grain residue can provide valuable feed for livestock after harvest (Table 9).

Faba bean has high protein levels and palatability. In Australia lupin grain is generally the preferred pulse for sheep and cattle due to its higher protein, higher fibre and lower starch levels, but field pea and faba bean are also useful.

Table 9: Grazing faba bean stubbles after harvest can provide valuable livestock feed during summer (wheat is shown for comparison).

Per kg dry matter	Faba bean grain	Faba bean stubble	Wheat grain
Metabolisable energy (MJ)	12.8	7.4	14.0
Rumen degradable protein (g)	130	20	87
Undegraded dietary protein (g)	65	6	16
Digestible protein percentage (%)	19.5	2.6	10.3
Fibre (g)	100	500	26
Calcium (g)	1.5	-	0.4
Phosphorus (g)	6.3	-	3.6
Sodium (g)	0.6	-	0.3

Source: Grain Legume Handbook

2.9.2 Introducing livestock to faba bean stubble

The stubble left after a faba bean crop is very nutritious livestock fodder. Sheep and beef cattle tend to respond better to pulse stubbles than cereal stubbles due to the high energy value and protein content of the remaining grain and the digestibility of the straw.

Comparisons between pulse crops have shown faba bean and lupin produce the best weight gains in young Merino sheep.

Summer rains may germinate the residual grain and reduce its food value.

One hectare with 0.5 t/ha on the ground should be able to carry 5 weaners or store lambs for about 3 months. Lower-yielding crops with low pod height may potentially incur harvest losses of 0.7–1.0 t/ha, which create a valuable feed source for livestock.[121]

If there are still reasonable quantities of grain remaining on the ground, older sheep can be used to clean up the area.

In trials Dorset-Merino cross lambs ranging from 6–23 kg liveweight (3–8 weeks old) grew well (0.18 kg/day, 1.26 kg/week) on faba bean and lupin stubble containing about 1.0 t/ha of fallen grain.[122]

Grazing lambs on faba bean stubbles has reportedly increased lamb weights by 2.0 kg/week over 5–7 weeks in a grower case study. The successful system involves gradually introducing faba bean grain to lambs prior to grazing the

121 K Penfold (2007) Beans drive up grazed-grain profits. GroundCover Issue 67 March–April 2007, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-67-March-April-2007/Pulses

122 Grain Legume Handbook Committee (2004) The role of pulses. Grain Legume Handbook. J Lamb, A Poddar (eds.) Grain Legume Handbook Committee.

stubbles and waiting until lambs weigh 40–50 kg before they enter a faba bean stubble paddock.[123]

2.9.3 Calculating grain residues

The grain on the ground should be measured to make the best use of the stubbles.

The amount of grain remaining on the ground can be measured by making a square with 50 cm sides out of fence wire.

The square should be taken out into the paddock and placed on the ground and the grain lying inside the square collected. This should be done at 30 places across the paddock.

Bulk all the grain collected and weigh it. The result (in grams) from the 30 samples should be multiplied by 1.33 to give the number of kilograms per hectare of grain.[124]

2.9.4 Withholding periods and export slaughter intervals

If the faba bean stubble has been treated with pesticides, growers must adhere strictly to withholding periods and, for exported livestock, to the export slaughter interval (ESI). For example, the ESI for faba bean stubble and grain treated with chlorothalonil is a minimum of 9 weeks.[125]

This means that stock grazing stubble of a faba bean crop that was treated with chlorothalonil during the growing season cannot be slaughtered for 9 weeks after their removal from that stubble. This ESI therefore often precludes the use of chlorothalonil for in-crop disease control because graziers aim to finish lambs on faba bean stubble and send them straight to abattoirs.

123 K Penfold (2007) Beans drive up grazed-grain profits. GroundCover Issue 67 March–April 2007, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-67-March-April-2007/Pulses

124 Grain Legume Handbook Committee (2004) The role of pulses. Grain Legume Handbook. J Lamb, A Poddar (eds.) Grain Legume Handbook Committee

125 C Benjamin (2015) Keep Australia's exports clean. Observe MRL and ESI regulations when feeding pulse grain and stubble. Pulse Industry Updates 22 September 2015. Pulse Australia, http://pulseausblog.tumblr.com/post/129634435305/keep-australias-exports-clean

Pre-planting

Key points

- **Faba bean and broad bean are more suitable for soils prone to waterlogging than other pulse crops.**
- **Broad bean is more suited to the high-rainfall zone as it requires a longer growing season.**
- **New varieties offer significant yield and disease-resistance improvements compared with older varieties.**
- **A variety with a specific trait such as a specific disease resistance may not necessarily yield as well as others, but disease resistance will reduce risk.**
- **Good-quality, undamaged seed is essential to ensure the best start for the crop.**
- **Test seed for germination percentage, weed contamination and disease.**

3.1 Bean types

The beans grown in Australia can be divided into two types. The smaller faba bean (*Vicia faba* var. *minor* and *Vicia faba* var. *equina*) and the larger broad bean (*Vicia faba var. major*). Broad bean is virtually identical to faba bean, but requires a slightly longer growing season and is usually grown in the high-rainfall areas.[1]

3.1.1 Faba bean types

Faba bean market categories for Australian growers include:

- the now-traditional medium-seeded faba bean markets, where seed size (50–70 g/100 seeds) and uniformity is important to attract market interest along with light colour (Fiesta VF type);
- the larger-seeded faba bean class where seed size (70–95 g/100 seeds) and uniformity is important for marketing along with pale colour (old Manafest, now PBA Rana⍉ type); and
- the small-seeded (35–50 g/100 seeds) class that used to be exported for human consumption markets, but is now considered too small and dark in all but a few niche markets (Fiord type).

The requirements of faba beans in terms of size and colour vary between importing countries and also according to the end use:[2]

- The predominant colour for international trade is beige or buff and to a large extent is genetically determined and highly heritable.
- Colour can also be influenced by the environment in which the crop is grown, post-harvest handling, time in storage and storage method.
- Seed size of faba bean can vary from 35 to 90 g/100 seeds according to the variety; e.g. small (Fiord, Ascot VF, Barkool), medium (Fiesta VF, Farah⍉, Nura⍉, PBA Samira⍉) and large faba bean (PBA Rana⍉, PBA Zahra⍉ and the superseded varieties Manafest and Icarus).
- Seed size is also influenced by the region (rainfall, soil type etc.) and season.

3.1.2 Broad bean types

Seed size of broad bean (Aquadulce, PBA Kareema⍉) is considerably larger than most faba bean, ranging from 100 to 170 g/100 seeds. They are of a light-brown to brown colour similar to Fiesta types. Broad bean market categories for Australian growers are based on size produced after grading for uniformity.

Market grade for broad bean size is usually classified by 'count' (seeds per 100 g) or sometimes by size (mm). Screens of 8, 11 or 14 mm are commonly used, with at least 70% of beans above that screen being required for the 'count'.

- The preferred market size is large broad beans, commonly over 14 mm in size (65–70 grades or 'count', which is 140–160 g/100 seeds),
- The medium-seeded broad bean grades (70–80 or 80–90 grades, which is 110–145 g/100 seeds),
- The small-seeded broad bean grade (90–110 grade, which is 90–100g/100 seeds).
- There is a very large market size of broad bean, commonly up to 17 mm in size (40–50, 50–55 grades or 'count', which is 180–220 g/100 seeds). Current broad bean varieties cannot achieve this grade.

Broad bean size produced depends on seasonal conditions and the environment where they are grown. The longer maturity restricts broad bean to the high-rainfall regions of south-east South Australia and south-west Victoria where they are well suited.

1 Pulse Australia (2016) Best management guide .Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

2 Pulse Australia (2016) Southern faba and broad bean best management practices training course – 2016. Pulse Australia.

3.2 Variety selection

Some bean varieties have limitations in agronomic adaptation and marketability and will not suit all areas or situations (e.g. broad bean, PBA Rana⁽ᴾ⁾).

When selecting a variety consider:

- season length;
- seed size with reference to sowing machinery;
- disease susceptibility to chocolate spot, Ascochyta blight and, to some degree, rust;
- seed availability;
- lodging resistance;
- maturity timing;
- yield potential;
- price potential; and
- market opportunities.

A variety with a highly specific trait such as disease resistance may not necessarily yield as well as another variety bred specifically for yield, but that resistance trait will diminish risk.

Varietal resistance to chocolate spot is extremely important as this disease is a potential problem with faba bean and broad bean in higher-rainfall areas, irrigated crops or wetter years. There is limited varietal resistance, so a strategic foliar fungicide program is essential in most areas.

The availability of varieties resistant to Ascochyta blight now lowers the disease risk for faba bean in southern Australia. Ascochyta blight-resistant varieties require fewer and later fungicide applications than those with less resistance, but still require fungicide control of chocolate spot. PBA Samira⁽ᴾ⁾ has good resistance to the new Ascochyta pathotype 2 that has been identified in the Mid North of South Australia.

Farah⁽ᴾ⁾ and Fiesta VF have lower resistance to chocolate spot and rust than the newer varieties and are more suited to areas with low disease pressure.

All varieties are susceptible to Cercospora.

PBA Rana⁽ᴾ⁾, PBA Samira⁽ᴾ⁾ and PBA Zahra⁽ᴾ⁾ have more potential to take advantage of good seasons in high-rainfall environments.

3.2.1 Introducing a new variety

Southern region growers who plan to introduce a new variety or sow several varieties of faba bean should ensure there is at least 500 m between those different varieties. Faba bean cross-pollinate, increasing the risk of disease resistance breaking down and producing mixed seed types that are difficult to market.

In practice, sowing a small area of a new variety into a separate, isolated paddock is difficult to do with small quantities purchased. The compromise when sowing the two varieties close to each other is to ensure that there is only a short distance where they are adjacent to each other. Then only retain the grain harvested for seed from furthest away from the other variety. This means that those areas of the new variety that are close to the other variety are not mixed in with the seed and are marketed only as commercial grain. More seed than originally planned needs to be purchased to achieve this compromise.

3.3 Area of adaption

Faba bean and broad bean varieties are bred for a range of different environments. These are categorised by Pulse Breeding Australia (PBA) into five regions based on rainfall and geographic location (Figure 1). Most faba bean varieties are adapted to Zones 4 and 5.

The area of adaption is specified for each variety so that potential users are aware of their best fit. Breeding trials and National Variety Trials (NVT) help indicate specific adaptation even within a region.

Faba bean and broad bean are more tolerant to soils prone to waterlogging than other pulse crops, but will experience higher disease pressure in these situations. Broad bean are more suited to the high-rainfall zone as they require a longer growing season.

Some of the newer varieties such as PBA Zahra⁽ᶦ⁾ offer substantial yield improvements in the high-rainfall zone. Southern Farming Systems are trialling faba bean in Tasmania with excellent results.[3]

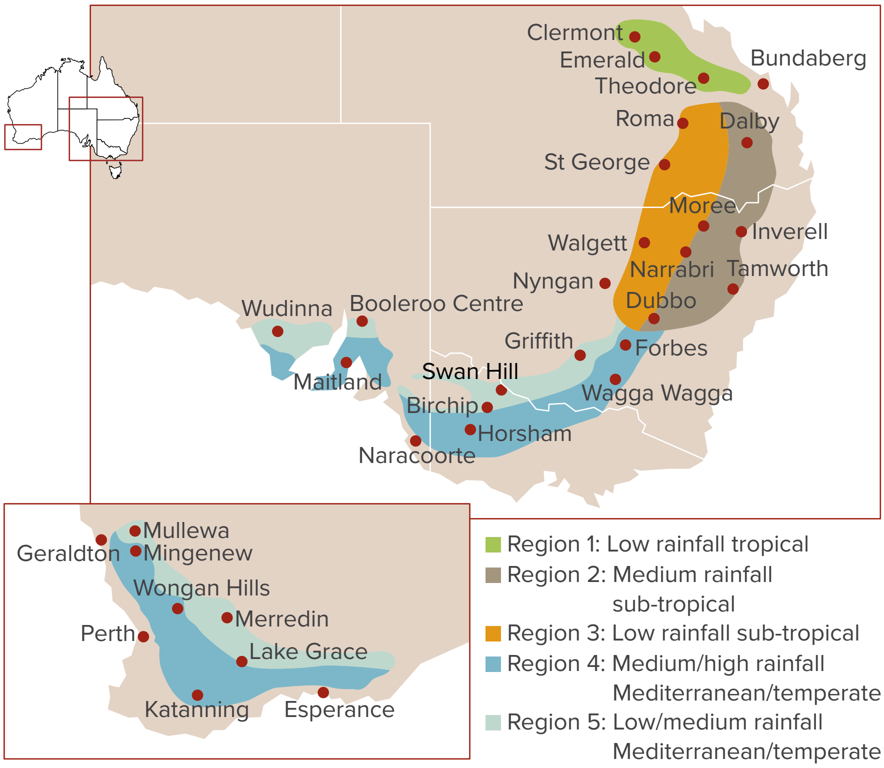

Figure 1: *Pulse Breeding Australia regions used to describe the area of adaption.*

Source: Pulse Breeding Australia

Broad bean are late to fill and mature and do not respond well to hot, dry finishes; however, they are more resistant to chocolate spot than faba bean. Broad bean require a cool finish to develop large, uniform seeds and will generally yield more than faba in high-rainfall areas.[4]

3 B Collis (2016) Grain with a history takes root in the Apple Isle. GroundCover Issue 124 September–October, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-124-SeptemberOctober-2016/Grain-with-a-history-takes-root-in-the-Apple-Isle

4 J Paull (2010) Faba bean variety trial – Dunkeld, Victoria. 2009 Trial report. Southern Farming Systems. pp. 74–75, http://www.farmtrials.com.au/trial/15943

3.4 Variety performance and yield

NVT grows current and potential varieties in multiple locations across all grain-growing regions in Australia. NVT trials are sown and managed as closely as possible to local best practice such as sowing time, fertiliser application, and weed, pest and disease management.

Growers are able to look at the annual yield and quality results for each variety at individual locations as well as regional and multi-year averages. The long-term yield averages for each region provide a guide to potential yield of each variety (Tables 1 and 2).

Table 1: Long-term yield of faba bean in National Variety Trials in South Australia, 2008–15.

	Lower EP		Mid North		Murray Mallee		South East		Upper EP		Yorke Peninsula	
Mean yield (t/ha)	2.2		2.77		1.48		2.78		1.66		3.52	
	Mean yield (%)	No. of trials	Mean yield (%)	No. of trials	Mean yield (%)	No. of trials	Mean yield (%)	No. of trials	Mean yield (%)	No. of trials	Mean yield (%)	No. of trials
Aquadulce	–		–		–		93	(13)	–		–	
Doza[PBR]	101	(10)	94	(27)	88	(3)	88	(19)	–		93	(6)
Farah[PBR]	98	(10)	99	(37)	103	(8)	101	(36)	97	(5)	100	(16)
Fiesta VF	98	(10)	99	(37)	103	(8)	102	(35)	97	(5)	100	(16)
Fiord	98	(7)	91	(22)	–		90	(18)	–		102	(4)
Manafest	–		93	(3)	–		89	(10)	–		–	
Nura[PBR]	97	(10)	97	(37)	105	(8)	95	(36)	96	(5)	101	(16)
PBA Kareema[PBR]	–		–		–		91	(13)	–		–	
PBA Nasma[PBR]	–		102	(8)	–		100	(6)	–		–	
PBA Rana[PBR]	94	(10)	94	(37)	92	(8)	94	(36)	89	(5)	92	(16)
PBA Samira[PBR]	103	(4)	105	(21)	107	(4)	106	(20)	100	(4)	103	(8)
PBA Warda[PBR]	105	(6)	99	(19)	–		98	(11)	–		–	
PBA Zahra[PBR]	105	(4)	109	(21)	109	(4)	109	(19)	101	(4)	107	(8)

Source: NVTOnline (2016)

Table 2: Long-term yield of faba bean in National Variety Trials in Victoria, 2008–15.

	North Central		North East		South West		Wimmera	
Mean yield (t/ha)	4.97		2.58		3.45		2.33	
	Mean yield (%)	No. of trials	Mean yield (%)	No. of trials	Mean yield (%)	No. of trials	Mean yield (%)	No. of trials
Aquadulce	–		–		88	(4)	–	
Doza⊕	–		87	(3)	–		97	(8)
Farah⊕	96	(6)	102	(8)	100	(6)	100	(28)
Fiesta VF	96	(6)	103	(8)	102	(6)	100	(22)
Fiord	–		–		–		99	(6)
Nura⊕	96	(6)	101	(8)	99	(6)	96	(28)
PBA Kareema⊕	–		–		91	(4)	–	
PBA Rana⊕	91	(3)	99	(8)	101	(6)	94	(28)
PBA Samira⊕	103	(4)	108	(4)	109	(4)	104	(14)
PBA Zahra⊕	106	(4)	111	(4)	109	(4)	104	(14)

Source: NVTOnline (2016)

Long-term yield predictions provided in this report have been produced using the NVT long-term multi environment trial (MET) analysis. The analysis produces predictions or 'production values' for every variety in every NVT trial across all years identified within the dataset. This report presents regional means for each variety, which reduces the accuracy and reliability of the results. Varieties present in less than three trials per region have been omitted from this report and some rounding variation may be present when compared with other reporting methods. More detailed yield information can be found using the NVT Long Term Yield Reports app or the Excel reporting tools available on the NVTOnline (www.nvtonline.com.au).

3.5 NVT apps for comparing varieties

NVT has launched two apps to help growers compare crop varieties. They can be downloaded from the NVT website (http://www.nvtonline.com.au/interactive-tools/apps/).

3.5.1 Yield app

The NVT Long Term Yield Reports app was developed to provide growers and advisers with an easy-to-use means of accessing and interpreting the data from the GRDC-funded NVT program.

The app dynamically aggregates the site mean yields into 0.5 t/ha increments and compares and presents the variety performances values in an easy-to-read table or graph. Users can select the state, region, site or group of sites. It is linked directly to the NVT database and will update automatically when additions are made to the data providing users with live data.

The app is available for Windows PC, Apple iPad and Android tablets.

3.5.2 Disease app

The Crop Disease Au app (NVT/GRDC) provides quick access to current disease resistance ratings, disease information and an extensive disease image library.

Compare disease symptoms with photographs and access detailed descriptions of each disease with management controls. Explore detailed information on crop varieties, map diseases and automatically share photographs with friends or colleagues via email.

With live feeds from the NVT database, variety information will always be up to date and information on newly released varieties will become instantly available upon their release.

The app is available for Android and iOS.

3.6 Quality traits

To access the export human food markets, Australian beans must be of a high quality and free from mechanical damage, weathering and disease staining and storage problems. Faba bean darken over time while in storage and seed can become unsuitable for the export market after about 9 months.

The medium-sized varieties are well accepted in the Middle East. The medium seed size 'Fiesta grade' is expected to remain the dominant quality type as it is currently well accepted in the Middle Eastern market and is also easier to manage for on-farm operations. The PBA faba bean breeding program has a major focus on developing new varieties to fit this grade.

The characteristics of the current varieties are listed in Table 3.

Market signals indicate that small-seeded faba bean varieties, such as the old Fiord and Ascot VF varieties, are no long desired in the Middle East. Mixing smaller-seeded varieties into the accepted larger Fiesta grade will downgrade the overall quality of the product.

PBA Rana⌽ and PBA Zahra⌽ seed is larger than other varieties and is considered to be of high quality by the major Egyptian market, representing a different grain category for faba bean growing and marketing in Australia. New varieties will also be developed for the large-seed type where premium prices might be obtained.

Table 3: Faba bean and broad bean agronomic guide.

Variety	Seed size	Seed size (g/100)	Seed colour	Plant height	Flowering time	Maturity	Lodging
Faba bean							
Farah⌽	Medium	55–75	Light brown to brown	Medium	Early to mid	Early to mid	MS
Fiesta VF	Medium	55–75	Light brown to brown	Medium	Early to mid	Early to mid	MS
Nura⌽	Small to medium	50–70	Light buff	Short	Mid	Early to mid	MR
PBA Rana⌽	Medium to large	65–85	Light brown	Medium/tall	Mid	Mid	MR
PBA Samira⌽	Medium	55–75	Light brown	Medium	Mid	Mid	MR
PBA Zahra⌽	Medium to large	60–85	Light brown	Medium/tall	Mid	Mid to late	MR
Broad bean							
Aquadulce	Large	110–150	Light buff	Tall	Late	Mid to late	MS
PBA Kareema⌽	Large	130–170	Light brown	Tall	Late	Late	MS

MR – moderately resistant, MS – moderately susceptible

Source: Victorian Winter Crop Summary 2017, and Pulse Australia (2016)

The choice of variety mainly determines seed size and colour. However, management from seeding to delivery can affect quality, with seed downgraded due to shrivelling,

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MORE INFORMATION

L McDonald (2017) Image analysis to quantify pulse quality traits. GRDC Update Paper February 2017: https://grdc.com.au/resources-and-publications/grdc-update-papers

L McMurray (2017) Pulse performance and agronomy update. GRDC Update Paper February 2017: https://grdc.com.au/resources-and-publications/grdc-update-papers

seed discoloration, breakage and insect damage. This damage will also lead to poor emergence and vigour when seed is sown.

Seed staining in beans is caused by:

- genetics (natural ageing, and high-tannin grains are more likely to discolour);
- late rain on maturing or mature crops;
- Ascochyta blight (susceptible varieties are more prone to discoloration, especially after late rains);
- exposure due to pod splitting (commonly caused by chocolate spot infection);
- frost;
- other diseases including Pea seed-borne mosaic virus (PSbMV); and/or
- poor storage conditions, including high moisture or exposure to sunlight.

3.7 Southern faba bean varieties

Please note that the specific disease-resistance ratings listed below are updated each season as pathogens evolve to overcome resistance. Always check the updated disease ratings each year in the current Crop Variety Guides for each state or on the NVT Crop Disease Au app.

3.7.1 Fiesta VF

Fiesta VF (Photo 1) has average yields similar to Farah⁽ᵇ⁾. It has early-to-mid flowering and maturity with good seedling vigour. Area of Adaption: Zone 4 and 5 (irrigated).[5]

Fiesta VF was the first Australian faba bean variety with medium-sized seed and is widely adapted throughout the southern region. It does not have the Ascochyta blight resistance of the newer varieties. As it is moderately resistant to moderately susceptible (MRMS) to pathotype 1 of Ascochyta blight and susceptible (S) to pathotype 2, it is only suited to regions where the risk is low or well managed. Fiesta VF is susceptible to chocolate spot and rust.

Fiesta VF is a medium-sized bean.

Released 1998. Fiesta VF is no longer protected by plant breeder's rights (PBR) and no end-point royalty (EPR) applies.

Photo 1: *Fiesta VF.*

Source: Pulse Australia

5 Pulse Australia (2011) Fiesta VF Variety Management Package. Pulse Australia, http://pulseaus.com.au/storage/app/media/crops/2011_VMP-Fababean-FiestaVF.pdf

3.7.2 Farah⚬

Farah⚬ (Photo 2) has average yields, similar to Fiesta VF, and performs best in medium-rainfall environments. It has early-to-mid flowering and maturity. Area of Adaption: Zone 4 and 5 (irrigated). [6]

It has better resistance to Ascochyta blight pathotype 1 than Fiesta VF but is susceptible to pathotype 2. It is susceptible to chocolate spot and rust. Farah⚬ may be preferred to Nura⚬ where the risk of chocolate spot is low, where sowing time is delayed or in low-rainfall areas where the shorter Nura⚬ may be at a disadvantage.

Farah⚬ has a medium seed size and is known for uniform seed size.

Released 2004, Heritage Seeds, EPR $3.00 ex-GST.

Photo 2: *Farah*⚬.

Source: Pulse Australia

6 Pulse Australia (2011) Farah⚬ Variety Management Package. Pulse Australia, http://pulseaus.com.au/storage/app/media/crops/2011_VMP-Fababean-Farah.pdf

3.7.3 Nura⁽ᵇ⁾

Nura⁽ᵇ⁾ (Photo 3) has average yields with wide adaptation throughout southern Australia. It is mid-flowering and has early-to-mid maturity. Nura⁽ᵇ⁾ needs to be sown early particularly in low to medium-rainfall areas as it flowers about 7 days later than Fiesta VF, but it matures at a similar time. It is not suitable for late sowing. Nura⁽ᵇ⁾ is a shorter plant that is less likely to lodge; however, the bottom pods are closer to the ground, which can make harvest more difficult. Area of Adaption: Zone 4 and 5 (irrigated).

It has good overall disease resistance and is resistant to moderately resistant (RMR) to both pathotypes of Ascochyta blight. As with other newer varieties it is moderately susceptible (MS) to chocolate spot and rust.

Nura⁽ᵇ⁾ has a small to medium seed size and is suited to Egyptian markets.

Nura⁽ᵇ⁾ is more sensitive to high rates of imazethapyr (e.g. Spinnaker®) than Farah⁽ᵇ⁾ but is more tolerant of simazine and metribuzin.

Released 2005. Seednet. EPR $3.00 ex-GST.

Photo 3: *Nura⁽ᵇ⁾*.

Source: Pulse Australia

3.7.4 PBA Rana⍤

PBA Rana⍤ (Photo 4) is a relatively late flowering and maturing variety suited to higher-rainfall, long-season regions. It is a vigorous plant with mid flowering and mid-maturity. Area of Adaption: Zone 4 and 5 (irrigated).

It has good overall disease resistance and is resistant to pathotype 1 of Ascochyta blight, but moderately resistant to moderately susceptible (MRMS) to pathotype 2. As with other newer varieties, it is moderately susceptible (MS) to chocolate spot and rust.

PBA Rana⍤ has a large seed size and is suited to Middle Eastern markets.

Released 2011. Seednet. EPR $3.50 ex-GST. Tested as AF10060/15-1 or 974*(611*974)/15-1.

Photo 4: *PBA Rana*⍤.

Source: Pulse Australia

3.7.5 PBA Samira⁽ᵈ⁾

PBA Samira⁽ᵈ⁾ (Photo 5) is a high-yielding variety with wide adaptation throughout southern Australia. It is a vigorous plant with mid to late-flowering and mid-maturity. While it flowers relatively late it matures at the same time as other varieties. It can perform very well in longer-season environments. Area of Adaption: Zone 4 and 5.

It has good overall disease resistance and is resistant to both pathotypes of Ascochyta blight. As with other newer varieties it is moderately susceptible (MS) to chocolate spot and rust.

PBA Samira⁽ᵈ⁾ has a medium seed size and is suited to Middle Eastern markets.

Released 2015. Developed by PBA (as AF05069-2). Seednet. EPR $3.50 ex-GST.

Photo 5: *PBA Samira⁽ᵈ⁾*.

Source: Pulse Australia

3.7.6 PBA Zahra⦹

PBA Zahra⦹ (Photo 6) is a high-yielding variety with wide adaption throughout southern Australia. It is the most recent release from the PBA faba bean breeding program and in the right conditions has the highest yield of current varieties. It is better suited to higher-rainfall, long-season regions. It is a vigorous plant with mid-flowering and mid-to-late maturity that can perform very well in longer-season environments. Area of Adaption: Zone 4 and 5.

It has good overall disease resistance and is resistant to pathotype 1 of Ascochyta blight, but moderately resistant to moderately susceptible (MRMS) to pathotype 2. As with other newer varieties it is moderately susceptible (MS) to chocolate spot and rust.

PBA Zahra⦹ has a large uniform seed size, similar to PBA Rana⦹, and is suited to Middle Eastern markets.

Released 2016. Developed by PBA (as AF05095-1). Seednet. EPR $3.50 ex-GST.

Photo 6: *PBA Zahra⦹*.

Source: Pulse Australia

3.8 Southern broad bean varieties

3.8.1 Aquadulce

Aquadulce (Photo 7) is a tall broad bean with late flowering and maturity suited to high-rainfall areas. It is more tolerant to waterlogging than most faba bean varieties and can tolerate soils with iron and manganese deficiencies. Area of Adaption: Zone 4 (SA and Victoria).

It is moderately susceptible (MS) to Ascochyta blight pathotypes 1 and 2, chocolate spot and rust.

Aquadulce has a large seed size and can attract a price premium over faba bean. Aquadulce is being superceded by PBA Kareema⁽ᵈ⁾.

Released 1982. Aquadulce is not protected by PBR, and no EPR applies.

Photo 7: *Aquadulce.*

Source: Pulse Australia

3.8.2 PBA Kareema⊕

PBA Kareema⊕ (Photo 8) is a tall broad bean with late flowering and maturity suited to high-rainfall areas. It is a direct replacement for Aquadulce and is also more tolerant of waterlogging than most faba bean and can tolerate soils with iron and manganese deficiencies. Area of Adaption: Zone 4 (SA & Victoria).

It is resistant to moderately resistant (RMR) to pathotype 1 and moderately resistant (MR) to pathotype 2 of Ascochyta blight, moderately resistant to moderately susceptible (MRMS) to rust and moderately susceptible (MS) to chocolate spot.

It has a larger and more uniform seed than Aquadulce with no 'evergreen' seeds. It can attract a price premium over faba bean.

Released 2009. PGG Wrightson Seeds. EPR $4.00 ex-GST.

Photo 8: *PBA Kareema⊕.*

Source: Pulse Australia

3.9 Faba bean variety seed availability

Seed can be sourced from the suppliers listed in Table 4.

Table 4: Seed distribution arrangements and end-point royalties of faba and broad bean.

Registered PBR Name	PBR	Type	Variety owner	Royalty manager charged with EPR collection	EPR rate $/t (GST exclusive)	Seed distribution arrangements 2016	Grower sales permitted
Farah^{⟨PBR⟩}	Yes	Faba bean	University of Adelaide	Heritage Seeds	$3.00	Heritage Seeds Broadacre Agents	No
Fiesta VF	No	Faba bean	University of Adelaide	N/A	–		
Nura⟨PBR⟩	Yes	Faba bean	University of Adelaide	SeedNet	$3.00	SeedNet	No
PBA Rana⟨PBR⟩	Yes	Faba bean	University of Adelaide	SeedNet	$3.50	SeedNet	No
PBA Samira⟨PBR⟩	Yes	Faba bean	University of Adelaide	SeedNet	$3.50	SeedNet	No
PBA Zahra⟨PBR⟩	Yes	Faba bean	University of Adelaide	SeedNet	$3.50	SeedNet	No
Aquadulce	No	Broad bean	None	N/A	–	–	
PBA Kareema⟨PBR⟩	Yes	Broad bean	University of Adelaide	PGG Wrightson Seeds	$4.00	PGG Wrightson Seeds	No

Source: Variety Central (2016)

3.10 Seed quality

High-quality seed is essential to ensure the best start for the crop. High-quality seed will germinate well providing the correct plant density and good seedling vigour.

Grower-retained seed, if not tested, may be of poor quality with reduced germination and vigour, as well as being infected with seed-borne pathogens. To maximise germination and early vigour:

- all seed should be tested for quality including germination and vigour (see Section 3.11 Seed testing for more information);
- if grower-retained seed is of low quality then consider purchasing registered or certified seed from a commercial supplier (always ask for a copy of the germination report regardless of the source);
- pay careful attention to the harvest, storage and handling of seed intended for sowing (see Section 12 Harvest and Section 13 Storage for more information); and
- use knowledge of seed quality (germination, vigour and seed size) to calculate seeding rates (see Section 4 Planting for more information).

It is important to know or test the germination rate to accurately calculate seeding rates for the targeted sowing density. A slight variation in seed size due to seasonal conditions or an incorrect germination percentage can make a significant difference in the final plant density.

Many seed buyers are unaware that the minimum germination requirement for certified pulse seed is only 70% compared with 80% in cereal grains and far less than 90% or greater that is often obtained in pulse seed. Test results must be made available under the *Seeds Act 1985* (see https://www.legislation.tas.gov.au/view/html/inforce/current/act-1985-087), and Australian Seed Federation guidelines, so ensure you receive a copy.

Seed quality problems often occur when the crop does not get harvested under ideal moisture or seasonal finishing conditions. A sharp seasonal finish, a wet harvest or delayed harvest can have a significant impact on seed quality. Seed may also be damaged by frost.

The large size or fragile nature of pulse seed, particularly faba bean and broad bean, makes them more vulnerable to mechanical damage during harvest and handling. This damage is not always visually apparent.

Rotary harvesters and belt conveyors are ideally suited to pulse grain and can reduce seed damage that often results in abnormal seedlings that germinate but do not develop further. Damage can be reduced by slowing header rotor speed and opening the concave, or by reducing auger speed and lowering the flight angle and fall of grain.

Low germination rates and poor seedling vigour can cause slower and uneven emergence that can result in sparse establishment and a weak crop. It can also be more vulnerable to virus infection, fungal disease and insect attack, and less competitive with weeds. Any of these can result in significantly lower yields.

Under ideal conditions abnormal seedlings may emerge, but will lack vigour. Factors such as low temperature, disease, insects, seeding depth, soil crusting and compaction are more likely to affect the establishment of weak seedlings. Those that do emerge are unlikely to survive for long or produce less biomass and make little or no contribution to final yield.

Diseases such as chocolate spot and Ascochyta blight can carryover from one season to the next on infected faba bean seed. Purchase disease-free seed or retain seed from the healthiest crop to avoid carryover on infected seed (see Section 9 Diseases for more information).

3.10.1 Sowing grower-retained seed

When saving seed, select the best area of a paddock and mark the area out well before harvest (see Section 12 Harvest for more information). Choose an area where weeds and diseases are absent and the crop is vigorous and healthy and likely to mature evenly with a good grain size. Seed from this area should be harvested first, ideally between 11–13% moisture to avoid low-moisture grain that is susceptible to cracking.

Glyphosate is not registered for seed crops (see Section 11 Pre-harvest treatments for more information). If desiccation is required do not use glyphosate as normal seed count and vigour can be severely reduced. Crop-topping will also reduce seed viability.

Seed-borne diseases can lower germination levels, and testing for their presence in seed can be conducted by specialist laboratories for several diseases such as Ascochyta blight and *Botrytis* (chocolate spot or grey mould) (see Section 9 Diseases for more information).

Harvest on time to minimise Ascochyta blight and chocolate spot infection on seed. Infection on the pods can spread to seed if harvest is delayed and conditions are wet.

Clean grain after harvest to remove weed seeds.

Seed with poor germination, high levels of seed-borne disease and weed seed contamination should not be sown. The cheaper cost of retaining this seed will often be offset by higher sowing rates needed and the potential risk of introducing further disease or virus into the crop.

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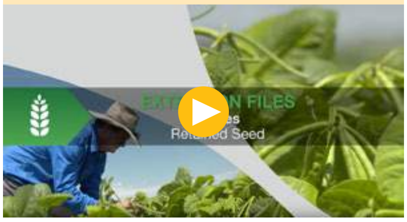
VIDEO

GroundCoverTM TV: Extension Files – Retained pulse seed
https://youtu.be/5Iq9T6_f6Tg



VIDEO

GRDC Over the Fence: Ensure seed viability with aerated storage – Apr 2011
https://youtu.be/8HFilsCnka0

The only way to accurately know the seed's germination rate, vigour and disease level is to have it tested.

Growers should also ensure that seed varieties are properly labelled in storage and that different varieties are not accidently mixed and sown together. Sowing varieties with different disease susceptibility will compromise disease management.

3.10.2 Seed storage

Seed quality is at its highest when first loaded into storage, but can steadily deteriorate if the storage environment is not well managed. A combination of good farm hygiene, storage choice and aeration cooling are important for maintaining grain quality and overcoming many problems with pests associated with storage.

Pulse grain placed in storage with high germination and vigour can remain viable for at least 3 years providing the moisture content of the grain does not exceed 11%.

As a general rule, every 1% rise in moisture content above 11% will reduce the storage life of pulse seed by one-third. Any pulse stored above 12% moisture content will require aeration cooling to maintain quality.

High temperatures in storage will cause deterioration in grain viability. Temperatures of stored pulse grain should not exceed an average of 25°C and the average temperature should preferably be below 20°C. In general, each 4°C rise in average stored temperature will halve the storage life of the grain.

While insects are not considered a major problem in stored faba bean and broad bean it is important to practice good hygiene to ensure grain is not damaged (see Section 13 Storage for more information).

3.11 Seed testing

3.11.1 Germination testing

Seed testing laboratories can conduct germination and vigour tests on a representative sample of seed. It is also possible to do a germination test at home. For beans, 1 kg is required for every 25 t of seed.

Sampling should be random and take numerous sub-samples to give best results. It is easier and more accurate to take numerous samples while seed is being moved either out of the seed cleaner, storage or truck or sampling from numerous bags if stored this way.

Do not sample from within a silo: it is dangerous for the operator and it difficult to obtain a representative sample, as is taking samples from the bagging chute. Mix sub-samples thoroughly and take a composite sample of 1 kg. Failure to correctly sample or test seed could result in poor establishment in the field.

If an issue with kept grain is suspected, it is better to get a sample tested early. If the sample is not of sufficient quality the cost of grading and seed treatment can be saved and there will be more time to source replacement seed. If the germination and vigour are below optimal or marginal or the crop was weather damaged at harvest, it may be advisable to have it re-tested closer to harvest after storage, handling and grading to check that quality has been maintained.

Doing your own germination test

Ideally, results from a laboratory germination and vigour test should be used in seeding rate calculations. However, a home test (Photo 9) after harvest can be useful to decide which seed to target for sowing or to check for deterioration in storage.[7]

Use a flat, shallow seeding tray about 5 cm deep. Place a sheet of newspaper on the base to cover drainage holes. Use clean sand, potting mix or a freely draining

7 Pulse Australia (2016) Southern faba and broad bean best management practices training course – 2016. Pulse Australia.

soil. Testing should be at a temperature of less than 20°C, so doing it indoors may be required. Randomly count out 100 seeds per test, but do not discard any damaged seeds.

After the tray has been filled with soil, sow 10 rows of 10 seeds in a grid at the correct seeding depth. Do this by placing the seed on the levelled soil surface and gently pushing each in with a pencil marked to the required depth. Gently cover seed holes with a little more soil and water.

Alternatively, place a layer of moist soil in the tray and level it to the depth of sowing that will be required. Place the seeds as 10 rows of 10 seeds in a grid on the seed bedformed. Then uniformly fill the tray with soil to the required depth of seed coverage (i.e. seeding depth). Ensure that the soil surface is uniformly levelled and water gently if required.

During the test, keep the soil moist, but not wet. Overwatering will result in fungal growth and possible rotting. After seven to 14 days the majority of viable seeds will have emerged. Count only normal, healthy seedlings. The number of normal and vigorous seedlings you count will be the germination percentage.

This germination test is in part a form of inbuilt vigour testing because it is done in soil. To further establish vigour under more adverse conditions, a second germination test done under colder or wetter conditions could be used as a comparison to the normal germination test done at the same time.

Photo 9: *Doing your own germination test.*

Photo: E Leonard, AgriKnowHow

Vigour testing

In years of either drought or a wet harvest seed germination can be reduced, but, more importantly, seedling vigour can also be reduced. Vigour represents the rapid, uniform emergence and development of normal seedlings under a wide range of conditions.[8]

Poor seedling vigour can impact heavily on establishment and early seedling growth. This often occurs under more difficult establishment conditions such as deep sowing, crusting, compaction, wet soils or when seed treatments have been applied.

Some laboratories also offer a seed-vigour test when doing their germination testing. Otherwise conduct your own test by sowing seeds into a soil tray that is kept cold (<20°C) and observing not only the germination but also speed and uniformity of emergence and any abnormal shoot and root development.

8 Australia (2016) Southern faba and broad bean best management practices training course – 2016. Pulse Australia.Pulse

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Several types of tests are used by seed laboratories to establish seed and seedling vigour.

Accelerated ageing vigour test

Accelerated ageing estimates longevity of seed in storage. It is now also used as an indicator of seed vigour and has been successfully related to field emergence and stand establishment. This tests seed under conditions of high moisture and humidity. Seeds with high vigour withstand these stresses and deteriorate at a slower rate than those with poorer vigour.

Results are expressed as a percentage normal germination after ageing (vigorous seedlings). The closer the accelerated ageing number is to the germination result, the better the vigour.

Conductivity vigour test

The conductivity test measures electrolyte leakage from plant tissues. Conductivity test results are used to rank vigour lots by vigour level.

Having a germination test done as well is important as a conductivity test cannot always pick up all chemical and pathogen scenarios, which may be seed-borne.

Cool germination and cold tests

A cool or cold test evaluates the emergence of a seed lot in cold, wet soils. In the field these conditions can cause poor performance. It is one of the oldest and most widely used vigour tests for many crops.

Uses for this test can include:

- evaluating fungicide efficacy;
- evaluating physiological deterioration resulting from prolonged or adverse storage, freezing injury, immaturity, injury from drying or other causes;
- measuring the effect of mechanical damage on germination in cold, wet soil; and
- providing a basis for adjusting seeding rates.

This test usually places the seed in cold temperatures (5°C–10°C) for a time that is then followed by a period of growth. The seed is evaluated relative to normal seedlings according to a germination test. Some laboratories also categorise the seedlings further into vigour categories and report both of these numbers.

Tetrazolium test as a vigour test

The tetrazolium test is used to test seed viability, but is also useful as a rapid estimate of vigour of viable seeds. Seed is dissected, stained and examined under a microscope. It is conducted in the same manner as a germination test, but viable seeds are evaluated more critically into categories of:

- high vigour: staining is uniform and even, tissue is firm and bright;
- medium vigour: embryo completely stained or embryonic axis stained in dicots; extremities may be unstained; some over-stained/less-firm areas exist; and
- low vigour: large areas of non-essential structures unstained; extreme tip of radicle unstained in dicots; tissue milky, flaccid and over-stained.

Results have shown good relationships with field performance, and are useful for pulses.

Other vigour tests

Another example of a vigour test used by some Australian laboratories is to test germination at 7°C for 12–20 days in the dark and under low-moisture conditions. If seed vigour is acceptable, then this germination result should be within 10% of the regular germination test.

3.11.2 Weed-contamination testing

Sowing seed free of weeds cuts the risk of introducing new weeds. It also reduces the pressure on herbicides, especially with increasing herbicide resistance. Tests for purity of a seed sample can be conducted if requested, including the amount and type of weed seed contamination.

3.11.3 Disease testing and major pathogens identified in seed tests

Disease risk can be reduced by using fresh, undamaged and robust seed to prevent disease build-up (see Section 9 Diseases for more information).

Seed-borne diseases such as Ascochyta blight and chocolate spot pose a serious threat to yields. Seed-borne diseases can strike early in the growth of the crop when seedlings are most vulnerable and result in severe plant losses and lower yields.

Seed transmission of viruses in faba bean is minimal relative to the spread by insect vectors, but can be minimised by purchasing virus-tested seed (see Section 9 Diseases for more information).

Testing seed before sowing will identify the presence of disease and allow steps to be taken to reduce the disease risk. If disease is detected, the seed may either be treated with a fungicide before sowing or a clean seed source may be used.

For a disease test, 1 kg of seed is usually required.

3.11.4 Agencies offering seed testing

South Australian Research and Development Institute (SARDI) – Plant Research Centre

Phone: 08 8303 9400

Germination, weed and disease testing, http://pir.sa.gov.au/research/services/crop_diagnostics/seed_and_crop_testing

Tasmanian Department of Primary Industries, Parks, Water and Environment – Plant Health Laboratories

Phone: 03 6165 3252 or 1300 368 550

Email: biosecurity.planthealth@dpipwe.tas.gov.au

Germination and weed testing, http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/tasmanian-seed-services

Virus testing, http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/tasag-elisa-testing

AsureQuality

AsureQuality is located in Melbourne.

Phone: 03 8318 9000 or 1800 247 478

Germination testing, https://www.asurequality.com/our-industries/seeds/

MORE INFORMATION

SARDI: Seed and crop testing http://pir.sa.gov.au/research/services/crop_diagnostics/seed_and_crop_testing

Tasmanian DPIPWE: Tasmanian Seed Services http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/tasmanian-seed-services

Agriculture Victoria: Seed health testing in pulse crops http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops

eXtensionAUS : Disease testing services around Australia http://extensionaus.com.au/field-crop-diseases/disease-testing-services-around-australia/

MORE INFORMATION

GRDC Nitrogen fixation of crop legume Fact Sheet. https://grdc.com.au/Resources/Factsheets/2014/07/Nitrogen-fixation-of-crop-legumes-basic-principles-and-practical-management

GRDC Rhizobial Inoculants Fact Sheet. https://grdc.com.au/Resources/Factsheets/2013/01/Rhizobial-Inoculants

Planting

Key points

- **Ensure faba bean is sown within the recommended window. Early sowing of faba bean within the sowing window is important in the medium and low-rainfall zones but responses are inconsistent in the high-rainfall zone.**
- **Sowing rate can have a major effect on yield and disease resistance. It should be based on target plant density and will vary with seed size.**
- **Faba bean is adaptable to a range of row spacings. Wide rows with stubble retention are becoming more popular as a farming system, but faba bean yield responses are inconsistent.**
- **Faba bean seed should be inoculated with Group F inoculant.**
- **Sowing equipment may need to be modified to accommodate large seed. Sow 5–8 cm deep. Dry sowing is an option.**
- **Paddocks may require rolling to make harvest manageable.**

4.1 Time of sowing

Faba bean and broad bean respond markedly to time of sowing, with crops sown at the optimal time having the best chance of producing high yields. Crops sown earlier or later than recommended will often suffer from reduced yields.

4.1.1 Optimal time of sowing in southern Australia

The ideal sowing time for pulses varies with location. Rainfall and the timing of risk periods, such as disease, frost and critical heat stress, are key factors but soil type and fertility can also be important. It is essential to have adequate soil moisture at sowing time, unless dry sowing.

Most faba bean and broad bean varieties are either susceptible (S) or moderately susceptible (MS) to chocolate spot (*Botrytis fabae*), meaning that sowing times in southern Australia may need to be delayed in some circumstances to reduce the risk of chocolate spot infection. However, most new varieties are either resistant (R) or moderately resistant (MR) to Ascochyta blight. Sowing times in southern Australia therefore no longer need to be delayed to specifically reduce the risk of Ascochyta blight infection with these varieties.

Avoiding frost or cold conditions during flowering can be important, particularly in areas with long growing seasons where sowing time may also need to be delayed to avoid chocolate spot.

Faba bean and broad bean show a marked response to time of sowing, with crops sown 'on time' having an excellent chance of producing very high yields. However, crops sown earlier or later than recommended will often suffer from reduced yields.

Water use efficiency is commonly in the range of 8–12 kg grain/ha/mm for sowings made during the preferred sowing window. This drops away to 4–6 kg/mm for very late or very early sowings.[1]

Growers are increasingly sowing pulse crops early (within the sowing window), to minimise the effects of heat and moisture stress during spring. Heat stress during flowering and pod-fill can have a significant impact on grain yield. For each week's delay in sowing, an average of 250 kg/ha yield may be lost. Early sowing requires greater attention to disease control, particularly for chocolate spot.

While early sowing is often beneficial in the low and medium-rainfall zones, the benefits are less definitive in the high-rainfall zone (HRZ), as it can result in excessive vegetative growth, increasing the likelihood of crop lodging and foliar diseases.

Delayed sowing may be necessary in some situations until risk factors, such as disease, reach an acceptable level.

Faba bean begin producing pods and filling seeds early in the season, usually before severe drought stress begins in spring (see Section 5 Plant growth and physiology for more information).

Some varieties such as Fiesta VF and Farah[⦶] faba bean and Aquadulce broad bean respond less to early sowing because they do not set early pods under cold and shaded conditions.

Optimum times of sowing for faba bean in South Australia and Victoria are shown in Table 1 and Table 2. However, a recent recommendation for Victoria is to sow faba bean between mid-April and the first week of May. For such early sowing to be successful, growers need to choose well-adapted varieties, and have excellent disease management and weed control.

On acidic soils in southern New South Wales, sow faba bean from 20 April to 15 May. Crops sown later than mid-May, flower and fill pods in rising spring temperatures and moisture stress, restricting plant height, dry matter production and grain yield.

1 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

Trials have found that sowing time is more important than variety choice in the Riverina.[2 3 4 5 6 7]

Table 1: Times of sowing for faba bean in South Australia.

Month	April				May				June			
Week	1	2	3	4	1	2	3	4	1	2	3	4
SA: less than 350 mm			Yellow	Green	Green	Green	Red					
SA: 350–450 mm				Yellow	Green	Green	Green	Green	Red			
SA: 450–550 mm					Yellow	Green	Green	Green	Green	Red		
SA: 550–650 mm						Yellow	Green	Green	Green	Green	Red	
SA: less than 350 mm						Yellow	Green	Green	Green	Green	Red	

Note: Sowing time needs vary with the variety flowering date and maturity rating.

Source: Southern faba and broad bean best management practices training course – 2016

Yellow Earlier than ideal sowing time.
Green Optimum sowing time.
Red Later than ideal but acceptable.

Recent recommendations encourage Victorian growers to sow between mid-April and the first week of May.[8] Recommendations for Tasmania may be based on those for Victoria and SA as information about sowing times was unavailable for Tasmania at the time of writing.

Table 2: Times of sowing for faba bean in regions of Victoria.

Region	April				May				June			
Week	1	2	3	4	1	2	3	4	1	2	3	4
Mallee		Yellow	Green	Green	Green	Red	Red					
Wimmera		Yellow	Yellow	Green	Green	Green	Green	Red	Red			
North Central (one week earlier for irrigation)		Yellow	Yellow	Green	Green	Green	Green	Red	Red			
North East			Yellow	Green	Green	Green	Red					
South West			Yellow	Yellow	Green	Green	Green	Green	Red	Red	Red	Red

Note: Recommendations for Tasmania may be based on those for Victoria as information about sowing times is unavailable for Tasmania at the time of writing.

Source: 2017 Victorian Winter Crop Summary

Yellow Earlier than ideal sowing time.
Green Optimum sowing time.
Red Later than ideal but acceptable.

2 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

3 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

4 C Walela, L McMurray, J Paull (2015) Variety and agronomic performance of faba beans in medium and high rainfall zones in SA. Hart Trial Results 2015. Hart Field Site, http://www.hartfieldsite.org.au/media/2015%20Trial%20Results/2015_Hart_Trial_Results_Variety_and_agronomic_performance_of_faba_beans_in_medium_and_high_rainfall_zones_in_SA.pdf

5 S Loss, K Siddique, L Martin (1997) Adaptation of faba bean (Vicia faba L.) to dryland Mediterranean-type environments II. Phenology, canopy development, radiation absorption and biomass partitioning. Field Crops Research 52(1–2). pp 29–41, www.sciencedirect.com/science/article/pii/S0378429096034545

6 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

7 E Armstrong, L Gaynor, G O'Connor, S Ellis, N Coombes (2015) Faba beans for acidic soils in southern NSW – yields and time of sowing effects. GRDC Update Paper 17 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Faba-beans-for-acidic-soils-in-southern-NSW

8 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

The sowing dates in Tables 1 and 2 should ensure that crops:

- flower over an extended period to encourage better podset and produce sufficient growth to set and fill an adequate number of pods; and
- finish flowering before they are subjected to periods of heat stress. This is generally when there are average maximum daily temperatures of 25°C for a week or more.

Faba bean and broad bean seedlings are tolerant of frost. Seed can germinate in soil temperatures from 5°C, but emergence is slow in cold soil. Seedling vigour improves when soil temperatures are at least 7°C.

Faba bean should be sown early in wet areas, on low fertility or acidic soils, and where it is unlikely that the crop will grow excessively tall.[9 10]

IN FOCUS

Dry sowing

Several factors need consideration before choosing to dry sow, including:

- the weed seed burden and weed control options;
- the need for rhizobia to survive in dry soil, particularly if the soil is acidic;
- type of soil and the ease of sowing into that soil when it is dry (including uniformity of sowing depth and soil tilth);
- the ability to enter the paddock after rain to perform operations in a timely manner;
- evenness of the soil after sowing and the impact of this on herbicide application and harvest operations; and
- the need for additional levelling to flatten any ridges, cover press-wheel furrows or flatten clods.

4.1.2 Sowing too early

Sowing too early, before the preferred sowing window, increases the risk of yield loss from both frost damage and disease.[11] It is better to stick to the recommended sowing date and change varieties if needed. Sowing before the recommended sowing window tends to result in crops suffering from:

- poor early pod-set because of low light or low temperatures (10°C or less) during early flowering;
- higher risk of chocolate spot at flowering and during pod development;
- excessively tall crops, more prone to lodging with a dramatically increased chance of fungal diseases in medium to high-rainfall districts;
- increased frost risk at flowering and early podding;
- high water use prior to effective flowering and the earlier onset of moisture stress during flowering and podding;
- increased risk of Ascochyta blight in susceptible varieties; and
- potentially, poor weed control.

Faba bean sown in trials at Wagga Wagga, NSW, during the first week of April grew too tall and lodged in 2010 and again in 2014. In 2010, plants lodged as early as

9 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

10 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

11 M Richards, E Armstrong, L Gaynor, N Graham, N Coombes (2016) Sowing time and variety selection in southern NSW. GRDC Update Paper 16 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Sowing-time-and-variety-selection-for-faba-bean-in-southern-NSW

September. In the 2014 trial, PBA Rana⁽ᵈ⁾ and Farah⁽ᵈ⁾ were most vulnerable to lodging under ideal early growing conditions.[12 13 14]

4.1.3 Sowing too late

Sowing later than the sowing window can expose slower-maturing crops to moisture and heat stress during flowering and podding. This results in shorter plants, lower height of bottom pods creating harvest difficulties, reduced biomass, less flowering nodes, fewer pods and low yields. [15 16]

Late-sown crops are more likely to suffer from more *Helicoverpa* spp. pressure and less branching and flowering sites, unless the plant population is increased.

4.1.4 Disease risk with early sowing

Sowing times in southern Australia may need to be delayed in some circumstances to reduce the risk of chocolate spot infection. Most faba bean varieties are either susceptible (S) or moderately susceptible (MS) to chocolate spot. Figure 1 shows the effect of time of sowing on yield of a chocolate-spot-susceptible variety, with different disease control strategies.

In the future, varieties with resistance to chocolate spot will enable earlier sowing in most areas. In the interim, wide row spacing (skip row or wider) is being used with early sowing to delay canopy closure to lessen disease risk (see Section 2 Planning and paddock preparation for more information).

Most new faba bean varieties are either resistant or moderately resistant to Ascochyta blight. Sowing times in southern Australia do need to be delayed to specifically reduce the risk of Ascochyta blight infection with these varieties. A 2010 trial at Tarlee in SA's HRZ showed the varieties Fiord and Nura⁽ᵈ⁾ had more Ascochyta blight infection when sown early.[17]

12 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

13 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

14 E Armstrong, L Gaynor, G O'Connor, S Ellis, N Coombes (2015) Faba beans for acidic soils in southern NSW – yields and time of sowing effects. GRDC Update Paper 17 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Faba-beans-for-acidic-soils-in-southern-NSW

15 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

16 M Richards, E Armstrong, L Gaynor, N Graham, N Coombes (2016) Sowing time and variety selection in southern NSW. GRDC Update Paper 16 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Sowing-time-and-variety-selection-for-faba-bean-in-southern-NSW

17 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

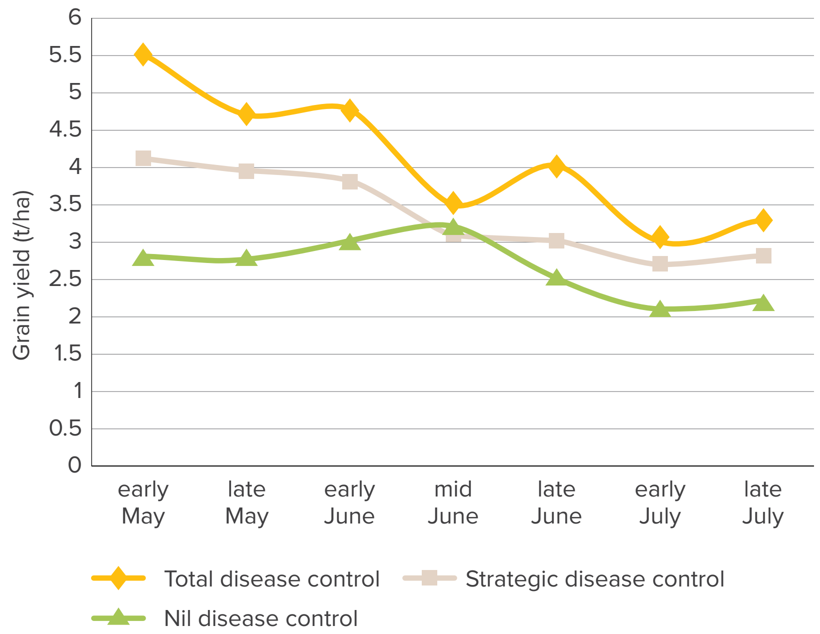

Figure 1: *The interaction between sowing date and fungicidal disease control on grain yield (t/ha) in Struan, south-east South Australia, with a chocolate-spot-susceptible variety (Fiord).*

Note: Early sowing produced highest yields only when disease was well controlled.

Source: Grain Legume Handbook (2008)

4.1.5 Early weed control *v.* early sowing

While timely sowing is important, good early weed control is also crucial because there are limited post-emergence broadleaf herbicide options for faba bean. To allow for sowing as close as possible to the ideal date, plan to manage weeds and prepare the seedbed.[18]

4.1.6 Variety and time of sowing interaction

Some varieties, such as Fiesta VF faba bean and Aquadulce broad bean, respond less to early sowing because they do not set pods early under cool conditions.

In trials at two sites in SA's Mid North in 2015 the early-flowering and early-maturing breeding line AF09167 was most responsive to mid-April sowing in 2015 (Table 3). This was followed by the mid-flowering PBA Rana⦶, which also responded to early sowing. PBA Samira⦶ and the new variety PBA Zahra⦶ yielded similarly over the three sowing times (mid April, early-to-mid May, late May) and generally the same as Nura⦶ and Farah⦶.[19 20]

4.1.7 Low-rainfall-zone time of sowing

In low-rainfall areas, faba bean must be sown early to minimise heat and moisture stress (Tables 1 and 2). Hot winds in spring cause faba bean to wilt, stop flowering and prematurely ripen. Compacted soils that inhibit root penetration will exacerbate this problem.

18 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

19 C Walela, L McMurray, S Day, A Pearce, J Paull, J Brand (2016) Maximising pulse performance in South Australian farming systems. GRDC Update Paper 9 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Maximising-pulse-performance-in-South-Australian-farming-systems

20 C Walela, L McMurray, J Paull (2015) Variety and agronomic performance of faba beans in medium and high rainfall zones in SA. Hart Trial Results 2015. Hart Field Site, http://www.hartfieldsite.org.au/media/2015%20Trial%20Results/2015_Hart_Trial_Results_Variety_and_agronomic_performance_of_faba_beans_in_medium_and_high_rainfall_zones_in_SA.pdf

While faba bean is the least susceptible of the pulse crops to frost, it does not tolerate high temperatures during flowering and podding on shallow soil.[21 22]

4.1.8 Medium-rainfall-zone time of sowing

Generally, early sowing within the preferred sowing window is best for the medium-rainfall zone (Tables 1 and 2).

Trials in 2015 at Hart in the medium-rainfall zone in SA's Mid North compared six varieties with three times of sowing in a below-average season with a very hot, dry and early finish (Table 3). At Hart, plots were sown on 14 April, 6 May and 27 May. Early sowing benefited yields in the less favourable low/medium-rainfall environments where biomass production was lower.

While the results showed that early-sown faba bean often do not provide a yield benefit compared with late-sown faba bean, they generally do not lead to a decrease in yields either. Researchers aimed to understand the performance of beans under these conditions and whether changes in phenology and morphology can improve performance.[23]

They found faba bean plots with mid-April sowing began flowering in mid-winter, while later sowing resulted in flowering during late winter and early spring.[24]

Table 3: Grain yield (t/ha) of faba bean varieties sown at three different times at Hart and Tarlee in 2015, Mid North South Australia.

Variety	Time of sowing (TOS)		
	TOS 1*	TOS 2*	TOS 3*
PBA Zahra⁽ᵖ⁾	1.81	1.85	1.87
AF09167	2.74	1.95	1.62
Farah⁽ᵖ⁾	2.05	1.86	1.75
Nura⁽ᵖ⁾	1.84	1.90	1.70
PBA Rana⁽ᵖ⁾	1.96	1.42	1.39
PBA Samira⁽ᵖ⁾	1.92	1.90	1.89
LSD=0.26			

*Hart TOS1 = 14 April; TOS2 = 6 May; TOS3 = 27 May
*Tarlee TOS1 = 15 April; TOS2 = 17 May; TOS3 = 25 May

Note: Growing-season rainfall was below average (228 mm at Hart and 329 mm at Tarlee). Biomass was higher at the Tarlee site.
Source: Walela *et al*. (2015) and Walela *et al*. (2016)

A trial at Vectis, near Horsham, Victoria, compared breeding lines and varieties with mid-May and late June sowing in 2010 (Figure 2). Mid-May sowing was optimal for all genotypes.

21 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

22 L McMurray, M Lines, A Ware, R Matic, S Nagel (2013) Best bet practices for pulses in the Mallee. GRDC Update paper 15 August 2013, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/08/Best-bet-options-and-practices-for-pulses-in-the-Mallee

23 C Walela, L McMurray, S Day, A Pearce, J Paull, J Brand (2016) Maximising pulse performance in South Australian farming systems. GRDC Update Paper 9 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Maximising-pulse-performance-in-South-Australian-farming-systems

24 C Walela, L McMurray, J Paull (2015) Variety and agronomic performance of faba beans in medium and high rainfall zones in SA. Hart Trial Results 2015. Hart Field Site, http://www.hartfieldsite.org.au/media/2015%20Trial%20Results/2015_Hart_Trial_Results_Variety_and_agronomic_performance_of_faba_beans_in_medium_and_high_rainfall_zones_in_SA.pdf

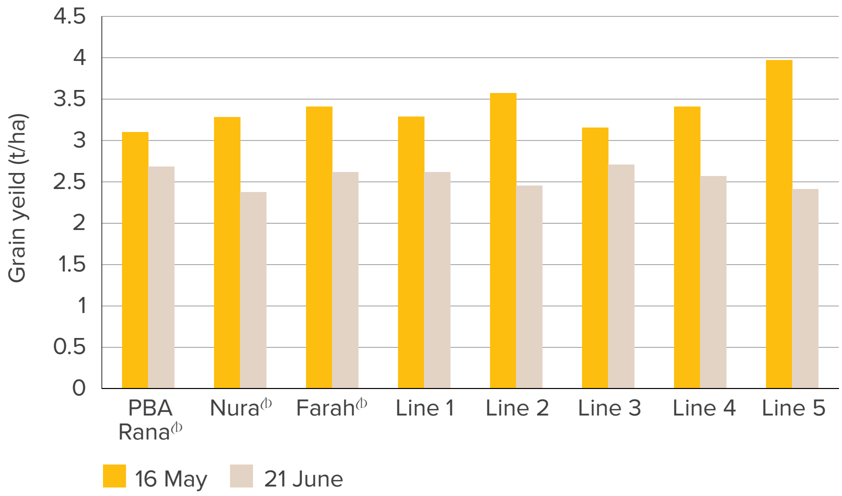

Figure 2: *Yields of different faba bean varieties at two times of sowing at Vectis, Victoria, 2010.*

Source: J Brand, Southern Pulse Agronomy Project

In southern NSW, sowing time is the most critical management factor for growing faba bean. Growers are recommended to sow between 20 April to 15 May in the region, preferably aiming for the first half of this window, especially in western areas. This maximises yield in crops that produce 6–9 t/ha dry matter (DM) with harvest indexes (HI per cent) of 30–35%.

In 2011, faba bean varieties were sown in a trial on 7 May and 10 June at Wagga Wagga, NSW. For each week's delay in sowing, yield was reduced by an average 0.21 t/ha.

Trials at three sites in southern NSW in 2015 found that yields declined by:

- 25% when delaying sowing from 1 May until 18 May at Wagga Wagga;
- 45% when delaying sowing from 16 April until 6 May at Junee Reefs; and
- 26% from 23 April to 13 May at Lockhart.[25]

In contrast, in 2014, a similar trial at Wagga Wagga produced reasonable yields but no significant differences between varieties and sowing times. Researchers suggested that moisture and temperature stress imposed a 'ceiling' to potential yield, as all treatments ran out of moisture.[26]

In 2010, yields were generally highest with the third time of sowing in a faba bean trial at Wagga Wagga, with sowing dates of 6 April, 29 April, 28 May and 16 June (Figure 3) In the high-yielding trial, plots with the first two sowing dates suffered severe lodging, causing major yield losses. Disease was also an issue in early-sown plots.[27]

25 M Richards, E Armstrong, L Gaynor, N Graham, N Coombes (2016) Sowing time and variety selection in southern NSW. GRDC Update Paper 16 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Sowing-time-and-variety-selection-for-faba-bean-in-southern-NSW

26 E Armstrong, L Gaynor, G O'Connor, S Ellis, N Coombes (2015) Faba beans for acidic soils in southern NSW – yields and time of sowing effects. GRDC Update Paper 17 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Faba-beans-for-acidic-soils-in-southern-NSW

27 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

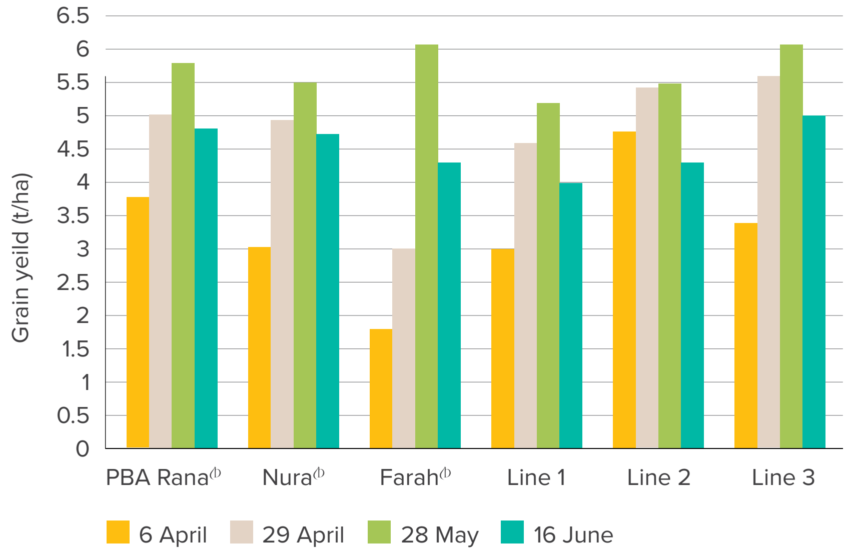

Figure 3: *Yields of different faba bean varieties at four times of sowing at Wagga Wagga, New South Wales, 2010.*

4.1.9 High-rainfall-zone time of sowing

Long-term analysis of faba bean sowing date trials has generally found no yield response to sowing date in higher-rainfall areas. However, between individual years, yield responses to sowing time have been highly variable.

In high-rainfall areas, early sowing can lead to high biomass production and poor harvest index (grain yield to biomass ratio).

Trials and local knowledge indicate that May sowing is best for faba bean in the HRZ of Victoria. This is provided soil moisture is adequate; for example, a mid-May sowing into insufficient moisture roughly halved the yield of Manafest faba bean in a field trial, compared with early August sowing.[28]

However, more recently, research has encouraged HRZ growers to sow faba bean early, between mid-April and early May. Sowing has traditionally been delayed to minimise disease risks and improve weed control. Better adapted varieties, improved disease resistance and weed management tools can now overcome these risks.

For example, a trial sown at Westmere, Victoria, in 2015 yielded 2.6 t/ha when sown in April compared with 1.9 t/ha with May sowing.[29] Of note, 2015 was a below-average season. Other researchers suggest that it may be necessary to delay sowing in certain areas of the HRZ. Frost and cold conditions during flowering, as well as chocolate spot, can be important factors affecting yield in areas with long growing seasons, and may be reduced by later sowing.

A trial in 2015 at Tarlee, SA, found that yield of early-sown (15 April) faba bean did not increase compared with later sowing dates (17 and 25 May), regardless of variety and in a below-average season with a hot, dry finish. The second and third sowing dates produced similar yields (Figure 4).[30] (Of note, yields were affected by pod losses in the early sown plots, due to strong winds in late November.[31])

28 M Slatter (2004) Pulse agronomy trials – Gnarwarre (Landmark). Trial Results 2003. Southern Farming Systems Limited. pp 78–79, http://www.farmtrials.com.au/trial/15604

29 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

30 C Walela, L McMurray, J Paull (2015) Variety and agronomic performance of faba beans in medium and high rainfall zones in SA. Hart Trial Results 2015. Hart Field Site, http://www.hartfieldsite.org.au/media/2015%20Trial%20Results/2015_Hart_Trial_Results_Variety_and_agronomic_performance_of_faba_beans_in_medium_and_high_rainfall_zones_in_SA.pdf

31 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

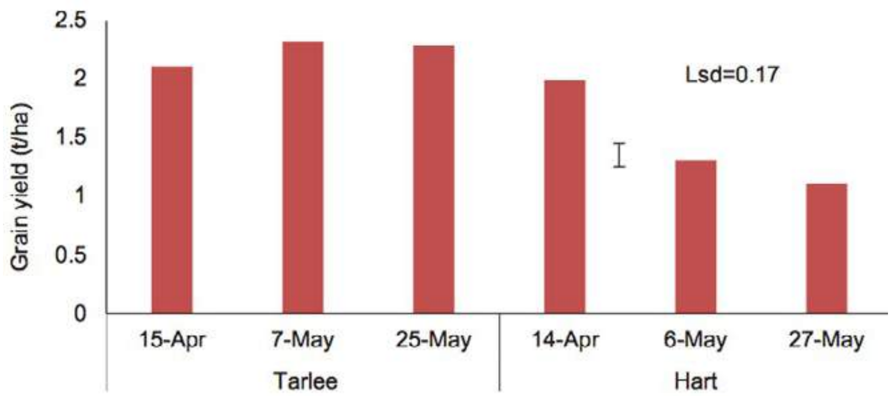

Figure 4: *Grain yield (t/ha) averaged across six faba bean varieties sown at three different sowing dates at Tarlee and Hart, South Australia, 2015.*

Source: Walela *et al.* (2016)

An earlier trial in Tarlee in 2010 found that faba bean yield was highest when sown in late May rather than two weeks earlier (Figure 5). The exceptions were Farah⫚ and Fiord, which showed no difference in yield at either sowing date. Ascochyta levels were higher in Fiord and Nura⫚ when sown too early.[32]

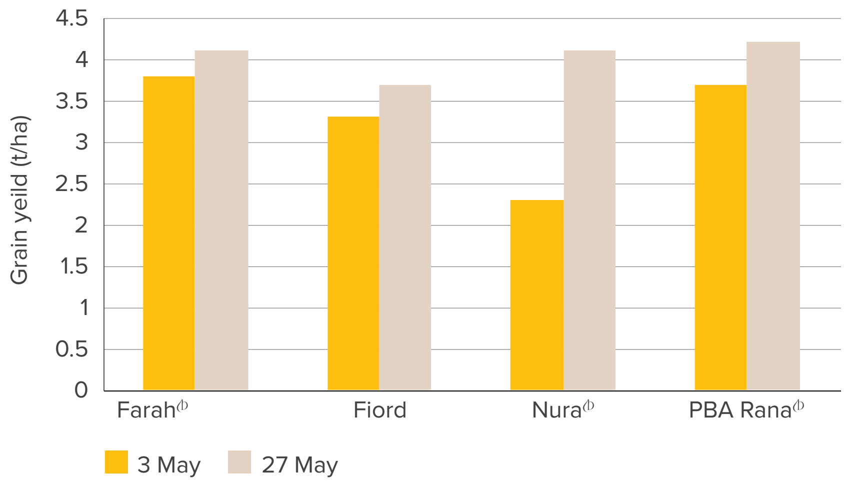

Figure 5: *Sowing in late May provided similar or higher yields for four varieties at a trial in 2010 at Tarlee, Mid North South Australia, compared with early May.*

Note: In the high-rainfall zone, yield results vary between seasons in response to time of sowing.
LSD (p<0.05) = 0.46 t/ha

Source: M Lines and L McMurray, Southern Pulse Agronomy Project

32 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

A trial at Moyhall in south-east SA showed that delaying sowing from mid-May until early June reduced yields by 12–42% in three varieties (Table 4). Early sowing also resulted in increased plant height and height of the lowest pod. However, the plants were more likely to lodge (Table 4). At the Conmurra site, yield was reduced with mid-June sowing in one breeding line, while differences for other varieties were not statistically significant (Table 4).

Table 4: Effect of time of sowing and variety on faba bean yield and lodging at Moyhall and Conmurra in south-east South Australia in 2010.

Variety	Moyhall, SA, 2010				Conmurra, SA, 2010			
	Yield (t/ha)		Lodging score (0–9)		Yield (t/ha)		Lodging score (0–9)	
	14 May	3 June	14 May	3 June	19 May	15 June	19 May	15 June
Breeding line	5.60	4.98*	7.1	8.0*	6.43	5.90*	8.5	9.0
Aquadulce					7.18	6.19	7.7	8.8
Farah^(D)	5.08	4.71ns	4.8	7.3*	6.95	6.51	5.3	8.3
Fiord	5.31	3.06*	8.1	8.7ns				
Nura^(D)	5.58	4.78*	6.7	8.8*	6.64	6.84	4.8	8.3
PBA Kareema^(D)					5.56	5.66	7.8	8.7
LSD interaction (ρ<0.05)	0.53 (comparing different time of sowing (TOS)) or 0.33 (same TOS)		0.7 (different TOS), 0.8 (same TOS)		1.40 (different TOS), 0.55 (same TOS)		0.8 (different TOS), 0.9 (same TOS	

Lodging: 0 = plants horizontal, 9 = vertical (lodged)
* = statistically significant difference for same variety but different times of sowing at a single site, ns = no significant difference
Note: While earlier sowing increased yields in most cases, plants were more likely to lodge.
Source: Lines and Potter (2010)

At Conmurra in 2011, a much drier season, yield was generally maximised with mid-May sowing compared with mid-June in the broad bean varieties. This was not necessarily observed in the faba bean varieties, particularly Nura^(D) (Figure 5).

Because broad bean varieties mature later than faba bean varieties, they may need to be sown earlier than faba bean in some more 'marginal' districts for broad bean. Sowing in traditional, higher-rainfall areas is often delayed until late May or early June.[33]

33 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

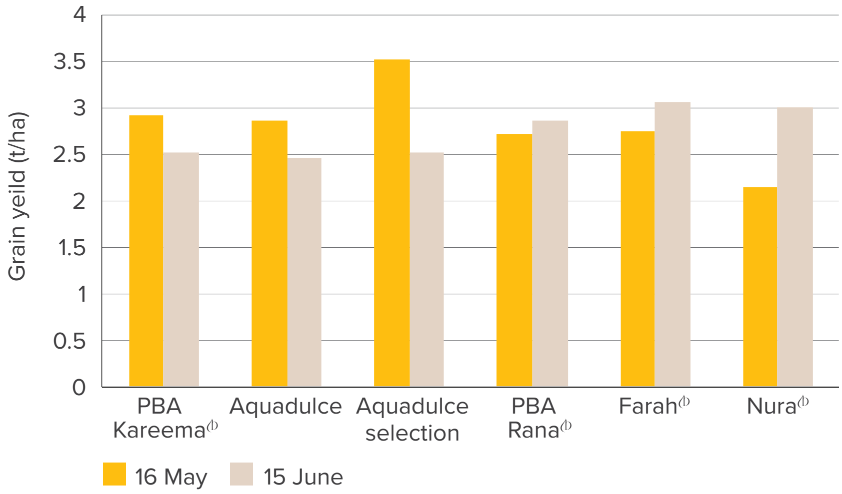

Figure 6: *Yields of different faba bean varieties responded differently to time of sowing at Conmurra, south-east South Australia in 2011, a dry season with several frost events.*

Source: M Lines & L McMurray, Southern Pulse Agronomy Project

In 2012 at Bool Lagoon, in south-east SA, delaying sowing from late May to late June caused a marked reduction in yield in a season with below-average growing-season rainfall and low disease levels. In seasons with favourable finishes, delayed sowing had less impact on faba bean grain yield in the region.

The variety Nura⍉ showed the greatest benefit from early sowing at the Bool Lagoon trial in 2012. Nura⍉ is suited to early sowing due to a combination of short height, mid flowering and improved chocolate spot and rust resistance. These characteristics favour this variety in short seasons with a dry finish, and where late-season humidity-driven diseases such as chocolate spot and rust are common.[34]

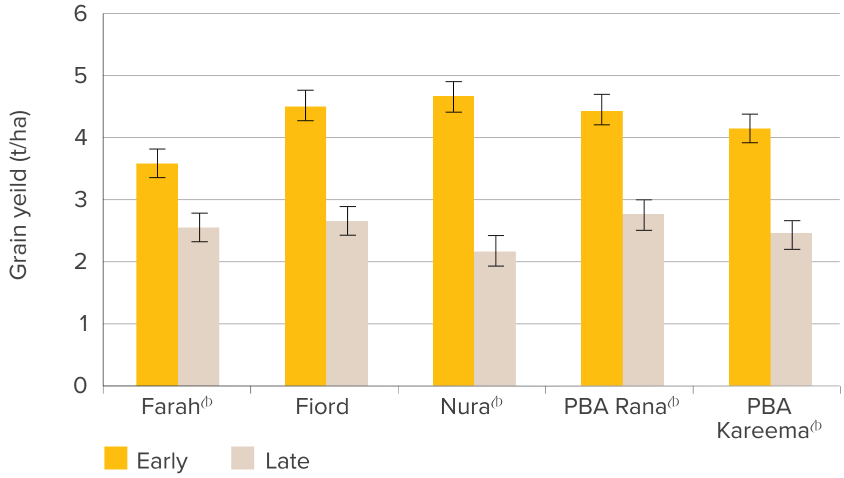

Figure 7: *Delayed sowing from 21 May to 27 June significantly lowered yields in four faba bean and one broad bean variety at Bool Lagoon in south-east South Australia.*

Source: Lines *et al.* (2013)

34 M Lines, L McMurray, J Paull, C Jeisman (2013) Faba bean varieties and management, 2012, Trials Results Book, MacKillop Farm Management Group, www.mackillopgroup.com.au/media/2012TrialBook/faba_beans.pdf

4.1.10 Spring sowing in the high-rainfall zone

Sowing in late winter to early spring (ideally late August), is also an option in the HRZ where there are deep soils.

Although not usually sown in spring, faba bean and broad bean, can be sown in August to September on deep, fertile soils that retain moisture. Yields may be compromised by delayed sowing; low crop height and hot conditions become yield-limiting factors. Other pulses are sometimes sown in August or September to avoid waterlogging and to reduce foliar diseases.[35]

In trial plots in southern Victoria, Manafest faba bean sown as late as 27 September yielded 1.4 t/ha, despite a very dry spring. August sowing also allows the crop to avoid the slow growth period over winter, which can cause disease and weed problems. August sowing allows for better weed control to manage herbicide resistance, as well as splitting the workload at sowing and harvest time.[36] [37]

4.2 Sowing rates and plant density

4.2.1 Recommended sowing rates and plant density

Sowing rate can have a major effect on crop yields. Sowing rates will vary with the size of the seed. Sowing rates for different seed sizes and target plant densities are shown in Table 5.

Be aware of very large differences in seed size between individual faba bean varieties. The size of faba bean can range from 35–160 g per 100 seeds depending on the type, variety and location it is grown.

Plant density requirements for faba bean also vary with time of sowing. Lower plant densities apply to early sowing (April to early May in Victoria) and the higher rates to late sowing (late May to June in Victoria).[38]

In general, faba bean plant populations in southern Australia should target between 20–30 plants/m^2. This equates to a sowing rate of 150–200 kg/ha for Fiesta VF, Farah⁽ᵈ⁾ or Nura⁽ᵈ⁾ with 85% germination, but only 100–160 kg/ha of a smaller variety such as Fiord.

35 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

36 M Slatter (2003) Pulse agronomy trials: Spring sown pulse trial (Gnarwarre). Trial Results 2002. Southern Farming Systems Limited. pp 92, http://www.farmtrials.com.au/trial/15546

37 M Slatter (2004) Pulse agronomy trials – Gnarwarre (Landmark). Trial Results 2003. Southern Farming Systems Limited. pp 78–79, http://www.farmtrials.com.au/trial/15604

38 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

Table 5: Sowing rate (kg/ha) required for targeted plants/m² for a range of faba and broad bean varieties and sizes at 85% germination and 95% establishment (in general, plant density should be between 20–30 plants/m²).

Example variety	Average size range (g/100 seeds)	Seed weight used (g/100 seeds)	Required plants/m²*			
			10	18	25	32
Fiord	35–55	45	56	100	139	178
Farah⌽, Fiesta VF	55–75	65	80	145	201	258
PBA Rana⌽, PBA Samira⌽	80–90	85	105	189	263	337
Aquadulce (small seed)	100–160	100	124	223	310	396
PBA Kareema⌽ (large seed)	100–160	150	186	334	464	594

* = targeted seeds/m²
Source: Pulse Australia (2016)

In most locations and rainfall areas, faba bean has shown yield increases in populations up to 30–35 plants/m².[39] A target population of 30 plants/m² is generally recommended as it generally produces the highest yields in southern Australia.[40]

Trials at Moyhall in south-east South Australia showed a trend of increased yield with higher plant density from 16 plants/m² to 32 plants/m², over two years and averaged across four varieties and two sowing dates (Table 6). Lowest pod height and plant height increased with more dense plants.[41]

In contrast, in a trial at Tarlee in SA's Mid North, increasing target plant density of PBA Samira⌽ beyond 24 plants/m² led to large increases in biomass production at flowering time; increasing target plant density from 24 to 32 plants/m² produced an extra 1 t/ha biomass. Despite this, different densities from 12–32 plants/m² had no effect on final grain yield in 2015 across a range of sowing dates. The hot, dry seasonal finish had a greater effect on faba bean yield than any traditional agronomic management practices.[42] [43]

Table 6: Faba bean yield increased with plant density to 32 plants/m² at Moyhall, south-east South Australia in 2010, using four varieties and two times of sowing.

Plant density (plants/m²)	Grain yield (t/ha)
16	4.43
24	4.87
32	5.36
L.S.D. (p<0.05)	0.20

Source: Lines and Potter (2010)

Lower plant populations tend to be used in the lower-rainfall areas. A low sowing rate also reduces the cost of seed per hectare. It is important for crops to have sufficient

39 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

40 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

41 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

42 L McMurray, M Lines, A Ware, R Matic, S Nagel (2013) Best bet practices for pulses in the Mallee. GRDC Update paper 15 August 2013, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/08/Best-bet-options-and-practices-for-pulses-in-the-Mallee

43 C Walela, L McMurray, J Paull (2015) Variety and agronomic performance of faba beans in medium and high rainfall zones in SA. Hart Trial Results 2015. Hart Field Site, http://www.hartfieldsite.org.au/media/2015%20Trial%20Results/2015_Hart_Trial_Results_Variety_and_agronomic_performance_of_faba_beans_in_medium_and_high_rainfall_zones_in_SA.pdf

plant numbers to compete with weeds. The initial cost of buying seed can be a limitation to growers.

The plant density of broad bean needs to be reduced to as low as 10–15 plants/m^2 as it is grown in areas with long, cool growing seasons or 8–12 plants/m^2 in high-rainfall areas (sowing rate about 200 kg/ha).[44] Higher rates are not necessarily cost effective or practical. The recommended plant densities will reduce the seed cost per hectare, reduce the density of the crop and help reduce the risk of foliar disease in broad bean.[45]

Use the same size seed for sowing broad bean as the intended harvested seed size; for example use 65–70 grade seed for sowing if that is the size seed being marketed.

In other literature, the recommended plant density for faba bean in Victoria is:

- 20–30 plants/m^2 for the small-seed types, such as the old varieties Fiord and Ascot VF;
- 18–23 plants/m^2 for medium-seed varieties, for example, Farah⁽ᵖ⁾ and Fiesta VF; and
- 15 plants/m^2 for large-seeded broad bean (this is equivalent to 7 seeds/m, at a row spacing of 18 cm).[46 47]

For SA, recommendations for plant density in the high and medium-rainfall zone are:

- 24 plants/m^2 for faba bean; and
- 12 plants/m^2 for broad bean.[48 49]

For small and medium-sized varieties such as Fiord, Fiesta VF and Farah⁽ᵖ⁾, growers commonly target more than 20 plants/m^2 in the medium to high-rainfall areas of southern Australia.

In the low to medium-rainfall areas, 15–20 plants/m^2 is often used to reduce the impact of moisture stress associated with the first hot winds of the season. A 2015 sowing rate trial in the Victorian Mallee found that 20 plants/m^2 was the optimum plant density.[50]

Avoid using use small (graded) seed to increase plant populations or reduce seed costs. Small seed has poorer vigour and yields. Continued use of small seed fractions after grading will genetically select for smaller-seeded line plant types.[51] This is particularly relevant for broad bean growers who may consider marketing the larger sized seed portion and retain the smaller-sized leftovers ('screenings') for seed.

4.2.2 Calculating sowing rate

Calculate the sowing rate based on a desired plant population, rather than kilograms of seed per hectare. Adjust the sowing rate to achieve a target plant population based on seed size and germination percentage. Be aware of the significant difference in seed size between individual varieties and the impact that variable seasons can have on grain size of even the same variety.

44 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

45 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

46 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

47 A Pearce, A Ware, R Kimber, J Paull (2015) Faba bean variety sowing guide 2015. Sowing Guide 2015. South Australian Research and Development Institute. pp 56–58, www.pir.sa.gov.au/__data/assets/pdf_file/0006/237903/faba_beans.pdf

48 C Walela, L McMurray, J Paull (2015) Variety and agronomic performance of faba beans in medium and high rainfall zones in SA. Hart Trial Results 2015. Hart Field Site, http://www.hartfieldsite.org.au/media/2015%20Trial%20Results/2015_Hart_Trial_Results_Variety_and_agronomic_performance_of_faba_beans_in_medium_and_high_rainfall_zones_in_SA.pdf

49 M Lines, L McMurray, J Paull, C Jeisman (2013) Faba bean varieties and management, 2012, Trials Results Book, MacKillop Farm Management Group, www.mackillopgroup.com.au/media/2012TrialBook/faba_beans.pdf

50 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

51 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Before deciding on a sowing rate take a representative sample, have it sized and then germination and vigour tested.

Sowing rate for the target plant density can be calculated using germination percentage, 100 seed weight and establishment percentage. Optimum plant populations vary with the location grown, the variety sown and the variety being sown.[52]

Sowing rate calculation

Sowing rate can be calculated by these steps:

1. Decide desired number of plants/m^2.
2. Weigh 100 seeds (in grams)# of a representative sample.
3. Obtain germination percentage from a seed test using a representative sample.
4. Estimate establishment likely during emergence (which will depend on conditions)*. Note: establishment percentage of 90–95% is a reasonable estimate, unless sowing into adverse conditions.
5. Sowing rate (kg/ha)

$$= \frac{\text{100 seed weight (grams)}^{\#} \times \text{target plant population (per m}^2) \times 1000}{\text{germination \%} \times \text{estimated establishment \%}}$$

For example:

100 seed weight = 60 grams

Target plant density = 25 plants/m^2 (i.e. 250,000 plants/ha)

Germination % = 90%

Estimated establishment %* = 95%

$$\text{Sowing rate (kg/ha)} = \frac{60 \times 25 \times 1000}{90 \times 95} = 175 \text{ kg/ha}$$

If using seeds per kilogram from a laboratory test, this can be easily converted to 100 seed weight, as follows:

$$\text{100 seed weight} = \frac{1000 \times 100}{\text{seeds per kg}}$$

4.2.3 Plant density x time of sowing interaction

Higher plant density with early-sown crops can encourage pods to develop higher up the plant. When the variety Fiord was sown at six plant densities from 20–56 plants/m^2 researchers found that early-sown plants at high density had fewer pods per node at the lower nodes. They also had more pods at the higher nodes than plants at low density.[53] However, using a high sowing rate with early sowing can lead to dense, vigorous crops early in the season that shade the flowers, reducing pod-set and leading to more foliar disease.[54]

Sowing date by plant density trials at HRZ sites in SA have shown that later-maturing crops with a large biomass generally show the highest yield losses from delayed sowing.[55]

52 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

53 T Adisarwanto, R Knight (1994) Effects of sowing date and plant density on yield and yield components in the faba bean. Australian Journal of Agricultural Research 48. pp 1161–1168, www.researchgate.net/publication/248896911_Effect_of_sowing_date_and_plant_density_on_yield_and_yield_components_in_the_faba_bean

54 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

55 M Lines, L McMurray, J Paull, C Jeisman (2013) Faba bean varieties and management, 2012, Trials Results Book, MacKillop Farm Management Group, www.mackillopgroup.com.au/media/2012TrialBook/faba_beans.pdf

Under conditions of very early sowing the optimum sowing rate for small-seeded faba bean can be 20 plants/m² in southern Australia, rather than the usual 30–35 plants/m².[56] Conversely, late sowing in the HRZ may require higher sowing rates (32–25 plants/m²), as shown in a Southern Farming Systems trial (Table 7) and trials at Bool Lagoon (Figure 8 and Figure 9).[57]

Table 7: Interaction between time of sowing and plant density on yield (t/ha) of early-to-mid-maturity faba bean varieties Farah⁽ᵈ⁾ and Nura⁽ᵈ⁾ in Victoria's high-rainfall zone. While later sowing reduced yields on average, a high plant density was important to offset yield loss.

Plant density Time of sowing	15 plants/m²	25 plants/m²	35 plants/m²
1 June	1.70	1.99	2.17
4 July	1.25	1.15	1.94

Least significant difference (L.S.D.) for interaction ($p<0.05$) = 0.36
Source: Brand *et al.* (2006)

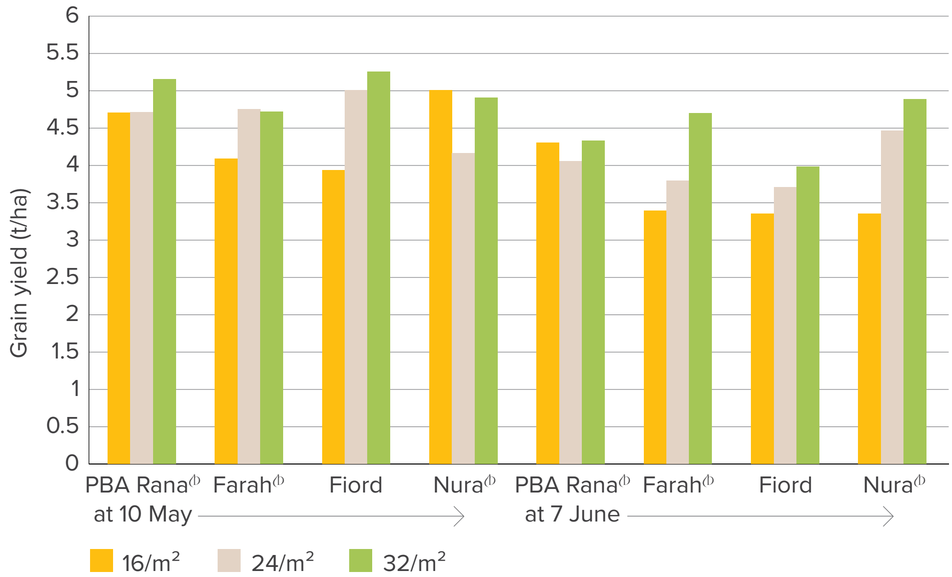

Figure 8: *With the exception of PBA Rana⁽ᵈ⁾, later-sown faba bean were more responsive to plant density and a greater need for higher plant populations to maximise yields at Bool Lagoon, South Australia, in 2011 in a Southern Pulse Agronomy Project trial.*

Source: Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4.

56 GRDC (2008) Seeding. Grain Legume Handbook. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook

57 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia

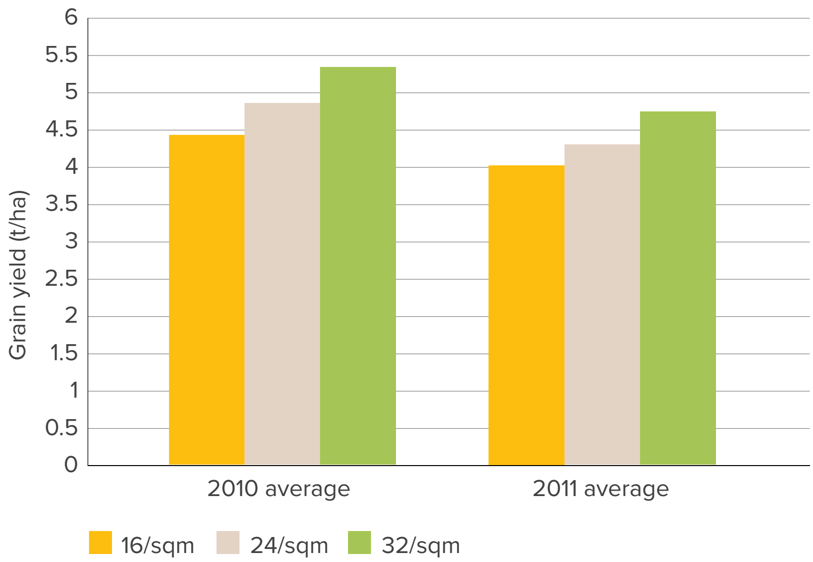

Figure 9: *The effect of plant density on average grain yield (t/ha) across four faba bean genotypes and two seeding dates Bool Lagoon, South Australia, in 2010 and 2011.*

Source: M. Lines, Southern Pulse Agronomy Project

4.2.4 Plant density x row spacing interaction

Sowing rate trials in 2015, which included the modern varieties PBA Zahra⁽ᶦ⁾ and PBA Samira⁽ᶦ⁾, support the traditional recommendation of 20 plants/m^2 when sowing in narrow rows. However, when using wider rows, yields were not reduced with 15 plants/m^2. A lower density of 10 plants/m^2 caused yields to fall by 20%.[58]

4.2.5 Plant density x disease interaction

Lower plant density can significantly reduce foliar disease levels by reducing the crop density, particularly in areas with long, cool growing seasons.[59]

In a trial in the HRZ at Tarlee in SA's Mid North in 2010, chocolate spot and Ascochyta infection increased with plant density.

Increasing plant density increased Ascochyta blight infection, likely resulting from increased canopy humidity. Chocolate spot infection averaged across all varieties was:

- 22% of plot infected at 16 plants/m^2;
- 29% at 24 plants/m^2; and
- 34% at 32 plants/m^2.

In spite of the additional disease burden, the highest sowing density produced the highest yield in this trial.[60]

4.2.6 Plant density effect on ease of harvest

Faba bean crops with low plant density may have pods close to ground level (Table 8), which can make harvest more difficult.

58 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

59 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

60 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

Increasing plant density from a low level can also increase plant height (Table 8). If plants become very tall, they are more prone to lodging. At Tarlee, SA, lodging was worse for early-sown faba bean sown at a higher plant density, particularly at wider row spacing in PBA Rana⁽ᶲ⁾ and Farah⁽ᶲ⁾ due to their bulkier canopies.

Table 8: Height of lowest pods and plant height increased with plant density from 16 to 24 plants/m^2 and was unaffected by higher plant density.

Plant density (plants/m^2)	Height of lowest pods (cm)	Plant height (cm)
16	27.3	107
24	34.4	111
32	34.4	112
L.S.D. ($p<0.05$)	2.8	4

Data from a trial at Moyhall, South Australia, Southern Pulse Agronomy project.
Source: Lines and Potter (2010)

4.3 Row spacing

4.3.1 Range of row spacing

Due to faba bean's indeterminate growth pattern, the crop is relatively adaptable to a range of row spacings and sowing rates.

Trials have mostly shown only small differences in yields with row spacings from 20–38 cm. Row spacing in faba bean crops commonly ranges from 15–25 cm, and up to 55 cm in broad bean. However, wider rows with stubble retention are becoming increasingly popular. Yield responses to row spacing in trials are inconsistent and vary with the system and location.

For faba bean, using wider row spacing (25–60 cm) may assist with control of the disease chocolate spot, by delaying canopy closure and reducing humidity between rows.

Some growers are now using row spacing of 75–100 cm, or using paired rows, to improve pod-set and delay canopy closure, with the intention of minimising disease. Wide rows may also lead to crop lodging; however, it can exacerbate disease. On the other hand, wide rows do allow herbicides to be sprayed between rows with hooded shields or targeted row spraying with fungicides to reduce the amount of chemical applied.[61] Retention of standing stubble is important with wide rows[62] (see Section 2 Planning and paddock preparation for more information).

4.3.2 Calibration of seeder with wide rows

Be aware of changes needed for sowing rate calibrations; for example, if row spacing is doubled, the sowing rate per row must also be doubled to maintain plant density.

The same considerations apply for fertiliser rates, but sowing into wider rows may require deep placement or side banding of the fertiliser; the risk of toxicity to the seed increases when fertiliser is more concentrated in the sowing furrow.

4.3.3 Time of sowing x row spacing

A trial at Tarlee in the HRZ in SA in 2009 and 2011 found that yields were highest with early time of sowing and narrow row spacings (Table 9).

With early sowing, the taller varieties Farah⁽ᶲ⁾ and PBA Rana⁽ᶲ⁾ yielded 13–15% more, on average, while Fiord and Nura⁽ᶲ⁾ yielded 3–5% more, with 22.5 cm rows compared with 45 cm rows.

61 Pulse Australia (2016) Faba bean: Integrated disease management. Australian Pulse Bulletin. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/idm-strategies

62 J Brand, L McMurray, C Walele, M Beveridge, M Rodda, J Paull (2016) Agronomy best practices with pulses – Victoria. GRDC Update Paper 23 February 2016.

Table 9: Row spacing had a bigger effect on faba bean yield than time of sowing at Tarlee in South Australia's high-rainfall zone, 2011.

Time of sowing (TOS)	22.5 cm	45 cm
Sown 29 April	5.55a	4.31 c
Sown 26 May	5.21 b	4.27 c
L.S.D. (p<0.05) =	0.24 TOS x row; 0.21 same row space	

Note: Narrow row spacing often maximises yields at high-yielding sites.
Source: Southern Pulse Agronomy project

4.4 Inoculation

4.4.1 Rhizobia and nitrogen fixation

Symbiotic nitrogen (N) fixation is the result of the mutually beneficial relationship between the pulse host and *Rhizobium* bacteria. These bacteria colonise legume roots soon after seed germination then form root nodules. Rhizobia live in the soil, on plant roots and in legume nodules, but only fix nitrogen when inside a legume nodule. Rhizobia in the nodules are dependent on the host plant for water, nutrients and energy, but in return supply the plant with available nitrogen for growth. This 'fixed' nitrogen is derived from the gaseous nitrogen in the air.

Nitrogen fixation by legumes does not happen as a matter of course. Compatible, effective rhizobia must be present in the soil in which the legume is growing before nodulation and nitrogen fixation can occur. When a legume is grown for the first time in a paddock, it is highly likely that compatible, effective rhizobia will not be present. In such circumstances, the rhizobia must be supplied in highly concentrated form as inoculants.

A well-nodulated and productive crop of faba bean or broad bean will fix up to 200 kg of N/ha. After grain harvest, more than 150 kg fixed N can remain in the stubble and roots which, when mineralised, becomes available to following crops: "on average, concentrations of soil mineral N after legumes [including bean] can be expected to be 25–35 kg N/ha higher than following cereals".[63]

4.4.2 Inoculants for faba bean

Faba bean, in common with lentil, field pea and vetch, are nodulated by *Rhizobium leguminosarum* bv. *viciae*. This species of rhizobia is produced and sold commercially as inoculant Groups E and F (Table 10).

Table 10: Inoculation Group E and Group F.

Field pea and vetch	Strain: SU303 (Group E)
Pisum sativum, *Vicia* species	*Rhizobium leguminosarum* bv. *viciae*
Faba bean, broad bean and lentil	Strain: WSM 1455 (Group F)
Vicia faba, *Lens culinaris*	*Rhizobium leguminosarum* bv. *viciae*

Source: D. Drew *et al.* (2012) Inoculating legumes: A practical guide

63 M Peoples *et al* (2015) Legume effects on soil N dynamics – comparisons of crop response to legume and fertiliser N. GRDC Update Paper 2015, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/legume-effects-on-soil-n-dynamics-comparisons-of-crop-response-to-legume-and-fertiliser-n

Group F (strain WSM1455) inoculant is recommended for faba bean. Faba bean can also be nodulated by strain SU303 (e.g. from a background population of rhizobia in a soil where field pea or vetch have been grown) but inoculation with this strain is not recommended.

Faba bean are not nodulated by the rhizobia that nodulate chickpea (Group N), lupin (Group G) or pasture legumes.

4.4.3 Inoculation in practice

Bean will be responsive to inoculation if they (or lentil, field pea and vetch) has not previously been grown in the paddock. Faba bean are also likely to be responsive to inoculation on acidic soils, because the rhizobia of these legumes are moderately sensitive to soil acidity. Faba bean rhizobia may be absent or their number may be suboptimal where soil pH ($CaCl_2$) is less than 6.0, even where there has been recent history of legumes that support bean rhizobia. See Table 11 for likelihood of response to inoculation.

Recent research in southern Australia has found a very strong negative correlation between soil pH in the top 10 cm of soil and faba bean nodulation.[64]

Table 11: Likelihood of response to inoculation for bean.

Likelihood of response to inoculation for sown pea, faba bean, lentil and vetch	
High	Soils with ph (CaCl₂) below 6.0 and high summer soil temperatures (>35°C for 40 days); or Legume host (pea, faba bean, lentil, vetch) in host not previously grown.
Moderate	No legume host (pea, faba bean, lentil, vetch) in previous 4 years (recommended pulse rotation); or Prior host crop not inoculated or lacked good nodulation.
Low	Loam or clay solis with neutral or alkaine pH and a recent history of host crop with good nodulation.

Source: D. Drew *et al.* (2012) Inoculating legumes: A practical guide

Inoculation of faba bean is generally not necessary where well-nodulated faba bean (or lentil, field pea or vetch) has been grown in the preceding 5 years and soil conditions are favourable to the survival of the rhizobia. Loam or clay soils with neutral or alkaline pH are favourable to the survival of bean rhizobia.

If paddock conditions and legume history indicate a likelihood of a response to inoculation (Table 11) then the following guidelines should be followed:

- Inoculate with inoculants approved by the Australian Inoculants Research Group (AIRG) ('Green Tick' logo). AIRG is part of the NSW Department of Primary Industries.
- Use Group F inoculant for faba bean.
- Do not expose inoculants to direct sunlight, high temperatures (>30°C), chemicals or freezing temperatures (they contain *live* bacteria).
- Always use inoculants before their expiry date has passed.
- Keep inoculants dry and cool. Reseal opened bags of inoculant and refrigerate; use resealed bags within a short time (days).
- Follow instructions on recommended rates of inoculation.
- Consider doubling the inoculation rate in very acidic soils or where faba bean, lentil, vetch, or field pea have not been grown previously. Start with a small batch of seed to establish that it can be satisfactorily dried in order to avoid auger and seeder blockages.
- Always sow freshly inoculated seed as soon as possible, within 24 hours.

64 H Burns, M Norton (2017) Topsoil pH stratification impacts on pulse production in South East Australia. GRDC Update Paper 2017, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/topsoil-ph-stratification-impacts-on-pulse-production-in-south-east-australia

MORE INFORMATION

More information: Section 3.4 Variety performance and yield

VIDEO

GroundCover™ TV: Legumes – Sowing Preparation
https://youtu.be/kcGu2CKwMS8

- When applying liquid or slurry inoculants, use clean, potable *non-chlorinated* water and ensure the mixing tanks are free of toxic chemical residues.
- Do not mix zinc or sodium molybdate with liquid or slurry inoculants.
- Check the product label or contact the manufacturer for compatibility of inoculants with fertilisers and seed dressings.
- Ensure inoculants remain cool in transport and do not leave inoculants or inoculated seed in the sun.

4.4.4 Types of inoculant

A range of different inoculant formulations are available to Australian legume growers (Table 12). Inoculant for faba bean can be obtained as peat, freeze-dried or granular formulations.

Table 12: Inoculant formulations available to Australian growers of faba bean.

Inoculant formulation	Composition
Peat	High organic matter soil, milled and irradiated, with rhizobia added in a nutrient suspension
Freeze-dried	Concentrated pure cells of rhizobia following extraction of water under vacuum
Granular	Clay or peat granules impregnated with rhizobia

Source: D. Drew *et al.* (2012) Inoculating legumes: A practical guide

The different formulations vary in the number of rhizobia they contain and so it is important that recommended application rates are followed.

Peat is the most commonly used formulation and provides reliable nodulation across a range of sowing conditions. Peat inoculants also provide some protection to the rhizobia where they are applied to seed treated with pesticides.

Freeze-dried inoculants should only be used where legumes are sown into moist soils. They provide a good option where liquid injection systems are used to deliver inoculant in furrow.

Granular inoculants can be used where separation between the rhizobia and pesticides or fertilisers is needed.

4.4.5 Storing inoculants

For maximum survival, peat and freeze-dried inoculants should be stored in a refrigerator until used. Both types of inoculant can be kept for many months if stored correctly (4°C–10°C), but pay attention to the date of expiry and do not freeze inoculant. If refrigeration is not possible, store in a cool, dry place away from direct sunlight. Granules also need to be stored in a cool place out of direct sunlight. Opened peat inoculum packets are best discarded, but if resealed and kept cool can be used within a few days.

Discard the inoculant after the expiry date shown because the population of rhizobia may have dropped to an unacceptable level.

4.4.6 Inoculation methods

Inoculation with rhizobia is a numbers game: aim is to get as many rhizobia as possible onto the seed or near the seed to maximise the potential for nodulation. There will always be a loss of rhizobia, but by using appropriate methods these losses can be minimised to obtain prompt and abundant nodulation. It is advisable to use high-quality inoculants, such as AIRG-approved (Green Tick) products.

Beans have historically been inoculated with a slurry of peat inoculant onto the seed. Rhizobia can now also be purchased in a freeze-dried form suitable for application to seed or water injection into the soil, or granules that are sown at same time as the seed from a separate box.

Peat inoculants

Most peat inoculants for bean now contain a pre-mixed sticker, and only require the addition of water to make the slurry. When preparing the slurry **do not** use hot or chlorinated or saline water.

How to apply slurry to the seed through an auger:

- Make sure the auger is turning as slowly as possible, to achieve effective mixing. Reduce the height of the auger to minimise the height of seed fall.
- Meter the peat slurry in, according to the flow rate of the auger (remember 1250 g packet per 500 kg of seed).

How to apply slurry to the seed through a tubulator:

- Similar to applying through an auger, except that the tubulator reduces the risk of damaging the seed. Its mixing ability is not as effective as an auger.

Peat inoculant can also be injected as dilute filtered slurry directly into the sowing furrow, with or below the seed.[65] Agitators and in-line filters may be necessary to avoid blockages to nozzles and capillary tubes. Typically, the peat inoculant is applied in a water volume of 50–100L/ha.

Dry-dusting the peat inoculant into the seed box is **not recommended**. This is not an effective means of getting good contact between rhizobia and seed. Attachment of the rhizobia to the seed can be very poor, and under some conditions rhizobial death is so rapid that no inoculant is alive by the time the seed reaches the soil.

Freeze-dried inoculants

Freeze-dried inoculants can be applied to seed or delivered as a liquid into the furrow. Freeze-dried inoculants are not suitable for application to dry soils.

The rhizobia become active when the inoculant is reconstituted with liquid. The product comes with a protective polymer in a separate packet, which assists survival of the rhizobia. A standard vial of inoculant will treat up to 500 kg of faba bean seed.

Treated seeds need to be sown into moist soil within five hours of application. Contact with seed-applied pesticides and fungicides must be avoided.

For liquid injection into the seeding furrow, add the inoculant suspension to 2 L of cool water containing the protective polymer. Add this solution to the clean spray tank and deliver at 50–100 L/ha into the furrow.

Granular inoculants

Granular inoculants are applied as a solid product directly into the seed furrow, near the seed or below the seed. They avoid many of the compatibility problems that rhizobia have with fertilisers and fungicides. They also eliminate the need to inoculate seed before sowing. Granular inoculants are reported to be effective where dry sowing is practiced.

If granules are mixed with the seed, rather than applied separately, then distribution of both seed and inoculum may be uneven, causing either poor and uneven establishment and/or patchy nodulation. Granules should not be stored in seeding boxes overnight.

Granules contain fewer rhizobia per gram than peat-based inoculants, so they must be applied at higher application rates. The size, form, uniformity, moisture content and rate of application of granules differ among products. Depending on product or row spacing sown, rates can vary from 2–10 kg/ha to deliver adequate levels of rhizobia.

65 J Brockwell, RR Gault and RJ Roughley (1982) Fact sheet: Spray inoculating grain legumes, www.ua.edu.au/legume-inoculation

4.5 Inoculant compatibility with pesticides

The survival of rhizobia may be compromised when mixed with pesticides, fertilisers or other amendments. Guidelines are provided by inoculant manufacturers on the compatibility of their specific products with commonly used pesticides and fertilisers. Pesticide labels may show compatibility of their seed dressing with inoculants on seed. For example, Gaucho® 600 Red Flowable Seed Treatment Insecticide (imidacloprid) label states that "Gaucho does not affect the viability of rhizobia when Gaucho® is mixed with inoculant". The guidelines should be strictly followed.

More generally, consideration of the following principles will help reduce the likelihood of killing inoculant rhizobia:

- Direct mixing of rhizobia with amendments in tank mixes or during preparation of the peat slurry is most likely to kill rhizobia.
- Most rhizobia are sensitive to pH below 5 or above 8. Avoid mixing rhizobia with very acidic or alkaline products. Fertilisers and trace elements are often outside this pH range. Material safety data sheets usually contain information on pH of the products.
- Metals such as zinc, mercury, copper and manganese are likely to be harmful. Sodium molybdate is toxic to rhizobia.
- When applying fungicides and insecticides to seed, minimise the time the rhizobia are exposed to the pesticide by applying the rhizobia last to the dried seed and sow as soon as possible. Where possible, sow with 6 hours of rhizobia application.
- Peat inoculant formulations may assist the survival of the rhizobia that come into contact with toxic chemicals.

MORE INFORMATION

GroundCover™ TV: Legume Nodulation – field sampling
https://youtu.be/bfnBsEM64t0

GRDC (2014) *Inoculating legumes: a practical guide*, https://grdc.com.au/Resources/Bookshop/2015/07/Inoculating-Legumes

4.6 Check for nodulation

It is important to determine how effective inoculant application has been and if the nodules are actively fixing nitrogen. By checking the number of nodules and their distribution on the roots, you can assess the effectiveness of the inoculum product used and the application method.

If you have not inoculated, it can still be helpful to assess nodulation of your faba bean crop, to assess whether inoculation may be needed in the future.

For bean, 50–100 pink nodules per plant after approximately eight weeks' plant growth is an adequate level of nodulation (Photo 1). A strong pink colour inside the nodule indicates the rhizobia are actively fixing nitrogen for use by the plant (Figure 9).

4.6.1 Sampling and processing

At least 30 plants should be sampled, 10 at each of three locations, spaced 40 m apart in the crop. Plants should be gently dug from the soil and the root system carefully rinsed in several changes of water before estimating nodule number. It is helpful to float the root systems in water on a white background (a cut down, clean chemical drum is easy to use).

4.6.2 Nodule number and distribution

Score each plant for nodulation. At least 50 pink nodules per plant is considered adequate (Photo 1). Separate plants into adequate and inadequate groups. If the adequate group contains more than 70% of the plants then inoculation has been successful.

Photo 1: *Well-nodulated roots of broad bean.*

Photo: Maarten Ryder, University of Adelaide

Observe the pattern of nodules on the root system. Following inoculation, nodules on the main taproot clustered near the seed are a clear indication that nodulation occurred early. These are referred to as 'crown nodules'. If there are no crown nodules, but nodules on the lateral roots, then it is more likely nodulation has been delayed, indicating that there may have been issues with the inoculation process.

Nodules on both the crown and lateral roots indicate that inoculation was successful, and that bacteria have spread in the soil. This is the ideal situation, with the crown nodules providing good levels of nitrogen fixation early in the plant's growth, supported by the lateral root nodules, which may extend nitrogen fixation activity later into the season because they are less affected by drying of the surface soil.

4.6.3 Nodule appearance

If necessary, cut or break open a few root nodules to check the colour: nodules that are actively fixing nitrogen are pink inside (Photo 2). Very young nodules (after a few weeks of plant growth) are usually white because they still need to develop. However, in older plants an abundance of white nodules may indicate the rhizobia in the soil that formed the nodules were poorly effective and they will not fix nitrogen. This is rare for faba bean, but indicates that the crop should be inoculated next time it is grown. White nodules can also result from trace element deficiencies such as molybdenum.

Photo 2: *Bean nodules with pink interior indicating active nitrogen fixation.*

Photo: Maarten Ryder

Sometimes nodules may appear green or grey inside. At the 8-week growth stage, this would likely indicate herbicide damage or that plant has suffered water stress or waterlogging. These nodules are unlikely to recover nitrogen-fixation activity. However, later in the season, as plants approach flowering, the development of green pigmentation in the nodules occurs as a normal part of nodule maturation. Faba bean nodules are indeterminate. This means they continue to grow and form lobed structures with distinctly different zones visible inside the nodule. With maturity, the section of nodule closest the plant root loses its pink colouration, turning grey or green. As long as the section of the nodule furthest from the root retains some pink tissue, the nodule remains actively fixing nitrogen.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

If you have spent time and resources on inoculation, it is worthwhile to carry out this nodulation check to determine whether your inoculation has been successful and is likely to provide nitrogen benefits. It may also indicate whether troubleshooting is required, or whether inoculation is needed in future.

4.7 Seed treatments

Seed treatment is very effective against seed rot, but it is not commonly used in faba bean and broad bean. If the seed is treated, it should be planted immediately after inoculation, as seed treatments can be toxic to the inoculant. The longer the inoculant is in contact with the seed treatment, the less effective it will be.

4.8 Sowing depth

4.8.1 Recommended sowing depth

The general recommended sowing depth for faba bean is 5–8 cm. Faba bean is relatively tolerant of deep sowing due to its hypogeal emergence.

Sowing seed outside this range will delay emergence and slow seedling growth. Sowing deeper than the recommended 8 cm can lead to poor establishment and lower seedling vigour.

Sowing depth needs to be varied between paddocks to take into account a range of factors including soil type, herbicides used, diseases likely to be present and the soil temperatures at sowing time, which affect how long the crop will take to emerge.

Fast emergence is needed on hard-setting soils, so that the seedling can germinate before the soil surface seals again after the sowing cultivation.

Sowing depth can also be adjusted if there is a risk of bird problems, such as cockatoos and skylarks, or when mouse numbers are high.[66 67]

4.8.2 Deep sowing

Deep sowing is sometimes used when the surface soil is dry. Burying seed too deep to 'chase' seedbed moisture for early sowing is not necessarily recommended, as this may affect weed control, establishment and possibly nodulation. However, it may sometimes be useful to ensure timely sowing. If there is a policy of 'sow deep, but cover shallow' to chase seedbed moisture at sowing, a deep seeding furrow will be left. This opens the possibility of damage from post-sowing herbicide applications that can wash into the seed furrow after rain.

Deeper sowing may be needed in some districts or seasons to reduce damage caused by birds and mice.

As a general rule, warm, sandy soils tend to suit deeper sowing while heavy, clay and/or hard-setting soils with low temperature will generally require more shallow sowing.

Deep sowing also allows more time in which to apply a knockdown herbicide prior to crop emergence.

4.8.3 Preventing crop damage from herbicides by sowing depth

Shallow sowing can make pulses less tolerant of some herbicides. Where a pre-emergent herbicide has been used, aim for deeper sowing. Lighter-textured soils can be more prone to herbicide leaching in wet winters, therefore deeper sowing in sandier soils is often recommended if applying a pre-emergent herbicide. Faba bean

66 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

67 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

and broad bean are less affected by simazine applied pre-sowing or post-sowing pre-emergence when sown deeper.

Some herbicides leach more than others (see Section 7 Weed Control for more information). This can be exacerbated by heavy rain on a dry soil surface, particularly sand. Leaving the soil ridged increases the risk of post-sowing pre-emergent herbicide washing into the furrow, especially on sand.

4.9 Sowing equipment

The large size of faba bean seed can make sowing with conventional seeders challenging.

The sowing mechanism of the seeder must be able to handle large seeds. Hoses, distributor heads and boots must also be able to handle faba bean and broad bean without blockages or bridging. Bridging in the seed box must also be avoided when sowing inoculated seed, therefore an agitator may be required.

Growers have reported that blockages are lessened by sowing faba bean more slowly than cereals (about 12 km/h slower).[68]

Faba bean can be sown with aggressive discs or narrow points in no-till or full soil disturbance in more conventional or direct-drill systems.[69]

4.9.1 Modifying seeders

If the seeder is not suitable, it may be adapted by:

- modifying the metering mechanism using manufacturer supplied optional parts;
- modifying seed tubes to reduce blockages, particularly on older machines; or
- modifying or replacing dividing heads on air seeders.

Faba bean and broad bean can be sown with a standard air seeder or conventional combine but take care as seeds tend to bridge over the outlets, causing very uneven sowing. This can be overcome by filling the box to only one-third or half capacity, or by fitting an agitator.

Faba bean can also cause problems in some combines but air seeders with adequate metering rollers can sow them successfully as long as the airflow is adequate.

4.9.2 Air seeders

Excessive air pressure in air seeders can cause significant seed damage; use only enough air to ensure reliable operation.

Air seeders using metering belt systems (such as Fusion, Alfarm, Chamberlain John Deere and New Holland) can meter large seed at high rates with few problems.

Air seeders that use peg roller metering systems (such as Napier and Shearer) will handle small faba bean seed without problems due to the banked metering arrangement. The optional rubber star roller is necessary for larger seeds, such as broad bean.

Air seeders with large or very coarse single fluted rollers cannot meter faba bean and broad bean bigger than 18 mm without modifications to the metering roller.

On some air seeders, the dividing heads may need modifying because there is too little room in the secondary distributor heads to allow seeds to flow smoothly. The conversion head increases the bore from 23–41 mm. Four larger hoses replace the original eight while row spacing is increased from 15–30 cm. This conversion allows large seeds such as broad bean to be sown easily.

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68 C Collis (2016) Faba beans find a southern home. GroundCover Issue 120 January–February 2016, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-120-Jan-Feb-2016/Faba-beans-find-a-southern-home

69 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

4.9.3 Combines

Combines with peg roller and seed wheel feeds will sow seed up to the size of faba bean without problems, providing adequate clearances are used around the rollers. Combines with fluted roller feeds have few problems feeding seed of less than 15 mm down to the metering chamber.

Smaller faba bean varieties such as Fiord can be metered with the more aggressive seed wheel system, but peg rollers are best replaced with 'rubber stars' for larger faba bean seed.

Broad bean seed can be metered through the rubber stars but this is not always efficient.

Combines with internal force feed seed meters perform well on small seeds but cannot sow seed larger than 9 mm, because of bridging at the throat leading to the seed meter. The restricted internal clearance in this type of design can damage larger seeds.

4.9.4 Seeder and tyne comparisons

Ensure that the sowing equipment:

- has adequate sowing mechanism (Photos 3, 4, 5, 6 and 7) to handle the faba bean seed without damaging it or bridging or blocking;
- has adequate sizes of tubes and boots;
- has an ability to sow uniformly at the desirable depth;
- covers seeds for good seed to soil contact; and
- uses press-wheels or closers, otherwise a prickle chain or roller may be required afterward.

Photo 3: *A Primary Precision Seeder fitted with Hydraulic breakout for consistent penetration. It is also fitted are narrow points that form an 'inverted T' slot and is capable of deep or side placement of fertiliser.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 4: *A Bio Blade or Cross slot™ disc opener with opening disc and seeding tine, followed by paired press-wheels. Note that the seed and fertiliser tube has sharp bends and may not be wide enough to avoid blockages while faba bean or broad beans are sown.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 5: *A Case IH SDX-40 single disc drill.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 6: *The DBS system parallelogram for uniform seeding depth and deep placement of seed or fertiliser.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 7: *Press-wheels can provide depth control.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Handling faba bean seed

Handle faba bean grain and seed carefully to prevent damage. Seed (for sowing) needs particular care to ensure good germination and vigour.

Augers with screen flighting can damage faba bean and broad bean. This may be partly overcome by slowing the auger. Augers with large flight clearances will cause less damage to large seed.

Tubulators or belt elevators are excellent for handling faba bean as they cause little to no damage. Cup elevators are less expensive than tubulators and cause less damage than augers.

Combine loaders which throw or sling, rather than carry the grain, can cause severe damage to seed and its germination.

Be aware that augers provide better mixing and seed coverage when inoculating faba bean seed than tubulators.[70]

4.10 Rolling

Rolling paddocks can make faba bean harvest more manageable. A flat and firm soil surface free of stumps, stones and clumps is essential for faba bean.

Traditionally, rolling of pulse paddocks has mostly occurred before crop emergence. Faba bean and broad bean can be rolled post-emergence if the plants are not taking the weight of the roller; generally the preferred timing is early post-emergence. However, there is a greater risk of foliar disease if beans are rolled post-emergence.

A flat soil surface at harvest is particularly important in lower-rainfall areas or late-sown crops, if crops are short and the lowest pods are close to the ground. It is also important when crops are tall but have lodged.

The flat surface left by rolling may also prevent herbicides washing into, and accumulating in, seed furrows after post-sowing pre-emergence herbicide application.

70 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

Rolling also improves seed–soil contact in sandy non-wetting soils, although press-wheels or closers on the seeder will normally achieve this.[71 72 73]

4.11 Dry sowing

Faba bean sowing dates are often a compromise between delaying sowing to reduce disease without severely reducing yield potential. Early sowing is a priority in some dry areas or where sowing needs to be early to optimise operations and enable optimum sowing times for other crops.

Dry sowing faba bean before the opening rains is common practice in some areas or years. Often this sowing is by the calendar, or when awaiting sowing rains to arrive. Dry sowing is sowing into completely dry soil before the opening rains, rather than sowing into marginal soil moisture. Dry sowing while awaiting a germinating rain can fit faba bean into the sowing program. This is an option in some seasons or locations, allowing the crop to be sown as early as practical and giving growers more time to sow other crops once the rain arrives.

Several factors need consideration before choosing to dry sow, including:

- the weed seed burden and weed-control options;
- the need for rhizobia to survive in dry soil, particularly if the soil is acidic (therefore the use of granular inoculum is common);
- type of soil and the ease of sowing into that soil when it is dry (including uniformity of sowing depth and soil tilth);
- the ability to enter the paddock after rain to perform operations in a timely manner;
- evenness of the soil after sowing and the impact of this on herbicide application and harvest operations; and
- the need for additional levelling to flatten any ridges, cover press-wheel furrows or flatten clods.,

4.11.1 Avoiding nodulation failure when dry sowing

Dry sowing seed of inoculated faba bean seed is not recommended where faba bean or lentil has not been sown in the paddock before, or where soil conditions are hostile to survival of the rhizobia. However, granular inoculum can be sown dry with faba beans as the inoculum has a longer survival rate in the granule until wetted (see Section 4.4.2 Inoculants for faba bean for more information).

The risk of nodulation failure due to dry sowing is much lower in paddocks where faba bean or lentil are frequently grown and where effective nodulation has been observed recently. These soils are likely to contain effective and compatible rhizobia. The same species of *Rhizobium* that nodulates faba bean and lentil also nodulates field pea and vetch, so soils with a strong history of vetch or field pea may also contain compatible rhizobia, although a different strain of inoculum is now used.

Where dry sowing is unavoidable, minimise the risk of nodulation failure by deep, moisture-seeking sowing and by limiting dry sowing to paddocks where faba bean or lentil have previously grown and were adequately nodulated.

Avoid dry sowing where peat or freeze-dried slurry is used to inoculatethe seed. Rhizobia may rapidly die on the seed in dry soil, resulting in poor nodulation (see Section 4.4.2 Inoculants for faba bean for more information).

71 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

72 Pulse Australia (2016) General Agronomy. Southern Faba and Broad Bean – Best Management Practices Training Course Module 4. Pulse Australia.

73 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

4.12 Irrigation

Refer to Section 2 Planning and paddock preparation.

Plant growth and physiology

Key points

- Faba bean and broad bean development is divided into five phases and secondary growth stages.
- Faba bean has hypogeal emergence, which can be an advantage.
- Faba bean development is mostly influenced by daily average temperature, longer days and, to a lesser extent, a cold requirement.
- Rhizobia bacteria in nodulated faba bean roots 'fix' nitrogen into a plant-available form.
- Honey bees can increase pollination and, therefore, the yield of faba bean crops.
- Low temperatures can cause flower and pod abortion. Low light can also reduce podset. Breeders aim to overcome these issues in the future with new varieties.
- Faba bean have poor tolerance to drought and high temperatures.
- High humidity and chocolate spot can reduce podset.
- Pod height is affected by agronomic practices.
- Breeders are developing more determinate varieties to reduce excess biomass.
- Breeders are developing lines with improved herbicide tolerance (Group B and Group C).

5.1 Developmental stages

Faba bean developmental stages are divided into five principal phases, with each phase sub-divided into secondary stages (Table 1 and Figure 1). The stages of development allow for better understanding of farm chemical labels for correct timing of applications. While the secondary stages are classed as 'growth stages', they are technically developmental stages.

Table 1: Developmental phases and 'growth stages' of faba bean.

Developmental phase	Growth stage (GS)	Description
00 Germination and emergence	GS000	Dry seed
	GS001	Imbibed seed
	GS002	Radicle apparent
	GS003	Plumule and radicle apparent
	GS004	Emergence
	GS005	First leaf unfolding
	GS006	First leaf unfolded
10 Vegetative	GS101	First node (i.e. first leaf fully unfolded with one pair of leaflets)
	GS10(x)	x = node x leaf fully unfolded with more than one pair of leaflets
	GS1(n)	n = last recorded node n – any number of nodes on main stem with fully unfolded leaves, according to variety
20 Reproductive	GS201	Flower buds visible and still green
	GS203	First open flowers on first flower cluster (raceme)
	GS204	First pod visible at first fertile node
	GS205	Green pods fully formed, small immature seeds within.
	GS207	Pod-fill, pods green
	GS209	Seeds rubbery, pods still pliable, turning black
	GS210	Pods dry and black, seeds dry
30 Pod senescence	GS301	10% of pods dry and black
	GS305	50% of pods dry and black
	GS308	80% of pods dry and black
	GS309	90% of pods dry and black
	GS310	All pods dry and black
40 Stem senescence	GS401	10% stem brown/black or most stem green
	GS405	50% stem brown/black or 50% stem green
	GS410	All stems brown/black, all pods dry and black, seed hard

Note: The vegetative and reproductive phases can run concurrently.
Source: *Faba beans: The Ute Guide* (2009)

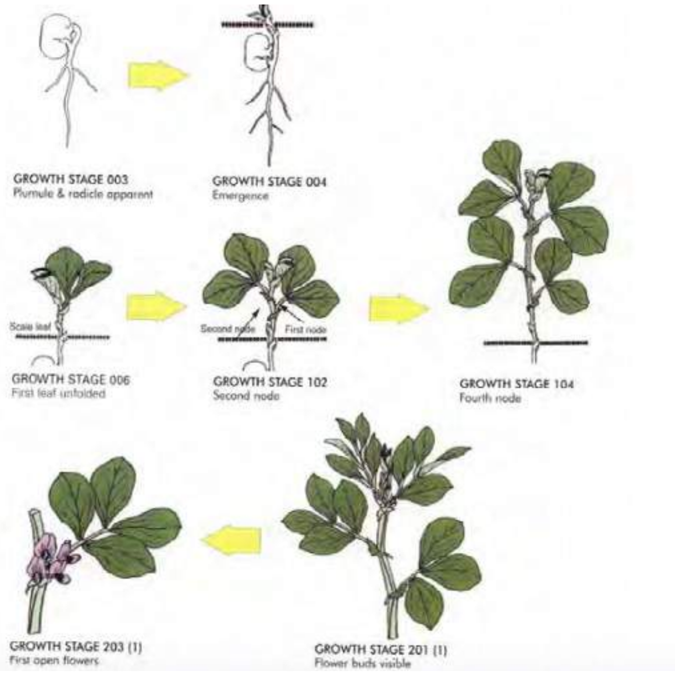

Figure 1: *Faba bean stages of development.*

Source: PGRO, UK

If a crop has uneven development, the average should be taken for the vegetative stage. Reproductive stages should not be averaged.

Once the crop reaches the reproductive phase, the timing of the growth stage should stay the same until 50% of plants demonstrate the characteristic of the next reproductive growth stage.

For an individual plant, the timing of a reproductive growth stage is based on the first occurrence of the specific trait on the plant. [1 2]

5.1.1 Germination and emergence

Faba bean germination is 'hypogeal', meaning the cotyledons stay beneath the surface. This allows plants to emerge from sowing as deep as 25 cm (Figure 2).

Under optimum conditions faba bean seeds imbibe water and germinate within a few days, provided temperatures are above 0°C. Depending on soil moisture, temperature and sowing depth, the plant should emerge 7–10 days after sowing. The first true leaves have a pair of leaflets.

After sowing, water uptake into the embryo is very fast, depending on soil moisture content. Seeds that are sown into marginal moisture and have imbibed some water may have either dried down or not taken up enough moisture to germinate. These 'primed' seeds will germinate quickly when the soil becomes wet again.

If the seed coat is cracked, water may be taken up too quickly or microorganisms may access the starch and protein in the seed's endosperm.

Seed that has undergone some pre-harvest sprouting from the year it was harvested will have lower germination percentage, seedling vigour and seed viability in storage.

Seedlings with hypogeal emergence, such as faba bean, are less likely to be killed by frost, wind erosion or insect attack as new stems can develop from buds at nodes, at/

1 CM Knott (1990) A key for stages of development of the faba bean (Vicia faba). Annals of Applied Biology 116. pp 391–404. Reprinted in: T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. Primary Industries and Resources South Australia, http://onlinelibrary.wiley.com/doi/10.1111/j.1744-7348.1990.tb06621.x/abstract

2 Pulse Australia (2016) Plant physiology. Southern Faba Bean – Best Management Practices Training Course manual. Pulse Australia.

or below ground level. In contrast, if an epigeal pulse (e.g. lupin) is broken below the cotyledons, the plant will die as there are no buds from which to shoot.[3 4]

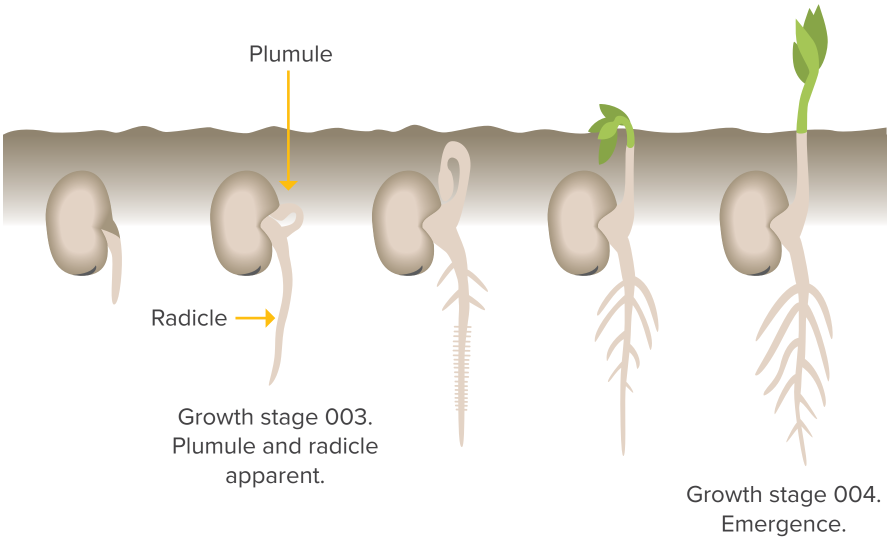

Figure 2: *Germination and hypogeal emergence of faba bean. Hypogeal emergence means cotyledons remain below the ground, while in epigeal emergence, cotyledons appear above the ground.*

Source: images based on slideplayer.com

5.1.2 Vegetative phase

Faba bean produce branches stemming from the base. Leaves from the early growth stages have only two leaflets, while leaves formed after the start of flowering have up to seven leaflets per leaf. [5]

The vegetative stage is determined by counting the number of developed nodes on the main stem, above ground level. Nodes are counted from the point at which the first true leaves are attached to the stem. The node at which the first leaflet arises from the main stem above the soil is counted as node one. A node is counted as developed when leaves are unfolded and flattened out. Scale leaves at the base of the plant and close to the ground are not counted as true nodes.

The last node counted must have its leaves unfolded (Figure 3). A node is counted as developed when leaves are unfolded and flattened out. Scale leaves at the base of the plant, close to the ground, are not counted as true nodes.

Faba bean stems do not actually have branches but produce tillers that grow from the nodes at the base of the plant, just above the main stem. Hereafter, tillers will be called branches. The leaves are alternate, up to 8 cm long, each with two to six leaflets. [6] Plants usually have one to five branches (tillers) on the main stem, depending on variety and growing conditions.

Unlike lupin and some other pulse crops, faba bean does not develop secondary or tertiary branches from the main stem of branches.

Faba bean canopies develop rapidly, especially in early-sown crops or during warm winters.[7]

3 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

4 Pulse Australia (2016) Plant physiology. Southern Faba Bean – Best Management Practices Training Course manual. Pulse Australia.

5 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

6 V Heuze, G Tran, R Delagarde, M Lessire, F Lebas (2016) Faba bean (Vicia faba). Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, www.feedipedia.org/node/4926

7 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

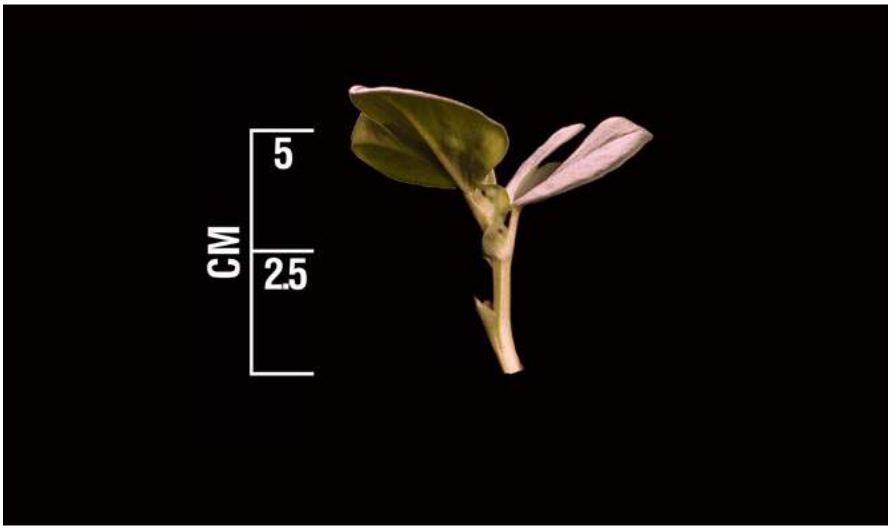

Photo 1: *The second leaf is fully unfolded in this plant at GS102 (second node stage).*

Photo: GRDC

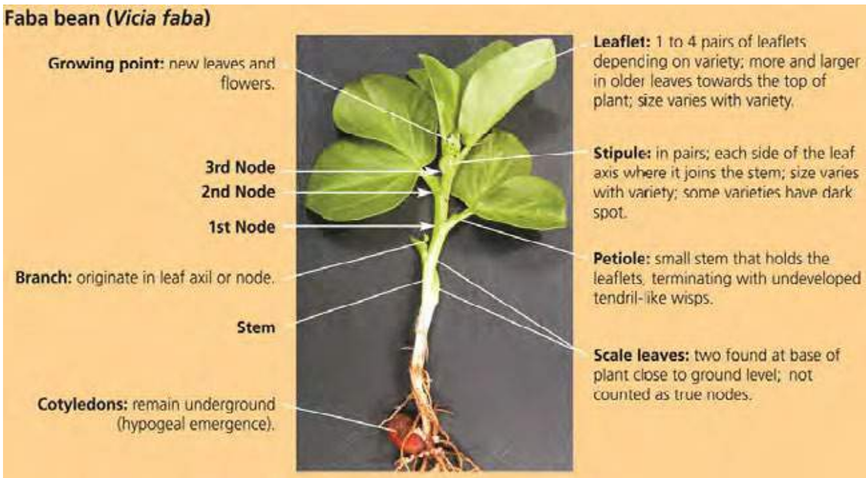

Figure 3: *Determine the vegetative stage of faba bean by counting the nodes on the main stem. The last node counted must have fully unfolded leaves.*

Source: D Holding, A Bowcher (2004) Weeds in Winter Pulses, CRC for Australian Weed Management

5.1.3 Reproductive phase

Flower development

Flowers develop from the bud at the axil of the leaf ('axillary bud') at the base of each node. Flowering usually begins at about the 6th to 10th node on the main stem and lower tillers, depending on variety, location and time of sowing (Photo 2). Flowers are borne on a stem called the peduncle that comes from the nodes.[8]

Flowers develop in clusters of 1–5, on up to 15 flowering nodes in a well-grown faba bean crop in Australia. Each flower cluster develops into 1–4 pods.

8 K Esau (1977) Anatomy of seed plants. 2nd edn. Wiley.

Photo 2: *GS203, first flowers open. Faba bean plants have alternate leaves along the branch, with multiple leaflets per leaf.*

Photo: GRDC

Flowering continues at intervals averaging 5–7 days between successive nodes on each tiller. The intervals between nodes are slow in winter during the vegetative and early reproductive phases (at least 7 days) but are fast during spring.

Most Australian faba bean varieties are 'semi-determinate'. This means vegetative growth continues once the plant switches to the reproductive phase – but can terminate before moisture becomes limiting.[9]

Other Australian varieties are indeterminate. An indeterminate variety will continue to flower if weather conditions in spring are favourable, with the potential to capitalise on the season or irrigation to produce high yields, similar to canola. In contrast, for fully determinate plants, all the flower buds open at about the same time, much like wheat.

Australian faba bean breeders are developing determinate attributes into locally adapted breeding lines[10] (see Section 5.6.2 Breeding determinate varieties for more information).

In southern Australia, flowering of faba bean continues for 6–10 weeks, depending on time of sowing, moisture and air temperature, from late July to mid-October.[11]

In cool, temperate environments, there can be a period of ineffective flowering that can be as long as 30 days. Early flowers can fail to set pods if there is a dense canopy and cold weather.

Pod and seed development

Once the flowers begin to develop and open, pollination (fertilisation) takes place. About 10–20% of flowers develop into pods. This is affected by variety and environmental factors (see Section 5.5 Effect of environment on yield components for more information).

9 GRDC (2016) Growth Stages for Faba Bean (unpublished). Grains Research and Development Corporation.

10 K Adhikari (2015) Faba bean. PBA Winter 15 News. Pulse Breeding Australia. pp 6–8, https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/Newsletters

11 RC Keogh, APW Robinson, IJ Mullins (2010) Faba beans. Pollination Aware. The Real Value of Pollination in Australia. Prepared by Strategen Environmental Consultants August 2010 RIRDC Publication No 10/081. Rural Industries Research and Development Corporation, https://rirdc.infoservices.com.au/items/10-081

The first pods appear about 6 days after pollination under favourable seasonal conditions. The pod wall grows rapidly for the first 10–15 days, while seed growth mainly occurs later.

The developing pods remain erect beneath the leaf canopy. Pods can contain up to eight seeds. Not every ovule (female reproductive cell) will develop into a seed. Pods may bend and point downward when seeds are near maturity in some varieties, particularly broad bean. Most of the seed yield is from the lower flowering nodes on the main stem and basal branches. Not all pods that set progress to fill seeds.

Photo 3: *Faba bean pod developing at leaf axil at base of node. Note the dead flower from which the pod arises.*

Photo: Wayne Hawthorne, formerly Pulse Australia

If moisture and temperature conditions are favourable, extra crop growth, node production, flowering and crop height occurs until flowering finishes. Hot conditions or a lack of moisture can end the flowering period and crop growth; faba bean plants stand upright and although they can grow to about 2 m, most Australian crops are shorter than 1.5 m. The height of the plant depends on soil moisture or rainfall, length of growing season and variety.

Pods in a well-grown crop (Photo 4) are produced about 20–30 cm above ground level, with each pod containing two to four seeds. Seed size varies with variety.

In a fully grown crop, the taproot will penetrate to about 60 cm with profuse fibrous roots that are less deep than cereals.[12]

Several factors can cause flowers to shed.[13] For the surviving pods, seed development goes through three stages: pre-storage, transition and storage, which have been described in detail in scientific literature.[14]

Faba bean seeds are oval and flat, sometimes with a ridged, dimpled or smooth seed coat. Seed coat colours also vary considerably.

12 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

13 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

14 JW Patrick, FL Stoddard (2010) Physiology of flowering and grain filling in faba bean. Field Crops Research 115. pp 234–242, https://www.researchgate.net/publication/236875206_Physiology_of_flowering_and_grain_filling_in_faba_bean

Photo 4: *Mature, well-podded faba bean before the pods and stems dry for harvest.*

Photo: Wayne Hawthorne, formerly Pulse Australia

5.1.4 Pod and stem senescence

Soon after the pods develop and seeds fill, the plant begins to senesce (die). The lowest pods will mature first and become black, along with the lower leaves. This will continue gradually upward as the plant senesces.

As leaves senesce, biomass (or dry matter) is rapidly translocated from the leaves and stems and into the seeds.

If soil moisture is adequate and maximum temperatures are favourable for growth, flowering and podding will continue on the upper nodes. As soil moisture depletes and temperatures rise, flowering ends and eventually the whole plant matures.

Faba bean crops in southern Australia reach maturity 180–220 days after sowing, depending on sowing date, variety and a range of environmental factors including temperature.

Faba bean are ready to harvest when more than 90% of the stems and pods have become black. At this stage, seeds are usually hard but do not rattle when the plant is shaken, unlike chickpea and lentil [15] (see Section 12 Harvest for more information).

5.2 Factors affecting development

The rate at which faba bean develop is largely affected by average daily temperature. Some faba bean varieties also flower in response to longer days, while others are not affected by day length ('photoperiod'). Some faba bean varieties have a cold requirement, called 'vernalisation', although this is less important in Australian than in some European varieties, particularly the 'winter' varieties.[16]

Scientists are yet to fully understand the genetic code and physiology of faba bean that will help predict the rate of development of faba bean varieties and breeding

15 Pulse Australia (2016) Best management guide. Faba bean production: Southern and Western Region. Pulse Australia, 15 January 2016, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

16 GK McDonald, T Adisarwanto, R Knight (1994) Effects of time of sowing on flowering in faba bean (Vicia faba). Australian Journal of Experimental Agriculture 34(3). pp 395–400, http://www.publish.csiro.au/an/EA9940395

lines in response to the plant's environment. However, there is some understanding of the effects of thermal time and photoperiod on the time it takes for a faba bean crop to emerge and flower.[17]

5.2.1 Thermal time

The time a faba bean crop takes to develop depends mostly on the accumulation of 'thermal time', a function of time and temperature.

In general, warmer temperatures hasten development; even for the same location and same sowing date, flowering times can differ by more than 10 days due to differences in the seasonal conditions.[18]

Thermal time is the sum of the average daily temperatures above a base temperature, and measured in 'degree-days'. For faba bean, the base temperature is usually 0°C. [19] The average daily temperature is the daily maximum temperature minus the minimum temperature, divided by two. For example, 10 days with an average daily temperature of 12°C equates to 120 degree-days, when 0°C is the base temperature.

Consequently, a faba bean crop sown in early April will flower in less time than one sown in mid-June, as the April-sown crop will accumulate thermal time more rapidly during the warm autumn months.

Thermal time effect on vegetative phase

Research comparing a diverse range of faba bean genotypes (different plant types) showed they responded in a similar way to thermal time.[20]

Australian research also showed that the thermal time taken from sowing to emergence varied little among a range of breeding lines used in the experiment. On average, it took 208 degree-days from sowing to emergence (base temperature 0°C). The later the sowing date (from April to August), the longer the crop took to emerge.[21]

Similarly, New Zealand research with a single faba bean variety using a range of sowing dates found that 75% of the crop emerged after 217 degree-days, using a base temperature of 1.2°C.[22]

Thermal time effect on reproductive phase

Thermal time is the most important contributor to progress to flowering in faba bean. A faba bean crop needs about 830–1000 degree-days before it will flower.[23]

In southern Australia, the optimum temperature for faba bean growth is 15°C–20°C,[24] while the optimum temperature for progress to flowering is considered to be 20°C–23°C.[25]

Australian research showed that faba bean sown between April and August took, on average, between 43 and 73 days from emergence to the first flower, depending on

17 JW Patrick, FL Stoddard (2010) Physiology of flowering and grain filling in faba bean. Field Crops Research 115. pp 234–242, https://www.researchgate.net/publication/236875206_Physiology_of_flowering_and_grain_filling_in_faba_bean

18 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

19 JW Patrick, FL Stoddard (2010) Physiology of flowering and grain filling in faba bean. Field Crops Research 115. pp 234–242, https://www.researchgate.net/publication/236875206_Physiology_of_flowering_and_grain_filling_in_faba_bean

20 RH Ellis, RJ Summerfield, EH Roberts (1990) Flowering in faba bean: Genotypic differences in photoperiod sensitivity, similarities in temperature sensitivity, and implications for screening germplasm. Annals of Applied Botany 65. pp 129–138, www.jstor.org/stable/42758294?seq=1#page_scan_tab_contents

21 GK McDonald, T Adisarwanto, R Knight (1994) Effects of time of sowing on flowering in faba bean (Vicia faba). Australian Journal of Experimental Agriculture 34(3). pp 395–400, http://www.publish.csiro.au/an/EA9940395

22 MM Yusoff, DJ Moot, BA McKenzie, GD Hill (2013) Quantification of vegetative development of faba bean, oats, and Italian ryegrass. Crop and Pasture Science 63(12). pp 1097–1105, www.publish.csiro.au/cp/CP12305

23 RH Ellis, RJ Summerfield, EH Roberts (1990) Flowering in faba bean: Genotypic differences in photoperiod sensitivity, similarities in temperature sensitivity, and implications for screening germplasm. Annals of Applied Botany 65. pp 129–138, www.jstor.org/stable/42758294?seq=1#page_scan_tab_contents

24 B Robinson, M Raynes (2013) Growing faba bean, Agnote, AG0083. Victorian Department of Environment and Primary Industries, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

25 JW Patrick, FL Stoddard (2010) Physiology of flowering and grain filling in faba bean. Field Crops Research 115. pp 234–242, https://www.researchgate.net/publication/236875206_Physiology_of_flowering_and_grain_filling_in_faba_bean

breeding line (Table 2). The thermal time to first flower varied considerably between sowing times, particularly with the later flowering accessions. The use of thermal time in isolation does not increase the accuracy of predicting flowering times in faba bean in southern Australia. Time from emergence to flowering across faba bean lines can be largely explained by the combined effects of the mean temperature and day length – and these two factors acted independently.[26]

Sowing times that resulted in flowering in winter had the greatest variation between plants, but with progressively later flowering than winter, this variation declined.[27]

At Rosedale, South Australia, Fiesta VF flowers 90 ± 3 days after sowing with a mid-May sowing. Therefore, it commences flowering in temperatures that average 11.4°C (maximum 16.5°C, minimum 6.3°C).

In many well-grown faba bean crops, podset does not occur until temperatures rise in August to September.

Table 2: Average time (days) and average thermal time (degree-days) from emergence to first flowering for cultivar Fiord and early and late-flowering accession of faba bean in southern Australia.

Accession	Time (days)			Thermal time (degree-days)		
		Range			Range	
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Fiord	53	34	68	724	534	889
ACC286	43	29	53	611	568	650
ACC863	73	50	96	972	731	1265
Average	59.50	39.0	77.8	807	620	1047

Source: Bennell *et al.* (2006)

5.2.2 Daylength

Faba bean varieties are either neutral-day or long-day plant.[28] This means that day length (or photoperiod) does not influence the time to flowering of some faba bean varieties, while for others, plants will begin to form flower buds when days are longer than their critical day length. The critical day length is between 9.5 and 12 hours for long-day faba bean varieties.

Breeders have identified improved variety breeding lines with low sensitivity to day length so that they flower early in southern Australian conditions of short days during a winter growing season.

Faba bean is a medium-duration crop, usually beginning flowering in 29–96 days of sowing, depending on photoperiod and temperature. European varieties are generally more photoperiod-sensitive; a critical day length of more than 12 hours may be required for them to flower under southern Australian conditions. In contrast, Mediterranean varieties flower with much shorter days.[29]

5.2.3 Vernalisation

Vernalisation is the process by which prolonged exposure to cold temperatures promotes flowering.[30]

26 GK McDonald, T Adisarwanto, R Knight (1994) Effects of time of sowing on flowering in faba bean (Vicia faba). Australian Journal of Experimental Agriculture 34(3). pp 395–400, http://www.publish.csiro.au/an/EA9940395

27 Pulse Australia (2016) Plant physiology. Southern Faba Bean – Best Management Practices Training Course manual. Pulse Australia.

28 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

29 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

30 R Amasino (2004) Vernalization, competence, and the epigenetic memory of winter, Plant Cell, 16(10). pp 2553–2559, http://www.plantcell.org/content/16/10/2553.full.pdf+html

In southern Australian trials, the greatest response of faba bean to vernalisation was with April sowing.[31] With late (August) sowing there was little response to vernalisation. Long and lengthening days partly overcame the vernalisation requirement of some varieties. The researchers concluded that, for normal sowing dates in dryland faba bean crops in southern Australia, there was little effect of vernalisation on the time to flowering. Instead, temperature and day length were the major controls of development.

'Winter' faba bean, which is grown in Europe (as opposed to 'spring' faba bean), will eventually flower, even without vernalisation. Mediterranean varieties of faba bean, as grown in Australia, do not have a high vernalisation requirement. Vernalisation of spring and Mediterranean varieties accelerated flowering in trials, but only in line with the accumulated thermal time.[32 33]

5.3 Nodulation

Faba bean roots develop nodules with rhizobia bacteria *Rhizobium leguminosarum* bv. *viciae*, a species capable of converting nitrogen gas from the atmosphere into forms of nitrogen that the plant can use, called 'fixation'. The plant provides carbohydrate in return.

Nodules are visible on faba bean about a month after emergence. They eventually form slightly flattened, fan-like lobes. Nearly all nodules are within the top 30 cm of soil, while 95% are in the top 15 cm. When cut open, active nodules have a 'pinkish' centre.[34]

Photo 5: *Faba bean with adequate nodulation. The inside of the nodules should be red/pink rather than grey or green.*

Source: GrowNotes™: Faba bean (northern region)

31 Pulse Australia (2016) Plant physiology. Southern Faba Bean – Best Management Practices Training Course manual. Pulse Australia.

32 GK McDonald, T Adisarwanto, R Knight (1994) Effects of time of sowing on flowering in faba bean (Vicia faba). Australian Journal of Experimental Agriculture 34(3). pp 395–400, http://www.publish.csiro.au/an/EA9940395

33 JW Patrick, FL Stoddard (2010) Physiology of flowering and grain filling in faba bean. Field Crops Research 115. pp 234–242, https://www.researchgate.net/publication/236875206_Physiology_of_flowering_and_grain_filling_in_faba_bean

34 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

5.3.1 Temperature effects on nodulation

Australian research in the 1980s showed that nodulation (and seedling growth) of the faba bean variety Fiord improves with warm temperatures at 15°C or 20°C, compared with 10°C, when grown in pots. The researchers concluded that the yield advantage of early planting of this variety may partly be due to better nodulation in warm soils.

5.3.2 Mineral nitrogen effects on nodulation

The researchers also compared two *Rhizobium* strains on Fiord faba bean and early dun field pea and found that nodulation of faba bean was remarkably slow, taking up to 50 days from sowing. Faba bean grown without mineral nitrogen showed poor early growth; however, low levels of nitrate stimulated nodule development. In contrast, doubling or tripling the level of nitrate for faba bean caused delayed nodulation, lower nodule production and poorer nodule activity.[35] This result ratifies the practice of using starter nitrogen to stimulate nodulation, but also sends the warning that it can be detrimental if soil nitrate levels are high.

5.3.3 Waterlogging effects on nodulation

Nitrogen fixation is highly sensitive to waterlogging.

5.4 Pollination

Faba bean can be self-pollinated or cross-pollinated (open-pollinated). To maximise podset and seedset, pollen is transferred between flowers. Faba bean pollen is heavy and sticky and is not released into the air. While the wind can assist in pollen transfer, insects carrying pollen between flowers is the most effective method of cross-pollination. Several insect species will do this, including bees, lacewings, flies and ants. About 30% of plants in a population are cross-fertilised; the main insect pollinators in Australia are honey bees. When commercial faba bean crops in SA and western Victoria were surveyed for flower visitors and incidence of pollination, honey bees were the only pollen vectors.[36]

As pulse crops have a short flowering period, the number of insects required to effectively pollinate the crop is beyond what may occur in nature. Introducing honey bees is the most effective way to manage this.[37]

5.4.1 Pollination efficiency

The presence of honey bees can accelerate the rate of podsetting in faba bean[38] (Photo 6). Plants with access to bees set more pods on the lower nodes and ripen earlier, with significantly more seeds per pod.[39]

35 A Herdin, JH Silsbury (1989) Nodulation and early growth of faba bean (*Vicia faba L.*) and pea (*Pisum sativum* L.) as affected by strain of *Rhizobium*, NO3- supply, and growth temperature. Australian Journal of Agricultural Research 40(5)) pp 991–1001, http://www.publish.csiro.au/cp/AR9890991

36 FL Stoddard (1991) Pollen vectors and pollination of faba beans in southern Australia. Australian Journal of Agricultural Research 42(7). pp 1173–1178, www.publish.csiro.au/paper/AR9911173.htm

37 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

38 GK McDonald, T Adisarwanto, R Knight (1994) Effects of time of sowing on flowering in faba bean (Vicia faba). Australian Journal of Experimental Agriculture 34(3). pp 395–400, http://www.publish.csiro.au/an/EA9940395

39 D Somerville (2002)"Honeybees in faba bean pollination. Agnote DAI-128, W Smith (ed.). NSW Agriculture, www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/117110/bee-faba-bean-pollination.pdf

Photo 6: *The presence of honey bees accelerates the rate of podsetting in faba bean.*

Photo: Felicity Pritchard

It is not unusual for less than one in five faba bean flowers to set pods.[40] One of the numerous causes of this is a lack of pollination. Sometimes a faba bean flower will not pollinate, either due to a lack of bees for cross-pollination or a physical problem with the flower that prevents self-pollination. An unpollinated flower will not set a pod or produce seeds.

Faba bean plants naturally produce an excess of flowers. This is an ecological survival strategy to enhance the plant's ability to compete for pollinating insects; it is inevitable that many flowers are lost.[41]

Large pods set very low on faba bean plants are common when bees are active. These additional and larger pods are a major contributor to the increased yield.[42]

In the past, Australian growers believed that introduced managed honey bees in flowering faba bean crops were not necessary due to sufficient feral bee activity. This was originally backed by trials in SA and western Victoria, which found the incidence of pollination was never less than 50% and averaged 80%. Only 40–50% of flowers need pollinating to provide an excess of pods for the plant.[43]

In contrast, newer research in New South Wales found that honey bee pollination significantly improved the number of pods and grain yield of faba bean (Table 3). Seed yield in cages with honey bees was 25% higher than in those without honey bees. The pollen harvested by honey bees from the faba bean met their nutritional requirements for protein and amino acids but there was no detectable nectar crop gathered from the faba bean. The researcher argued there is a strong case for using managed honey bees to improve pollination and yields of Australian faba bean where feral bee populations may be insufficient.[44]

More recently, researchers studied 17 faba bean paddocks in SA and showed an average yield benefit of 17%, 90% of which is attained within 767 m of hives. The effect was most noticeable when far from timbered areas. The researchers observed that bee activity, pods per stem and average yields were higher when closer to hives. Yield maps showed the presence of this 'distance gradient', which was consistent across all paddocks, across 2 years, two faba bean varieties and two different bee-

40 Pulse Australia (2014) Northern faba bean best management practices training course – 2014. Pulse Australia.

41 GK McDonald, T Adisarwanto, R Knight (1994) Effects of time of sowing on flowering in faba bean (Vicia faba). Australian Journal of Experimental Agriculture 34(3). pp 395–400, http://www.publish.csiro.au/an/EA9940395

42 W Hawthorne (2013) Maximising yield potential in irrigated faba beans. IREC Farmers' Newsletter – Large Area 189: Spring 2013. Irrigation Research and Extension Committee, http://irec.org.au/farmers-newsletter/

43 D Somerville (2002)"Honeybees in faba bean pollination. Agnote DAI-128, W Smith (ed.). NSW Agriculture, www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/117110/bee-faba-bean-pollination.pdf

44 DC Somerville (1999) Honeybees (*Apis mellifera L.*) increase yields of faba beans (*Vicia faba L.*) in New South Wales while maintaining adequate protein requirements from faba bean pollen. Australian Journal of Experimental Agriculture 39(8). pp 1001–1005, www.publish.csiro.au/paper/EA99023.htm

hive management methods. An economic analysis found hives are profitable for faba bean crops.[45]

Reliance of feral bees for pollination may become a 'luxury of the past', due to the prevalence of several pests and disease likely to affect bee populations in the future. The potential incursion of the parasitic mite *Varroa* poses considerable threat. The success of feral bee populations in pollinating faba bean depends on crop size, population of feral bees and the health of colonies closest to the crop.[46] All these factors can vary between locations and seasons.[47]

Table 3: Honey bees significantly increased yield of faba bean by up to 25% in southern New South Wales trials. Yield of plants in cages increased by 24% when honey bees were included in the cages.

Treatment	Yield (t/ha)
Uncaged, open to bees (control)	1.86
Shaded but open to bees	1.73
Caged with bees	1.51
Caged with no bees	1.22

Source: Somerville (1999), Sommerville (2002)

5.4.2 Bee activity

Bees transfer pollen between flowers, thereby pollinating the crop while collecting pollen and, to a lesser extent, nectar.[48] Pollen collecting by bees peaks between 1 p.m. and 4 p.m. in the southern region. Each faba bean flower has up to 18 hours in which it can be pollinated, as flowers remain viable for 6 days when unpollinated.[49]

Honey bee activity is highest at temperatures above 19°C and almost stops when temperatures fall below 13°C. Bees can fly up to 150 m between rain showers but stop flying when it is raining. Strong winds will also reduce the number of flights taken by bees.

A bee colony with strong numbers will enable honey bees to leave the hive at lower temperatures, while surplus bees can remain in the brood nest to keep it at a constant temperature of 37°C.

The number of honey bees visiting the blossom is correlated with the amount and concentration of nectar produced, which is highest in old flowers.[50]

5.4.3 Hive management

Faba bean provides very little, if any, nectar to honey bees, due to the shape of its flower. Only some hives are suitable for pollinating faba bean.

It had been thought that hives needed to be managed by providing sugar syrup early in the flowering period or ensuring there was stored honey in the hive before the bees go into the crop so they collect pollen rather than seeking nectar. These artificial nectar sources were thought to stimulate the colony to breed, thereby increasing demand for pollen. There is now a changed attitude to faba bean pollination.

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45 S Cunningham, D Le Feuvre (2013) Significant yield benefits from honeybee pollination of faba bean (Vicia faba) assessed at field scale. Field Crops Research 149. pp 269–275, www.researchgate.net/publication/257214174_Significant_yield_benefits_from_honeybee_pollination_of_faba_bean_Vicia_faba_assessed_at_field_scale

46 D Somerville (2002) Honeybees in faba bean pollination. Agnote DAI-128, W Smith (ed.). NSW Agriculture, www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/117110/bee-faba-bean-pollination.pdf

47 RC Keogh, APW Robinson, IJ Mullins (2010) Faba beans. Pollination Aware. The Real Value of Pollination in Australia. Prepared by Strategen Environmental Consultants August 2010 RIRDC Publication No 10/081. Rural Industries Research and Development Corporation, https://rirdc.infoservices.com.au/items/10-081

48 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

49 DC Somerville (1999) Honeybees (Apis mellifera L.) increase yields of faba beans (Vicia faba L.) in New South Wales while maintaining adequate protein requirements from faba bean pollen. Australian Journal of Experimental Agriculture 39(8). pp 1001–1005, www.publish.csiro.au/paper/EA99023.htm

50 D Somerville (2002) Honeybees in faba bean pollination. Agnote DAI-128, W Smith (ed.). NSW Agriculture, www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/117110/bee-faba-bean-pollination.pdf

It has now also been established that hives need constant management to adequately pollinate a faba bean crop. Bees should generally be introduced when about 5% of the crop has started to blossom, for them to start working immediately. Hive placement and management is critical. Moving hives into a crop at night is less stressful for the bees.[51]

Growers should agree on the number of combs of brood or bees before agreeing to hire bees.[52]

The new-to-Australia method of hive management markedly increases the number of forager bees collecting pollen from faba bean. This involves keeping significantly less stored honey in the hives to maintain the demand for pollen and nectar.[53] The overwhelming demand for pollen means that the bees travel to the closest source of pollen, which reduces the distance they travel from the hive. They visit every flower in the crop, including older flowers and those lower in the canopy. This method requires fortnightly servicing of hives.

Trials conducted indicate that the flight of the bees is restricted to about 200–300 m from the hive placed in the faba bean crop. This means, in order to achieve effective pollination, precise placement and density of hives is crucial for uniform pollination.

In the past, apiarists supplied hives that contained a significantly higher amount of stored honey and pollen. As a result there was not a significant immediate demand in the hive for pollen and nectar, as they had sufficient stores to sustain the hive. With a reduced demand in the hive for pollen and nectar, the bees travelled further from the hive to find more preferable areas to graze. (e.g. warm gullies, areas protected from winds or alternative native vegetation). Bees can travel up to 5 km to find alternative flora.

Trials conducted in 2007 and 2008 across SA have indicated that yield increases of up to 50% may be easily achievable with the addition of the managed hives to pulse crops.

Historically, the ideal pollination unit had been considered to be approximately six frames of brood and bees. With an expanding brood nest, the bees need more pollen to feed their larvae. This was thought to encourage them to fly more often, even when conditions were not ideal.

It had also been thought that generally, the minimum requirement was a very strong single hive or a colony expanding into a double hive. Pollen-gathering honey bees are said to fly shorter distances than nectar gatherers. Most faba bean seeds are set within a 100 m radius of a colony. If bees need to fly more than 500 m, they should be split up and placed in appropriately spaced intervals.

It is now established that for faba bean crops, apiarists must manage hives as ‘pollinators’ rather than honey producers, placing and managing hives differently than simply leaving them in the paddock corner.

The more pollen-gathering insects visiting a crop, the greater the chance of maximum pollination. The number of bees and other insects pollinating faba bean flowers is more important than hive density.

A hive density of one hive/ha is practical and profitable; grouping 30 hives together every 300 m, or using larger groups further apart, will achieve a yield response. Yields have been found to increase by 30–100% by introducing two hives/ha in a grid. In the past, one colony/10 ha of faba bean was proposed as sufficient.

Precise placement and density of hives is crucial for uniform and effective pollination (Photos 7 and 8).

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51 RC Keogh, APW Robinson, IJ Mullins (2010) Faba beans. Pollination Aware. The Real Value of Pollination in Australia. Prepared by Strategen Environmental Consultants August 2010 RIRDC Publication No 10/081. Rural Industries Research and Development Corporation, https://rirdc.infoservices.com.au/items/10-081

52 D Somerville (2002) Honeybees in faba bean pollination. Agnote DAI-128, W Smith (ed.). NSW Agriculture, www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/117110/bee-faba-bean-pollination.pdf

53 K Esau (1977) Anatomy of seed plants. 2nd edn. Wiley.

It had been thought that, where possible, hives should be placed in a warm, sunny, elevated position, protected from prevailing winds. This is no longer considered the case with faba bean.

Growers are now recommended to introduce managed honey bee colonies into a faba bean crop where it is more than 500 m from stands of mature trees that are likely to harbour feral bees or if the crop is too large to be adequately pollinated by feral bees. Hive placement should also be considered in relation to other crops such as canola that bees will preferentially visit.

Hives should not be placed within 100 m of gates, lanes, stock troughs or sheds. They should also not be placed in long rows; an irregular layout is best, with hives spaced apart and facing different directions. Ideally, beekeepers should have all-weather truck access, as limited access can increase the workload and lead to uneven placement of hives, causing inefficient pollination.[54]

Photo 7: *Bee hives need to be strategically placed within the faba bean crop and managed well to ensure adequate pollination.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 8: *Bee hives need to be strategically placed within the faba bean crop and managed well to ensure adequate pollination.*

Photo: Wayne Hawthorne, formerly Pulse Australia

54 RC Keogh, APW Robinson, IJ Mullins (2010) Faba beans. Pollination Aware. The Real Value of Pollination in Australia. Prepared by Strategen Environmental Consultants August 2010 RIRDC Publication No 10/081. Rural Industries Research and Development Corporation, https://rirdc.infoservices.com.au/items/10-081

5.4.4 Pesticide sprays

If bee hives are placed in the faba bean crop, talk with your apiarist about fungicide and insecticide use.[55] Pesticides are one of the biggest dangers to bee colonies or feral bees.

Some products, if applied at the right time of day, can be used without needing to shift hives.[56] Otherwise, remove or house bees before fungicide or insecticide is sprayed.[57]

When spraying, the further the beehives are placed away from the crop, the better.[58]

Pesticides should be kept to a minimum while hives remain on your property. Most poisoning occurs when pesticides are applied to flowering crops, pastures and weeds.

Growers should take the following steps to minimise bee losses:

- always warn nearby growers and beekeepers of your intention to spray, with at least 2 days' notice;
- follow warnings on pesticide labels;
- select the least harmful pesticide for bees and spray late in the afternoon or night (but be aware of the risk of inversion layers);
- do not spray in conditions where the spray may drift into neighbouring paddocks, supporting foraging bees; and
- dispose of waste chemicals correctly.[59]

55 Pulse Australia (2014) Northern faba bean best management practices training course – 2014. Pulse Australia.

56 W Hawthorne (2013) Maximising yield potential in irrigated faba beans. IREC Farmers' Newsletter – Large Area 189: Spring 2013. Irrigation Research and Extension Committee, http://irec.org.au/farmers-newsletter/

57 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

58 RC Keogh, APW Robinson, IJ Mullins (2010) Faba beans. Pollination Aware. The Real Value of Pollination in Australia. Prepared by Strategen Environmental Consultants August 2010 RIRDC Publication No 10/081. Rural Industries Research and Development Corporation, https://rirdc.infoservices.com.au/items/10-081

59 D Somerville (2002) Honeybees in faba bean pollination. Agnote DAI-128, W Smith (ed.). NSW Agriculture, www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/117110/bee-faba-bean-pollination.pdf

VIDEO

GroundCover™ TV: Extreme Temperature Analysis to Better Understand Frost Events https://youtu.be/Zw637FiX5PU

MORE INFORMATION

GroundCover™ TV: Legume Nodulation – field sampling www.grdc.com.au/ManagingFrostRisk

Frost: Frequently Asked Questions, https://grdc.com.au/frost-faq

Frost Management Tips and Tactics fact sheet

GRDC (2014) *Inoculating legumes: a practical guide*, https://grdc.com.au/Resources/Bookshop/2015/07

5.5 Effect of environment on yield components

Stresses to the plant can affect its ability to *produce* grain. Flower and pod retention is sensitive to transient stress. Faba bean podset is reduced by a number of factors, including extremes of temperature, wind, drought, poor pollination, low light and an excess of flowers.

Photo 9: *Faba bean podset is reduced by a number of factors, including extremes of temperature, wind, drought, poor pollination, low light and an excess of flowers. Here, flowers are lost at each node near a single pod.*

Source: Wayne Hawthorne, formerly Pulse Australia

5.5.1 Low temperature

The optimal temperature for cool-season pulses is between 10°C and 25°C–30°C.

Low average daily temperature may cause faba bean to abort flowers and pods (while low levels of daylight will also cause flower abortion). A daily average temperature between 0°C and 10°C is considered a threshold for cold or chilling stress in cool-season pulses. Flower buds and flowers are the most sensitive parts. Faba bean and lentil are more tolerant of cold than chickpea and field pea. Unlike chickpea, low temperatures are not known to cause pollen sterility in faba bean.

Temperatures below 10°C are not necessarily an impediment to flowering in faba bean in southern Australia, unless frosts occur. Further, faba bean in southern Australia is less likely to experience damage from temperatures below 5°C during the reproductive phase, compared with northern Australia.

When temperatures rise in August to September, pods can develop quickly, within 3–6 days. Even after flowers develop into pods, periods of low temperature and poor conditions can cause seed and pod abortion before seedfilling begins. Poor conditions can include less sunlight, as well as windy or rainy weather, which affect pollinator activity.

Early-flowering varieties can be an advantage in some situations, despite the increase in flower and pod abortion with low temperatures.[60 61]

60 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

61 K Siddique (2000) Abiotic stresses of cool season pulses in Australia. Birchip Cropping Group Trials Results Book 1999. Birchip Cropping Group, www.farmtrials.com.au/trial/13486

5.5.2 Frost

Temperatures below 0°C can damage leaves and stems and can cause a characteristic 'hockey stick' bend in the stem (Photo 10). Faba bean can recover from damage in the vegetative phase by generating new tillers in severe cases, if soil moisture is favourable. Severe frosts can cause distortion of vegetative parts, total defoliation and even plant death.

Photo 10: *Severe frost during the vegetative phase can cause characteristic 'hockey stick' bends; faba bean plants have some ability to recover if conditions are favourable.*

Photo: Gordon Cumming, formerly Pulse Australia

In the reproductive phase, temperatures below 0°C can cause faba bean flower, pod and seed abortion. Small pods are more susceptible to frost damage than larger pods (Photo 11); however, larger pods may develop mottled darkening of the seed coat (Photos 12 and 13).

If seasonal conditions are favourable, later-forming pods can compensate for the effects of frost during early flowering on early podset.

Photo 11: *Flowers and smaller pods are more likely to be aborted by frost than larger pods. The extent of damage also depends on the severity of the frost.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 12: *Frost can cause 'staining' of the seed coat next to the pod wall.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 13: *Normal (top) and frosted faba bean seeds.*

Photo: Grain Legume Handbook (2008)

Cold temperatures are moderated by topography and altitude, so there will be warmer and cooler areas in undulating paddocks.

Podset often occurs in August to September, once temperatures rise (and as there is more sunlight and pollinator activity).[62]

5.5.3 High temperature and wind

Faba bean is considered one of the least tolerant winter pulses to drought stress and high temperatures (Photo 14).

Temperatures above 27°C can cause faba bean flowers to abort,[63] while temperatures above 30°C (or a lack of moisture) can stop flowering completely, after which only a few leaf-bearing nodes are produced.

62 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

63 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

Photo 14: *Faba bean are relatively intolerant of high temperatures and drought.*

Photo: Felicity Pritchard

Faba bean flowers are particularly sensitive to hot, dry winds in their early stages of development. As flowers develop, they become less sensitive and once a pod has set and grown longer than the withered petals, it stops being vulnerable to wind and has a good chance of fully developing – if there is adequate soil moisture. If hot, windy days persist and moisture is limiting, more flowers will abort. Researchers suggest planting windbreaks to reduce wind speed on crops.

Faba bean are also particularly sensitive to hot, dry conditions during podding; prolonged cool weather in spring is ideal for pod development. Maximum temperatures above 30°C can reduce the time available for seed-filling.

Faba bean are also prone to lodging and 'necking' – or both, which are two different processes. Lodging and necking both create a crop that is no longer upright and can be difficult to harvest.

Necking is where the faba bean plant remains erect but a proportion of the stem 'necks' over between 90 and 180 degrees (Photo 15). Strong wind conditions can cause faba bean to 'neck', and this seems to be more pronounced during times of moisture stress during the reproductive phase. The stems bend over sharply, virtually snapping, at about pod height. The upper part of the plant either dies or is less able to fill pods.

Sometimes, plants recover from necking and the growing points turn to grow upright again, at times forming an 'S' shape.

Faba bean varieties differ in their susceptibility and resistance to necking but its effect on yield and seed size is largely unknown (Table 4). 'Harvestability' is often reduced. Results from trials in 2014 show the variety Nura⁽ᴾ⁾ is most susceptible. The results for necking were different to lodging; generally, Nura⁽ᴾ⁾ and PB⁽ᴾ⁾ Samira⁽ᴾ⁾ showed improved results over Farah⁽ᴾ⁾. Apart from the Maitland site, lodging was generally low in 2014.

Table 4: Standing ability and necking scores of faba bean varieties from Pulse Breeding Australia trials and National Variety Trials, southern Australia, 2014.

Variety	Standing ability (1–9 = all plants fully upright)					Necking (1–9 = no plants with necking)				
	Freeling, SA	Saddleworth, SA	Bool Lagoon, SA	Maitland, SA	Tarlee, SA	Pinery, SA	Wonwondah, Victoria	Kalkee, Victoria	Maitland, SA	Tarlee, SA
Farah⌽	6.9	8.3	7.3	5.7	7.0	6.7	4.7	6.3	8.3	7.3
Fiesta VF	6.5	7.7	8.0	5.0	7.3	7.3	5.7	no result	8.7	6.7
Nura⌽	7.8	9.0	9.0	4.7	7.7	2.0	2.7	5.0	8.3	7.3
PBA Rana⌽	7.9	7.7	8.3	4.0	8.3	5.0	6.3	5.0	9.0	9.0
PBA Samira⌽	7.8	9.0	8.0	6.7	8.3	3.3	4.7	5.7	7.3	7.3

Source: PBA and NVT trials

Photo 15: *Faba bean can be subject to 'necking' when the stems bend sharply, almost snapping off. Hot winds and moisture stress make the crop more prone to necking.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Lodging can also be caused by strong winds and rain, as well as other factors such as variety, disease, tall crops due to early sowing and dense crops (Photo 16) (see Section 12 Harvest for more information).

Photo 16: *Faba bean crops can lodge, often severely, when stems bend gently. Dense, tall crops, wind and disease increase the chance of the crop lodging.*

Photo: Wayne Hawthorne, formerly Pulse Australia

5.5.4 Drought

The ability of faba bean to retain its flowers is affected by several factors, including drought. Moderate drought and other physiological stressors can reduce the number of pods on faba bean, rather than the number of seeds per pod or the size of the seed.

Faba bean is not deep-rooted, limiting its ability to withstand dry conditions. Although the roots are robust, they can struggle to penetrate hardpans or other subsoil constraints and the crop can leave moisture at depth late in the season. While root growth is rapid before flowering, it can continue until maturity if conditions are favourable.

In a 2008 study, wheat and barley were more effective at extracting soil water than faba bean. In contrast to the cereals, faba bean used 50 mm less water, which was related to its inability to extract water below 85 cm depth and its failure in dry soil below 20% volumetric water content. This additional soil water could be of benefit to the following wheat crop in dry seasons if it could be stored in the profile until the next growing season. Faba bean roots do not produce as much biomass as chickpea or wheat roots.

Under mild moisture stress, faba bean is incapable of accumulating solutes (sugar, protein and other compounds) in its cells; photosynthesis and movement of water and carbon dioxide through the stomata (pores) stop.

5.5.5 Low light

Low light can reduce flower retention and podset in faba bean. If leaves near flowers are shaded or daylight levels are low, there may be insufficient sugars to feed the flowers as photosynthesis is affected.

Intervals of heavy, overcast weather causing low levels of light can reduce flower retention in the critical 4-day window after flowering, even with adequate pollination.

Early-sown faba bean crops in high-rainfall areas may have poor early podset; low light in dense canopies, causing low photosynthesis, is likely to be the major cause, in conjunction with low pollinator activity and possibly chocolate spot.

5.5.6 Humidity

High humidity can reduce podset in faba bean.

5.5.7 Waterlogging

While faba bean is relatively tolerant of waterlogging, the crop is most sensitive to waterlogging at flowering (Photo 17), causing flowers to die and leading to a reduction in yield. For example, at Kerang in north-west Victoria, irrigated faba bean grown on drained soils using tile drains yielded 4.2 t/ha. Faba bean on raised beds yielded 2.7 t/ha and 1.9 t/ha where sown into a conventionally laser-levelled bay.

Photo 17: *Faba bean is particularly sensitive to waterlogging at flowering.*

Photo: Felicity Pritchard

5.5.8 Disease

Chocolate spot in flowers is sometimes thought to cause poor podset. The faba bean strategic disease management plan places strong emphasis on protecting early flowers with fungicide before canopy closure occurs (see Section 9 Diseases for more information).

5.5.9 Agronomic factors

Research at the Waite Research Institute in SA found that sowing rate and time of sowing influence the distribution of faba bean pods along the stem. This may be partly due to poor light penetration into the canopy with a higher sowing rate and early sowing.

More pods set on the lower nodes with a low sowing rate. Pods are more evenly distributed along the stem with a high sowing rate.

Fewer pods per node are set when early sowing, compared with late sowing. However, the individual seed weight is more uniform along the stem for early-sown faba bean. Seed size is reduced significantly towards the top of the plant in late-sown crops. Seed size is affected by weather conditions as well as the number of seeds set and variety.

5.6 Genetic variation

5.6.1 Varietal differences

Varieties differ in the time it takes from first flowering to producing the first pod (early podset). For example, the old variety Barkool sets a pod soon after flowering, whereas Fiesta VF has a delay of several days.

While there is potential for breeders to select for varieties with better early pod retention, some management practices can reduce the amount of inter-plant competition.

Pod size is more affected by variety than environment. Faba bean pods vary considerably between varieties. Seed size is also highly affected by variety, as well as the number of seeds set and environmental conditions.

5.6.2 Breeding determinate varieties

Plant breeders are developing determinate varieties into locally adapted breeding lines. Determinate faba bean plants are much shorter than conventional plant types and may be useful in situations where excessive biomass causes problems. Australian faba bean crops (Photo 18) are prone to excessive biomass and lodging with poor podset when irrigated or grown with high rainfall.

While several determinate faba bean varieties (Photo 19) have been released in Europe, they have not been widely grown as they generally have lower yield than conventional types.

Australian faba bean breeders have attempted to introduce the trait to elite Australian lines that have been in trials in southern Australia. The trials results should give a much clearer indication of whether determinate varieties might overcome some of the problems associated with faba bean in conditions that are conducive to high biomass production.

Photo 18: *An Australian semi-determinate faba bean that is typical of our varieties.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 19: *A breeding line that is determinate: no new growth appears above the pods.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Nutrition and fertiliser

Key points

- **Fertilisers must supply a balance of required nutrients for a crop to achieve its potential yield. Nutrient budgeting and soil and plant tissue tests are tools to help determine fertiliser needs.**
- **Each tonne of faba bean grain removes about 40 kg/ha of nitrogen, 4 kg/ha phosphorus, 10 kg/ha sulfur, 1.3 kg/ha calcium and 1.2 kg/ha magnesium, as well as micronutrients. Faba bean should not normally require any nitrogen fertiliser, except for 'starter' nitrogen in soils with extremely low levels of nitrogen.**
- **Micronutrients are important, particularly zinc, boron, copper, manganese and molybdenum. Deficiencies of micronutrients can be overcome by applying granular or foliar nutrients. Liquid in-furrow treatments can be applied for immobile nutrients such as zinc and copper.**
- **Aluminium and manganese can become toxic to faba bean on acid soils. Boron can also reach toxic levels on alkaline soils. Toxicity from saline soils can be a problem.**
- **Micronutrient deficiencies and toxicities show specific symptoms in faba bean.**
- **Fertiliser applied too close to the seed can be toxic. Acid fertilisers can also inhibit nodulation.**
- **Understanding the nutrient status of a paddock is essential for optimum plant growth.**
- **Healthy plants are more likely to ward off disease, pest and environmental stresses and achieve higher yield and better grain quality.[1]**
- **Nutrients are removed as grain and need to be replaced to ensure adequate soil fertility for following crop yields.**
- **Fertilisers are a major cost of growing a crop. Fertiliser decisions are complex and although individual growers may have different objectives, regardless of circumstance they should know which nutrients are in short supply and which are adequate.[2]**
- **Both under-fertilisation and over-fertilisation can lead to economic losses due to unrealised crop potential or wasted inputs.**

1 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

2 GRDC (2013) Crop nutrition fact sheet: Better fertiliser decisions for crop nutrition. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-BFDCN

6.1 Declining soil fertility

The natural fertility of cropped agricultural soils is declining over time. For example, organic nitrogen in southern Australian soil declines at about 2–3% per year in cropped soils with a 'half-life' of 34–23 years. In the absence of legume-based pastures, mineral nitrogen from native organic matter or pasture residue declines and must be replaced with other legume or nitrogen fertiliser sources.[3]

Grain growers must continually review management programs to ensure the long-term sustainability of high-quality grain production. Pasture leys, legume rotations and fertilisers all play an important role in maintaining the chemical, biological and physical fertility of soils.

Nutrition programs should be reviewed regularly due to more frequent opportunity cropping from improved farming techniques and new higher-yielding varieties. Paddock records, fertiliser test strips, crop monitoring, and soil and plant tissue tests all assist in the formulation of an efficient cropping program.

Although crop rotations with grain legumes and ley pastures play an important role in maintaining and improving soil fertility, fertilisers remain the major source of nutrients to replace those removed by grain production. Fertiliser programs must supply a balance of the required nutrients in amounts needed to achieve a crop's yield potential. High-yielding crops remove large amounts of nutrients once harvested.

The yield potential of a crop will be limited by any nutrient the soil cannot adequately supply. Poor crop response to one nutrient is often linked to a deficiency in another nutrient or management technique. Sometimes, poor crop response can also be linked to acidity, sodicity or salinity, pathogens or a problem with beneficial soil microorganisms.[4]

6.2 Nutrient requirements and fertiliser recommendations

As for all crops, faba bean needs an adequate supply of nutrients for growth and to maximise yield.[5]

Plant nutrients are categorised as either macronutrients or micronutrients (or trace elements).

Macronutrients are those elements that are needed in relatively large amounts. They include nitrogen (N), phosphorus (P) and potassium (K), which are the primary macronutrients, with calcium (Ca), magnesium (Mg) and sulfur (S) considered to be secondary. Higher expected yields of crops for grain or forage will place greater demand on the availability of major nutrients such as phosphorus, potassium and sulfur. Nitrogen, phosphorus and at times sulfur are the main nutrients commonly lacking in Australian soils. Others can be lacking under certain conditions.

Micronutrients are those elements that plants need in small amounts, for example, iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), chlorine (Cl), and molybdenum (Mo).

Macronutrients and micronutrients are taken up by the roots and certain soil conditions are required for that to occur. Soil must be sufficiently moist to allow roots to take up and transport the nutrients. Plants that are moisture-stressed from either too little or too much moisture (saturation) can often exhibit deficiencies even though a soil test may show these nutrients to be adequate.

3 J Kirkegaard (2017) Opportunities and challenges for continuous cropping systems. GRDC Update Paper February 2017, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/opportunities-and-challenges-for-continuous-cropping-systems

4 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

5 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

MORE INFORMATION

A paper on 'Maximising the fixed nitrogen benefits of pulses' was delivered by SARDI's Ross Ballard and the University of Adelaide's Maarten Ryder at the GRDC Updates in February 2017, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/maximising-the-fixed-nitrogen-benefits-of-pulses

The optimum range of temperature, pH and moisture can vary for different pulse species. Soil pH has an effect on the availability of most nutrients and must be within a particular range for nutrients to be released from soil particles.

Soil temperature must be within a certain range for nutrients to be taken up.[6]

In addition to the usual nutrients needed by plants, legumes require the trace element molybdenum, which is critical for the enzyme responsible or nitrogen fixation.[7]

Fertiliser recommendations for faba bean are often generic, with excessive reliance on monoammonium phosphate (MAP) based 'starter' fertilisers.

Fertiliser recommendations should take into account:

- soil type;
- rotation (fallow length and impact on arbuscular mycorrhizae fungi levels);
- yield potential;
- plant configuration (row spacing, type of opener and risk of 'seed burn');
- soil analysis results; and
- effectiveness of inoculation techniques.[8]

6.2.1 Nutrient removal

If nutrients removed as grain from the soil are not replaced, crop yields and soil fertility will fall.

This means that fertiliser inputs must be matched to anticipated yields and soil type. The higher the expected yield, the higher the fertiliser input, particularly for the major nutrients (phosphorus, potassium and sulfur).

The nutrient removal by one tonne of grain in faba bean is shown in Table 1. Actual values may vary by about 3%, due to the differences in soil fertility, varieties and seasons. For example, phosphorus removed per tonne of faba bean grain can vary from 2.8 kg on low-fertility soils to 5.4 kg on high-fertility soils.

A 2.0 t/ha crop of faba bean will, on average, remove approximately 8.0 kg/ha of phosphorus; this is the minimum amount of phosphorus that needs to be replaced. Higher quantities may be needed to build up soil fertility or overcome soil fixation of phosphorus.

Table 1: Nutrients removed by 1 t of faba bean grain; wheat is shown as a comparison (this table is a guide only).

Source	Grain	Kilograms				Grams				
		Nitrogen	Phosphorus	Potassium	Sulfur	Calcium	Magnesium	Copper	Zinc	Manganese
CSIRO 2001	Faba bean at 10% moisture	38	3.8	9.7	1.5	1.3	1.2	10	28	30
Grain Legume Handbook 2008	Faba bean	41	4.0	10.0	1.5	1.3	1.2	10	28	30
	Wheat	23	3.0	4.0	1.5	0.4	1.2	5	20	40

Sources: Grain Legume Handbook (2008) and CSIRO (2001) as cited by Incitec Pivot

6 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

7 E Drew, D Herridge, R Ballard, G O'Hara, R Deaker, M Denton, R Yates, G Gemell, E Hartley, L Phillips, N Seymour, J Howieson, N Ballard (2012) Inoculating Legumes, a Practical Guide. Grains Research and Development Corporation, https://grdc.com.au/GRDC-Booklet-InoculatingLegumes

8 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

Soil types vary in nutrient reserves. Some soils may have substantial nutrient reserves that vary in availability during the growing season or are unavailable due to the soil pH. This can often be the case with micronutrients and foliar sprays can be used in these cases to correct any deficiencies.[9 10]

Figure 1 shows how the availability of nutrients and other elements to plants may be affected by soil pH in mineral soils. In highly organic soils, the influence of pH differs from mineral soils, with maximum availability of nutrients shifting towards the acid end.[11]

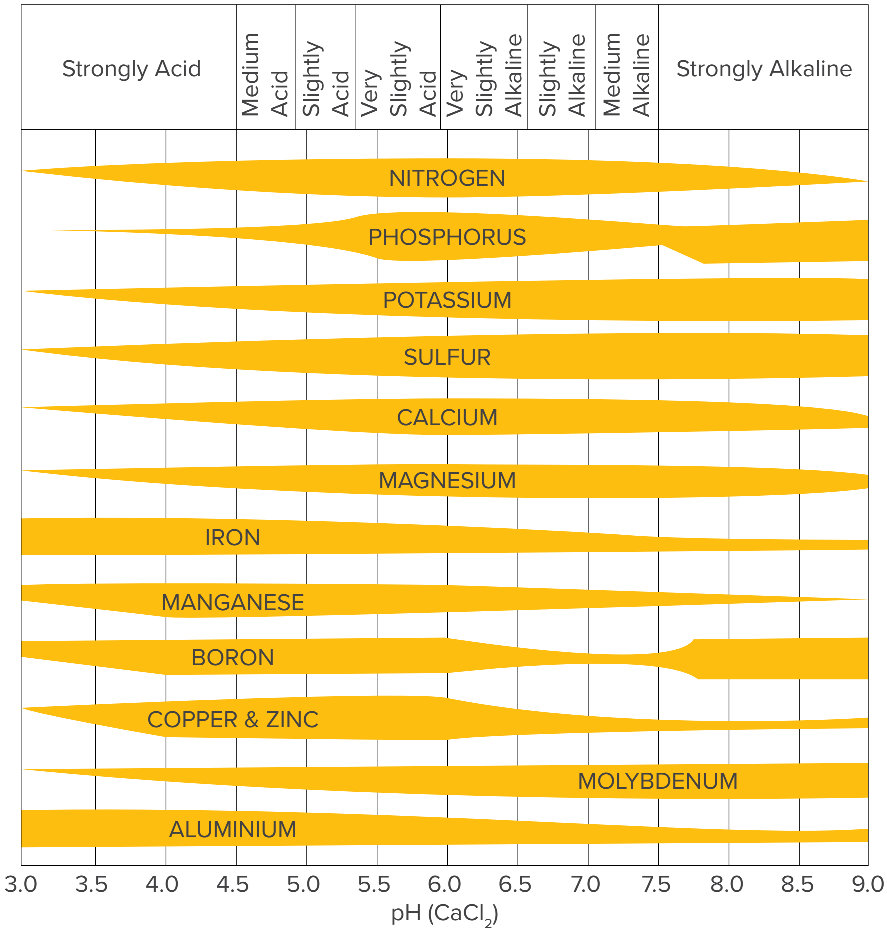

Figure 1: *Influence of soil pH on nutrient availability (wider bars indicate a nutrient is more available to plants at a given soil pH).*

Source: E Truog (1946), Soil reaction influence on availability of plant nutrients, Soil Science Society of America Proceedings

Nutrient removal data will vary with the source of information. Several apps for smartphones and tablets are available with nutrient removal data, such as the International Plant Nutrition Institute's Crop Nutrient Removal Calculator (http://www.ipni.net/article/IPNI-3346).

9 T Rose, P Damon, Z Rengel (2010) Phosphorus-efficient faba bean (Vicia faba L.) genotypes enhance subsequent wheat crop growth in an acid and an alkaline soil. Crop and Pasture Science 61(12). pp 1009–1016, http://epubs.scu.edu.au/plantscience_pubs/165/

10 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

11 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

6.2.2 Nutrient budgeting

A balance sheet approach to inputs is a good starting point in considering fertiliser amounts to apply. Other factors such as soil type, paddock history, soil test and tissue analysis results, as well as experience, all affect fertiliser decisions.

Precision agriculture can help growers manage land and crop variability; fertiliser rates can be varied to allocate higher rates to high-performing parts of a paddock. Fertiliser replacement maps can be created, based on previous crop yield.[12]

A simple nutrient budget, such as the one shown in Table 2, still requires careful interpretation.[13] This is a useful tool for assessing the nutrient balance of a cropping rotation. However, it needs to be considered in conjunction with other nutrient management tools such as soil and tissue testing, soil type, soil fixation and potential yields.[14]

Table 2: An example of a four-year nutrient budget of a cropping paddock including faba bean.

			Nutrients removed (kg/ha)			
			N	P	K	S
2014	Faba bean	2.2	90	9	22	3
2015	Wheat	3.8	87	11	15	6
2016	Barley	4.2	84	11	21	6
2017	Chickpea (desi)	1.8	59	6	16	4
Total			**230**	**37**	**74**	**19**
			Nutrients applied (kg/ha)			
	Fertiliser (N:P:K:S)	kg/ha	N	P	K	S
2013	0:20:0:0.5	50	0	10	0	1
2014	18:20:0:0.5	70	13	14	0	1
2015	18:20:0:0.5	70	13	14	0	1
	Urea	60	28	0	0	0
2016	0:16:0:20	80	0	13	0	16
Total		**53**	**0**	**51**	**0**	**19**
Balance			**–267**	**+14**	**–74**	**0**

Source: Modified from example in Grain Legume Handbook

The deficit of 267 kg/ha nitrogen in Table 2 needs to be countered by any nitrogen fixation. If this is estimated to be 50 kg/ha for each pulse crop, the budget suggests that the soil nitrogen status is declining and should be increased by using more nitrogen in the cereal phase. Estimating nitrogen fixation is not easy. One 'rule of thumb' to use is 20 kg nitrogen fixed for each tonne of plant dry matter at flowering.

The credit of 14 kg/ha of phosphorus (Table 2) will be used in the soil in building soil phosphorus levels. No soil fixation of phosphorus has been considered.

In this budget, the sulfur levels are in balance (Table 2).

Trace elements such as zinc and copper can also be included in a nutrient budget.

As there are many fertilisers available to use on pulses, for the best advice check with your local fertiliser reseller or agronomist.[15]

12 GRDC (2009) Precision agriculture fact sheet. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2010/02/precision-agriculture

13 GRDC (2014) GrowNotes™: Faba bean (northern region). Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes™

14 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

15 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

6.2.3 Acid fertilisers reduce nodulation

Inoculated seed and acidic fertilisers should not be sown through the same tube, as the acidity will kill large numbers of rhizobia. Neutral and alkaline fertilisers can be used (Table 3).

Table 3: Some acid, neutral and alkaline fertilisers used for faba bean crops. Acid fertilisers should not be sown through the same tube as inoculated seed but neutral and alkaline fertilisers can be used.

Acid	Neutral	Alkaline
Superphosphates (single, double and triple)	Super lime	DAP (also known as 18:20:0)
Fertilisers with copper and/or zinc		Starter NP
MAP (also known as 11:23:0 and Starter 12)		Lime

Source: Southern faba and broad bean best management practices training manual (2016)

6.3 Soil testing

Soil testing is the only quantitative nutrient information that can be used to predict yield response to nutrients. To determine how much fertiliser to apply, soil test results need to be considered in combination with information about potential yield, soil type and nutrient removal in previous seasons (see Section 2 Planning and paddock preparation for more information).

Soil samples should be taken before sowing so that results and recommendations are available in time to order the right fertiliser products. Regular planned sampling of paddocks (for example, every 3 years) allows monitoring of fertility trends over time.[16]

Soil test results are part of the information that supports decisions about fertiliser type, rate, timing and placement. Principal reasons for soil testing for nutrition include:

- monitoring soil fertility levels;
- estimating which nutrients are likely to limit yield;
- measuring properties such as pH, sodium (sodicity) and salinity, which affect the crop water demand as well as the ability to access nutrients;
- zoning paddocks for variable application rates; and
- as a diagnostic tool, to identify reasons for poor plant performance.[17]
- The soil test for measuring nitrogen, phosphorus, potassium and sulfur in the southern region are:
- bicarbonate extractable P (Colwell-P);
- diffusive gradients in thin-films (DGT) for P (DGT-P is a relatively new method currently being tested for use with Australian soils, and mimics the action of the plant roots in accessing available phosphorus (more information is available in the phosporus fact sheet from soilquality.org.au: http://www.soilquality.org.au/factsheets/phosphorus);
- bicarbonate extractable K (Colwell-K);
- 2 M KCl extractable inorganic N, which provides measurement of nitrate-N and ammonium-N; and
- KCl-40 extractable S test method (the KCl-40 test is also called the CPC or the Blair sulfur (KCl 40)) is also reported as the MCP test.[18]

16 GRDC (2013) Crop nutrition fact sheet: Better fertiliser decisions for crop nutrition. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-BFDCN

17 GRDC (2014) Crop nutrition fact sheet: Soil testing for crop nutrition (southern region). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SoilTestingS

18 DEDJTR (2015) Interpreting soil and tissue tests. Victorian Department of Education, Jobs, Transport and Resources, http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/soils/understanding-soil-tests-pastures

MORE INFORMATION

Listen to an interview on soil testing
https://grdc.com.au/~/media/Audio/Driving-Agronomy/nigel-wilhelm-mp3.mp3

The soil P test needs to be interpreted in association with the soil's phosphorus-adsorption capacity, which is estimated by the phosphorus buffering index (PBI). The higher the PBI value, the more difficult it is for a plant to access phosphorus. Phosphorus is relatively immobile in soils and phosphorus applied to the 0–10 cm layer tends to remain in that layer, especially in no-till systems.[19]

Choose a laboratory that has the Australasian Soil and Plant Analysis Council (ASPAC) certification for the tests they offer. National Association of Testing Authorities (NATA) accreditation is also desirable.[20]

6.3.1 Critical values and ranges

A soil test critical value is the soil test value required to achieve 90% of crop yield potential. The critical range around the critical value indicates the reliability of that single value.

Recently, revised critical soil test values and ranges were established for nutrients, crops and soil classes in south-east Australia. While the revised values and ranges do not include faba bean, for field pea, the Colwell-P soil test critical value is 24 mg/kg, with a range of 21–28 mg/kg; field pea grain removes slightly less phosphorus per tonne than faba bean. Currently used critical values for faba bean are shown in Table 4.

Critical ranges are established for 0–10 cm; however, soil sampling to greater depth (60 cm) is important for more mobile nutrients, such as nitrogen, sulfur and potassium, as well as for pH, salinity and sodicity. Use local data and support services to help integrate soil test data into making profitable fertiliser decisions.[21]

19 GRDC (2014) Crop nutrition fact sheet: Soil testing for crop nutrition (western region). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SoilTestingW

20 GRDC (2013) Crop nutrition fact sheet: Better fertiliser decisions for crop nutrition. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-BFDCN

21 GRDC (2014) Crop nutrition fact sheet: Soil testing for crop nutrition (southern region). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SoilTestingS

Table 4: Adequate nutrient levels for various soil test results. If a soil test value is less than the lower limit of the range, the site is highly likely to respond to an application of the nutrient.

Nutrient	Test used		
Phosphorus			
	Colwell (mg/kg)	Olsen	
Sand	20–30	10–15	
Loam	25–35	12–17	
Clay	35–45	17–23	
Potassium			
	Bicarbonate	Skene	Exchangeable K
Sand	50	50–100	Not applicable
Other soils	100	100	0.25 meq/100g
Sandy loam	–	–	–
– Faba bean	100–120	–	–
– Field pea	70–80	–	–
– Lupin	30–40	–	–
– Canola	40	–	–
– Cereals	30	–	–
Sulfur			
	KCl (mg/kg)		
Low	5		
Adequate	8		

Sources: Nutrition management (2010); Queensland DAF, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview; Soil testing for crop nutrition (2014)

6.4 Plant tissue testing

Tissue testing is the best way to accurately diagnose a suspected micronutrient deficiency.

Plant tissue testing is most useful for monitoring crop health, because by the time noticeable symptoms appear in a crop the yield potential can be markedly reduced. A plant tissue analysis can detect non-visible (sub-clinical) symptoms, and to fine-tune nutrient requirements.

When tissue testing, sample the appropriate tissues at the right time. Plant nutrient status varies according to the plant's age, variety and weather conditions. Technology is allowing quicker analysis and reporting of results to enable timely application of foliar or soil-applied fertiliser, for a rapid crop response.[22]

Different plants have different critical concentrations for a nutrient and in some cases varieties can vary in their critical concentrations.[23] Table 5 lists the plant analysis criteria for faba bean.

6.4.1 Critical nutrient levels

Table 5: Critical nutrient levels for faba bean at flowering. (These should be used as a guide only and care should be taken to use plant tissue tests for the purpose for which they have been developed; most tests diagnose only the nutrient status of the plants at the time they are sampled and cannot reliably indicate the effect of a particular deficiency on grain yield.)

Nutrient	Plant part	Critical Range *
Nitrogen (%)	Youngest open leaf	4.0
Phosphorus (%)	Youngest open leaf	0.4
Potassium (%)	Youngest mature leaf	1.0
Calcium (%)	Youngest mature leaf	0.6
Magnesium (%)	Youngest mature leaf	0.2
Sulfur (%)	Whole shoot	0.2
Boron (mg/kg)	Youngest open leaf	10
Copper (mg/kg)	Youngest mature leaf	3.0 to 4.0
Manganese (mg/kg)	Youngest mature leaf	<40
Zinc (mg/kg)	Youngest open leaf	20–25

* Any nutrient level below the critical range will be deficient; any level above will be adequate.
Source: Southern faba bean best management practices training course manual (2016)

22 GRDC (2013) Crop nutrition fact sheet: Micronutrients (northern, southern and western regions). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

23 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

6.5 Nutrient disorders

Visual symptoms of nutrient disorders do not develop until a major effect on yield, growth or development has occurred (Figure 2). This is called sub-clinical deficiency or toxicity.

Healthy plants have a greater potential to ward off disease, pests and environmental stresses leading to higher yields and better grain quality.

6.5.1 Diagnosing nutrient deficiency

The following points should be considered when diagnosing nutrient disorders:

- Visual symptoms on lentil may be caused by damage from herbicides, insects, and pathogens. Damage may also be from physiological disorders arising from adverse environmental effects such as salinity, drought, cold, heat or high temperature stresses. Such symptoms can be indistinguishable from nutrient deficiency, although it should be obvious if environmental conditions are limiting (moisture stress).
- Factors that influence both nodulation and nitrogen fixation can result in symptoms of nitrogen deficiency.
- There can be differences between cultivars in the manifestation of symptoms.
- Visual symptoms in one pulse do not necessarily mean that it is the same in other pulses.

Table 6 provides a key to diagnosing nutrient deficiencies in faba bean.

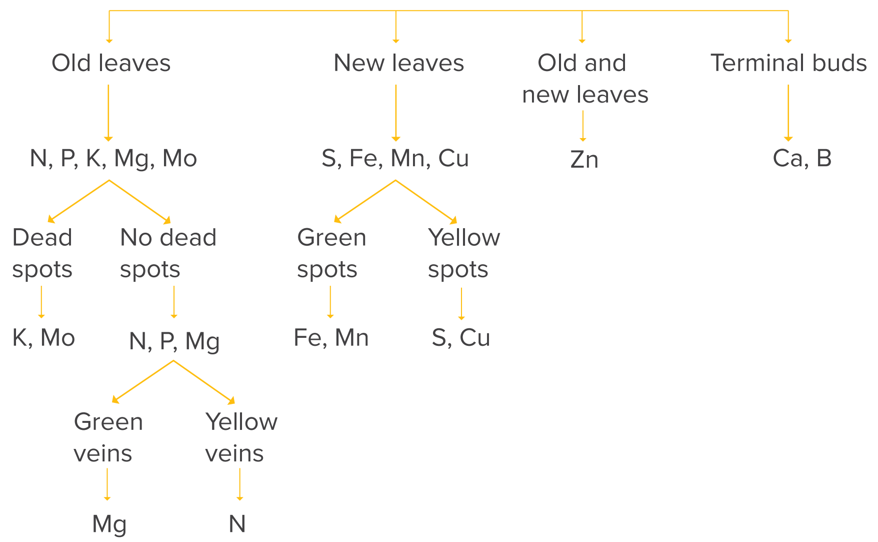

Figure 2: *Flow chart for the identification of deficiency symptoms.*

Source: T Reddy, G Reddi (1997)

Table 6: Key to nutrient deficiencies in faba bean.

Deficiency symptom	Old to middle leaves						Middle to new leaves					New leaves to terminal shoots					
	N	P	S	K	Mg	Zn	N	Mg	Mn	Zn	B	Mn	Fe	Zn	Cu	Ca	B
Chlorosis (yellowing)																	
Complete	X		X									X#	X				X#
Mottled	X	X	X		X					X	X						
Between veins					X						X						
On margins			X		X												
Necrosis (dead tissue)																	
Complete		X				X											
Distinct areas (including spotting)				X		X		X	X		X	X		X			
Margins													X			X	
Tips				X		X			X			X		X	X		
Pigmentation within necrotic or chlorotic areas																	
Purple	X	X	X	X		X		X	X	X		X				X	
Dark green		X									X						
Brown		X	X						X		X	X	X	X			
Red					X						X			X			
Malformation of leaflets																	
Rolling-in of margin				X				X					X			X	X
Wilting						X	X								X		
Twisting									X			X			X		X
Malformation of leaves																	
Cupping	X						X								X		
Umbrella formation								X			X						
Malformation of stems and roots																	
Internode shortening											X			X			X
Petiole collapse																X	
Root distortion											X		X			X	X

Mild

Sources: Snowball and Robson via Southern faba bean best management practices training course manual (2016); Symptoms of nutrient deficiencies and toxicities: faba beans and field peas (1991)

Many nutrient deficiencies may look similar. It is important to:

- know what a healthy plant looks like in order to recognise symptoms of distress;
- determine what the affected areas of the crop look like (for example, are they discoloured (yellow, red, brown), dead (necrotic), wilted or stunted);
- identify the pattern of symptoms in the field (patches, scattered plants, crop perimeters);
- assess affected areas in relation to soil type (pH, colour, texture) or elevation; and
- look at individual plants for more detailed symptoms such as stunting, wilting and where the symptoms are appearing (whole plant, new leaves, old leaves, edge of leaf, veins etc.).

If more than one problem is present, typical visual symptoms may not occur. For example, water stress, disease or insect damage can mask a nutrient deficiency. If two nutrients are simultaneously deficient, symptoms may differ to that when deficient alone.

Micronutrients are often used by plants to process other nutrients or work together with other nutrients, so a deficiency of one may look like another. For instance, molybdenum is required by pulses to complete the nitrogen fixation process.

6.5.2 Nutrient toxicity

Soil pH affects the availability of most nutrients. Occasionally some nutrients are made so 'available' that they inhibit plant growth. For example, on some acidic soils, aluminium and manganese levels may restrict faba bean growth, usually by restricting the rhizobia and the plants' ability to nodulate.[24]

The most common nutrient toxicities in subsoils of the medium and low-rainfall areas of south-eastern Australian are boron, sodium, carbonate and bicarbonate. In the high-rainfall regions, where high rates of leaching occur, subsoil acidity can develop. This causes specific nutrient toxicities, especially aluminium and manganese.

Under saline conditions, the presence of high concentrations of salts reduces growth by osmotic stress, in which the presence of high salt concentrations restricts water uptake, and by the direct toxic effect of sodium and chloride ions in the plant tissues.[25]

Table 7 shows the sensitivity of faba bean to boron, aluminium and manganese.

Table 7: Pulse crop sensitivity to toxic levels of manganese, aluminium and boron.

	Manganese	Aluminium	Boron
Faba bean	Sensitive	Sensitive	Tolerant
Field pea	Sensitive	Sensitive	Sensitive
Lentil*	Very sensitive	Very sensitive	Very sensitive
Chickpea	Very sensitive	Very sensitive	Sensitive
Lupin*	Tolerant	Tolerant	–

*These crops are not usually grown on alkaline/high boron soils.

Source: Southern faba bean best management practices training course manual, (2016), Pulse Australia Limited.

24 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

25 D Adcock, R Armstrong, F Best, D Chittleborough, M Imhof, G McDonald, A McNeill, J Nuttall, N Wilhelm (2009) Nutrient deficiencies, toxicities and imbalances. Identifying, Understanding and Managing Hostile Subsoils For Cropping – A Reference Manual for Neutral-Alkaline Soils of South-Eastern Australia. The Profitable Soils Group. pp 31–39, http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_mgmt_subsoil

Soil acidity

Soil acidity and alkalinity are measured in units of pH. The pH scale is from 0 (most acid) to 14 (most alkaline) and a pH of 7 is neutral. The pH of a soil will change over time influenced by factors including parent material, weathering and current agricultural practices. It will also fluctuate through the year. Soil pH will affect how plants grow[26] (Figures 3 and 4).

While faba bean is generally considered sensitive to soil acidity, it may be successfully grown on slightly acidic soils (pH ($CaCl_2$) >5.0– 6.0) in the high and medium-rainfall zones of south-eastern Australia with inconsistent yields.

Use appropriate lime rates to maintain pH ($CaCl_2$) >5.5 in the entire top 10 cm layer. Under no-till systems, lime topdressing with no incorporation is ineffective in neutralising acidity below about 5 cm depth. Acidic soil layers below 5 cm adversely affect root growth and architecture, nodulation, plant vigour and N_2 fixation potential of acid-sensitive pulses.[27]

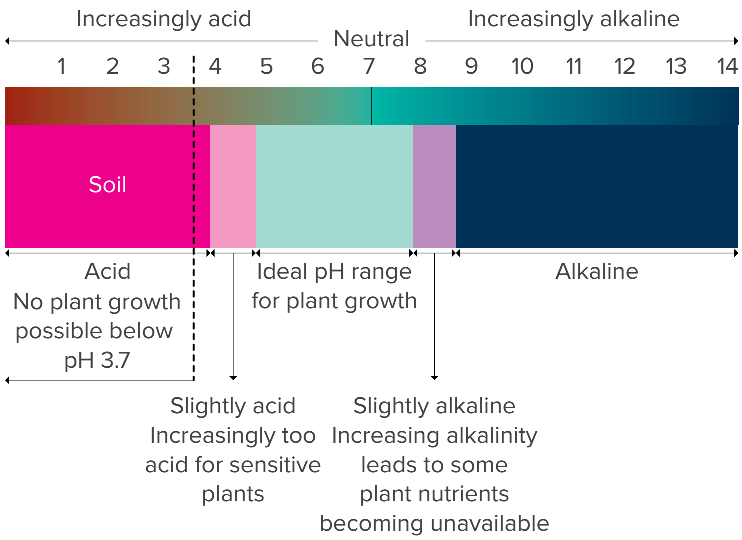

Figure 3: *Plant growth and pH ($CaCl_2$) scale*

Note: Faba bean prefers alkaline soils. The crop may benefit from lime application on acid soils.

Source: B Lake (2000) Understanding soil pH

26 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

27 H Burns (2017) Topsoil pH stratification impacts on pulse production in South East Australia, GRDC Update Paper February 2017, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2017/02/Topsoil-pH-stratification-impacts-on-pulse-production-in-South-East-Australia

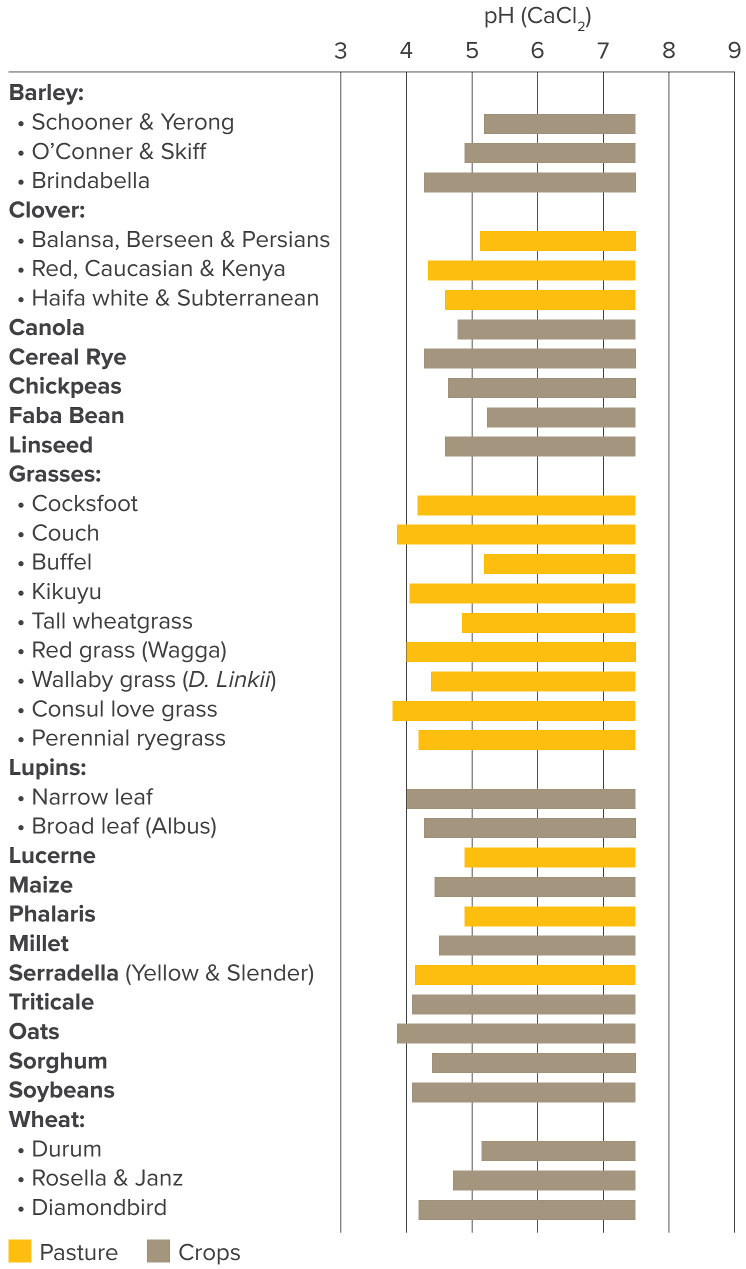

Figure 4: *Optimum pH ($CaCl_2$) range up to pH 7.5 for a number of crops and pastures. Above pH 7.5 the acidity/alkalinity is no longer the principal factor that controls growth. Other factors, such as phosphorus, zinc, cobalt or boron deficiency or the sodicity of soil are most likely to affect production.*

Source: B Lake (2000), Understanding soil pH

Concentrations of elements such as aluminium, iron and manganese can reach toxic levels because their solubilities increase in acid soils.

Nitrogen fixation (see Section 2 Planning and paddock preparation for more information) by faba bean and other legumes can be greatly reduced in acid soils. The optimal pH for nitrogen fixation is a narrow range for different crops. For example, in soybean, this is pH ($CaCl_2$) 6.0–6.2.

The availability of nutrients such as phosphorus and molybdenum is reduced on acid soils, while potassium may be more likely to leach (see Figure 1).

Manganese toxicity

Faba bean is very sensitive to aluminium and manganese toxicity, which often occur on acidic soils and are generally unsuited to the crop.[28] Manganese becomes more soluble in acid soils and can reach toxic levels.[29]

Symptoms of manganese toxicity appear on new leaves first (Photo 1). Small purple spots appear from the margins on young leaves. Symptoms later develop in middle and older leaves. Slightly older leaves take on a red colour.[30]

Leaf crinkling and cupping is also symptom of manganese toxicity in faba bean. The cupping is thought to be caused by manganese accumulation in the leaf margin area, slowing the growth of that area relative to the rest of the leaf.[31]

Hydroponic faba bean grown in high concentrations of manganese had less chlorophyll than healthy plants, while root and shoot development were more than halved in trials.[32]

Photo 1: *Manganese toxicity in faba bean in young leaflets (left) and middle leaflets (right).*

Photo: Alan Robson; Grain Legume Handbook (2008)

Where faba bean is grown on acid soils of 5.0 pH ($CaCl_2$), a topsoil test for aluminium and/or manganese should be carried out. Lime should be incorporated at 2.5–5.0 t/ha if manganese exceeds 50 mg/kg.[33]

Aluminium toxicity

Aluminium toxicity can develop in faba bean crops that are well-nodulated but grown in low pH soils. Aluminium becomes more soluble in acid soils, and can reach toxic levels.

Although aluminium has not been shown to be essential for plant growth, it becomes increasingly soluble as the soil pH ($CaCl_2$) falls below 5.0. The aluminium in the soil solution restricts cell wall expansion and root growth.

Aluminium toxicity is probably the most important growth-limiting factor for plants in many strongly acidic soils where pH ($CaCl_2$) is less than 4.5 (or pH in water <5.0).

Symptoms of aluminium toxicity in faba bean are delayed germination and miniature, dark green plants. Roots are extremely stunted and with many laterals appearing to

28 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

29 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

30 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

31 KR Helyar (1981) The symptoms and effects on plants of nutrient disorders in acid soils. Proceedings The Acid Soils Affair: Riverina Outlook Conference. Riverina College of Advanced Education, www.regional.org.au/au/roc/1981/roc198147.htm

32 S Arya, BK Roy (2011) Manganese induced changes in growth, chlorophyll content and antioxidants activity in seedlings of broad bean (*Vicia faba* L.). Journal of Environmental Biology 32(6). pp 707–711, www.researchgate.net/publication/223983778_Manganese_induced_changes_in_growth_chlorophyll_content_and_antioxidants_activity_in_seedlings_of_broad_bean_Vicia_faba_L

33 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

be dead. Under field conditions it is often difficult to observe root systems because affected plants are very susceptible to moisture stress and die easily.[34, 35]

Aluminium in plants upsets the phosphorus metabolism; symptoms may be confused with phosphorus deficiency.

Where faba bean is grown on acid soils a topsoil test for aluminium and/or manganese should be carried out. Lime should be incorporated at 2.5–5.0 t/ha if aluminium exceeds 20 mg/kg. Table 8 shows the effect of liming on the level of exchangeable aluminium.[36]

Table 8: Liming at 2.5 t/ha on a red chromosol in southern New South Wales reduced exchangeable aluminium content by 93%.

Treatment	Soil pH ($CaCl_2$)	Exchangeable aluminium (cmol(+)/kg)
No lime	4.2	1.08
Lime	5.0	0.08

Source: Australian Soil Fertility Manual (2006)

In a long-term trial in southern New South Wales, soil pH ($CaCl_2$) at 15–20 cm depth increased gradually from about 4.1–4.6 by liming the topsoil, while the topsoil pH was maintained. As the subsoil became less acidic, the percentage of exchangeable aluminium at 15–20 cm dropped from 42 to 10% by 2005, 13 years after initial liming.[37]

A trial in Hamilton, Victoria, found no differences in yield of faba bean due to lime application, with rates varying from 0–3.5 t/ha on a soil with pH ($CaCl_2$) 4.7 (pH 4.0 in water). The researchers concluded the results may have been due to the unusually low aluminium levels in the soil.[38]

Boron toxicity, salinity and sodicity

Faba bean are affected by high salinity (salt) and boron levels in alkaline subsoils in many parts of the southern region.[39] High boron and salt can restrict root growth and water uptake.[40] Salinity often occurs with sodicity (excessive sodium). Field research in Victoria and South Australia shows that soil salinity and sodicity can substantially reduce crop yields.

In south-eastern Australia, a short-term change in soil salinity is termed 'transient salinity', which often occurs with transient sodicity in semi-arid environments such as the Victorian Wimmera and Mallee. The constraints caused by saline and sodic soils operate at the same time to decrease the effective root zone of crops, limiting plant-available water.[41]

Developing varieties with boron and salt tolerance is a long-term aim of the pulse breeding programs in southern Australia, to help alleviate the effects of soil variability.[42]

MORE INFORMATION

Identifying, understanding and managing hostile subsoils for cropping – A reference manual for neutral-alkaline soils of south-eastern Australia, http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_mgmt_subsoil

34 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

35 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

36 KR Helyar (1981) The symptoms and effects on plants of nutrient disorders in acid soils. Proceedings The Acid Soils Affair: Riverina Outlook Conference. Riverina College of Advanced Education, www.regional.org.au/au/roc/1981/roc198147.htm

37 G Li, M Conyers, B Cullis (2010) Long-term liming ameliorates subsoil acidity in high rainfall zone in southeastern Australia. Proceedings 19th World Congress of Soil Science for a Changing World 1–6 August 2010, Brisbane, vol. 1. pp 2375–2378, www.soilscienceaustralia.com.au/19th-world-congress-of-soil-science

38 S Holden, A Spiers (2000) Lime trial. Southern Farming Systems 1999 research manual. Southern Farming Systems, www.farmtrials.com.au

39 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

40 S Arya, BK Roy (2011) Manganese induced changes in growth, chlorophyll content and antioxidants activity in seedlings of broad bean (*Vicia faba* L.). Journal of Environmental Biology 32(6). pp 707–711, www.researchgate.net/publication/223983778_Manganese_induced_changes_in_growth_chlorophyll_content_and_antioxidants_activity_in_seedlings_of_broad_bean_Vicia_faba_L

41 D Adcock, R Armstrong, F Best, D Chittleborough, M Imhof, G McDonald, A McNeill, J Nuttall, N Wilhelm (2009) Salinity and sodicity. Identifying, Understanding and Managing Hostile Subsoils For Cropping – A Reference Manual for Neutral-Alkaline Soils of South-Eastern Australia. The Profitable Soils Group. pp 41–50, http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_mgmt_subsoil

42 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

The most characteristic symptom of boron toxicity in pulses is chlorosis (yellowing) and, if severe, some necrosis (death) of leaf tips or margins. Older leaves are usually more affected. There appears to be little difference in reaction between current faba bean varieties.

Shallow (top 10 cm) and deep (10–90 cm) soil tests can be a good guide of the suitability of some soils for growing faba and broad bean to indicate which toxicities may impact on plant growth and rooting depth.[43]

The degree of salinity in the soil is measured as electrical conductivity (EC). Plants growing on saline soils often exhibit wilting even when the soil water is adequate.[44]

Photo 2: *Boron toxicity in old and middle faba bean leaves.*

Photo: Alan Robson; Grain Legume Handbook (2008)

6.6 Nitrogen

6.6.1 Nutrition effects on following crop

Agricultural legumes fix large quantities of Nitrogen. This represents a huge saving of fertiliser Nitrogen that would otherwise need to be applied, and has positive economic and environmental consequences. Assuming 80% conversion of fertiliser N into plant N, the 40 million t of biologically fixed Nitrogen has a fertiliser-N equivalence of 50 million t, or about 50% of current global inputs of nitrogenous fertilisers. The nominal annual value of the fixed Nitrogen is about $63 billion (assuming cost of fertiliser N of $1.25/kg).[45]

In Australia, 23 million ha of legume based pastures are estimated to fix around 2.5 million t of Nitrogen annually, based on average production of 3.0 t/ha of legume biomass and rates of Nitrogen fixation of 110 kg N/ha (Table x). Nitrogen fixation by the crop legumes is estimated at greater than 0.2 million t annually. Using

the assumptions above, the economic value of the Nitrogen fixed by legumes in Australian agricultural systems is greater than $4 billion annually.

43 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

44 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

45 D Herridge (2013). Managing Legume and Fertiliser N for Northern Grains Cropping (GRDC)

Table 9: Estimates of the amounts of N2 fixed annually by crop legumes in Australia

Legume	%Ndfa	Shoot DM[1] (t/ha)	Shoot N (kg/ha)	Root N[2] (kg/ha)	Total crop N (kg/ha)	Total N fixed[3] (kg/ha)
Soybeans	48	10.8	250	123	373	180
Lupins	75	5.0	125	51	176	130
Faba beans	65	4.3	122	50	172	110
Field peas	66	4.8	115	47	162	105
Peanuts	36	6.8	190	78	268	95
Chickpeas	41	5.0	85	85	170	70
Lentils	60	2.6	68	28	96	58
Mungbeans	31	3.5	77	32	109	34
Navy beans	20	4.2	105	43	148	30

%Ndfa, % of legume N derived from N2 fixation

1 DM = dry matter 2 Root N = shoot N x 0.5 (soybeans), 1.0 (chickpeas) or 0.4 (remainder) 3 Total N fixed = %Ndfa x total crop N

Source: Primarily Unkovich et al. (2010) via D Herridge (2013) Y Managing Legume and Fertiliser N for Northern Grains Cropping (GRDC).

6.6.2 Nitrogen fertiliser

Well-nodulated faba bean crops should be self-sufficient for nitrogen and should not normally need nitrogen fertiliser.[46]

Crops with larger biomass generally fix more nitrogen and also remove more nitrogen in grain. Table 9 shows how nitrogen is likely to be distributed in faba bean crops yielding between 0.5–3.0 t/ha of grain.

Table 10: Estimated nitrogen distribution and removal in faba bean crops with a range of grain and dry matter yields. The more dry matter, generally the more nitrogen fixed and removed from the soil.

Total plant dry matter (t/ha)	Total shoot dry matter yield (t/ha)	Grain yield (t/ha) at 40% harvest index*	Total crop nitrogen requirement (2.3% N) (kg/ha)	Nitrogen removal in grain (kg/ha)
1.75	1.25	0.5	40	17
3.50	2.50	1.0	80	33
5.25	3.75	1.5	120	0
7.00	5.00	20	160	66
8.75	6.25	2.5	200	83
10.50	7.50	3.0	240	100

Source: Southern faba bean best management practices training course manual (2016)

In southern Australia 'starter' nitrogen fertiliser, such as monoammonium phosphate (MAP) and diammonium phosphate (DAP), is not considered necessary in most situations, except for pulses growing in soils with extremely low levels of plant-available nitrogen.[47]

46 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

47 E Drew, D Herridge, R Ballard, G O'Hara, R Deaker, M Denton, R Yates, G Gemell, E Hartley, L Phillips, N Seymour, J Howieson, N Ballard (2012) Inoculating Legumes, a Practical Guide. Grains Research and Development Corporation, https://grdc.com.au/GRDC-Booklet-InoculatingLegumes

Nitrogen fertiliser should be considered:

- with late sowing or low fertility situations, where rapid early growth is critical in achieving adequate height and sufficient biomass to support a reasonable grain yield; or
- where the grower is unwilling to undertake recommended inoculation procedures.

Many growers use starter fertilisers on pulses. Rates of 5–10 kg/ha of starter nitrogen may aid establishment of faba bean on light, slightly acid soils. Nodulation is not affected by low rates of nitrogen nor will it make the nodules 'lazy'; early plant vigour and yields are often improved.[48] Starter MAP or DAP. can encourage early root growth to establish a stronger plant.

This is supported by pot experiments, where nodule development in the faba bean variety Fiord was slightly stimulated in the presence of low levels of nitrate, which compensated for the poor early seedling growth that occurred when plants were grown without mineral nitrogen. However, doubling or trebling the concentration of nitrate delayed nodulation, decreased nodule number and decreased nodule activity of Fiord.[49]

Excessive use of starter nitrogen fertiliser, or high levels of soil nitrate can delay or reduce nodulation and reduce nitrogen fixation.[50]

6.6.3 Nitrogen deficiency symptoms

The first sign of nitrogen deficiency in faba bean is a general paleness of the whole plant.[51] The middle to new leaves may 'cup'. A mottled yellowing (chlorosis) of old leaves slowly develops with little sign of dead tissue (necrosis). Oldest leaves are most affected.[52] Nitrogen-deficient plants are also stunted[53] (Photo 3).

Nodulation failure

If nitrogen deficiency is suspected, assess nodulation (Photo 4).

Nodulation should be assessed 10–12 weeks after sowing until early flowering.

48 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

49 A Herdin, JH Silsbury (1989) Nodulation and early growth of faba bean (*Vicia faba* L.) and pea (*Pisum sativum* L.) as affected by strain of *Rhizobium*, NO_3- supply, and growth temperature. Australian Journal of Agricultural Research 40(5). pp 991–1001, http://www.publish.csiro.au/cp/AR9890991

50 BASF (undated) Nodulaid N/T. Group F faba bean inoculant label. BASF Australia Ltd, http://www.agro.basf.com.au/images/Labels/NODULAID-NT-Group-F-Favabean-TXT-LABEL.pdf

51 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

52 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

53 M Wurst, W Hawthorne, A Nikandrow, M Ramsey, T Bretag, J Davidson, R Gilbert, W MacLeod, G Murray, K Panagiotopoulos, M Schwinghamer (2002) Winter Pulse Disorders: The Ute Guide. Primary Industries and Resources South Australia.

Photo 3: *Nitrogen deficiency in faba bean. Plants show signs of stunting, yellowing and poor growth compared with well-nodulated plants.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 4: *When plants show signs of nitrogen deficiency, check nodulation and nodule colour to confirm nodulation failure and nitrogen deficiency.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 5: *Good nodulation (left), poor nodulation (right).*

Photos: Maarten Ryder

Nodulation has failed where few or no nodules are present on the root system and those present lack red pigmentation inside[54] (Photo 5). Nodulation around the crown of the taproot are more effective than nodules scattered along lateral roots.[55]

Poor nodulation may be caused by low number of viable rhizobia due to:

- incorrect strain of rhizobia;
- incompatibility with some seed dressings and superphosphate;
- inoculant not stored on-farm in cool conditions;
- inoculated seed left for more than two days before sowing; or
- inoculated seed left in hot, dry or windy conditions or in direct sunlight for some time.

Alternatively, poor nodulation may be caused by a poor method of inoculation:

- inoculant is used but seed covering is poor;
- there are poor conditions for nodulation; or
- the crop under stress (for example, herbicide injury, waterlogging, nutritional deficiency or toxicity) (see Section 4.4 Inoculation for more information).

54 M Wurst, W Hawthorne, A Nikandrow, M Ramsey, T Bretag, J Davidson, R Gilbert, W MacLeod, G Murray, K Panagiotopoulos, M Schwinghamer (2002) Winter Pulse Disorders: The Ute Guide. Primary Industries and Resources South Australia.

55 M Raynes, K Wansink (2000) Growers' guide to assessing nodulation in pulse crops. Topcrop fact sheet. Victorian Department of Natural Resources and Environment.

6.7 Phosphorus

Phosphorus is the major nutrient required for faba bean. Fertiliser programs are built on the amount of phosphorus needed, as phosphorus is the basis of soil fertility.

6.7.1 Occurrence of phosphorus deficiency

Phosphorus deficiency may be more limiting to world crop production than other deficiencies, toxicities and diseases. Most Australian soils do not have sufficient phosphorus. Many factors affect the availability of applied and residual phosphorus to plants (Table 10).

Table 11: The availability of phosphorus to crops varies with several factors.

Factor	Details
Soil pH	Availability is best when pH ($CaCl_2$) is between 5.0 and 6.0.
Clay content	High clay soils 'tie-up' (fix) more phosphorus than sandy soils.
Type of clays	Soils high in certain types of clay fix more phosphorus; including those common in high-rainfall areas and soils formed from volcanic ash.
Phosphorus buffer capacity	The ability of a soil to resist a change in the status of plant-available phosphorus.
Time of application	The longer the phosphorus is in contact with the soil, the more is fixed.
Aeration	Makes more phosphorus available by allowing organic matter breakdown.
Compaction	Makes less phosphorus available by reducing aeration.
Moisture	Optimum levels improve phosphorus availability.
Phosphorus status of soil	Soils that have received more phosphorus than removed may have more available phosphorus. This may be enough to reduce current fertiliser needs.
Temperature	Warm temperatures encourage organic matter decomposition. If too hot or too cold, phosphorus uptake can be restricted. This is why crops may respond well to starter phosphorus in cold soils, even when soil phosphorus levels are high.
Other nutrients	Added nutrients can stimulate phosphorus uptake. Calcium on acid soils or ammonium-nitrogen or sulfur on acid soils increase uptake of phosphorus. Zinc fertilisation on soils with marginal phosphorus can restrict phosphorus uptake further.
Crop	Deeply rooted crops and crops infected with arbuscular mycorrhizal fungus (AMF) can have better phosphorus uptake.

Source: Australian Soil Fertility Manual (2006)

6.7.2 Phosphorus deficiency symptoms

Symptoms of phosphorus deficiency take time to develop because of initial seed reserves of phosphorus. When symptoms start to appear, phosphorus-deficient faba bean plants have smaller leaves and less growth than those with adequate phosphorus.

Phosphorus deficiency is difficult to detect visually in field crops, often because the whole paddock is affected.

Visual symptoms in faba bean and broad bean first appear on the oldest leaves as a mildly mottled chlorosis (yellowing) over much of the leaf. These symptoms could be confused with either nitrogen or sulfur deficiency, but middle and new leaves remain a healthy green so that the whole plant does not appear pale.

As symptoms on old leaves develop, round purple spots may appear within areas of dark green, in an otherwise mildly chlorotic leaf (Photo 6).[56, 57]

Photo 6: *Symptoms of phosphorus deficiency in old leaflets of faba bean. Note the spotting within darker green areas of an otherwise mildly chlorotic leaf.*

Photo: Alan Robson; Grain Legume Handbook (2008)

6.7.3 Phosphorus management

Table 11 shows the rates of phosphorus and equivalent rates of various fertilisers (each tonne of faba bean grain removes about 4 kg/ha of phosphorus).

Apply enough phosphorus to replace that removed in grain as well as soil 'tie-up' to maintain soil phosphorus levels. More is required on soils with a high buffering index such as calcareous soils.[58] If the soil phosphorus status is sufficient, there may be an opportunity for growers to save money on phosphorus fertiliser by cutting back to a maintenance rate.

Phosphorus should be applied at rates of at least 12 kg/ha, and up to 22 kg/ha, for faba bean. In Victoria, growers are advised to add 6 kg/ha of phosphorus for every tonne per hectare of faba bean grain expected to be harvested.[59] The phosphorus rate should be higher (about 15 kg/ha) on medium acid soils (pH ($CaCl_2$) 5.0 to 5.7) due to unavailability of the nutrient.[60]

Field research in Victoria and SA shows that soil salinity and sodicity can substantially reduce crop yields.[61] While faba bean is very responsive to phosphorus fertiliser, the zinc status must be adequate to achieve a phosphorus response. High phosphorus rates can induce zinc deficiency on 'black' soils with pH ($CaCl_2$) more than 8.0. High soil phosphorus levels also increase the rate of nodule growth.[62]

Most crops only recover 20–30% of the fertiliser phosphorus applied during the year of application.[63] The remainder may become available to subsequent crops over several seasons.

MORE INFORMATION

GRDC 2012 Crop nutrition Fact Sheet: Phosphorus management (southern region) www.grdc.com.au/GRDC-FS-PhosphorusManagement

VIDEO

GroundCover™ TV: Phosphorus uptake https://www.youtube.com/watch?v=qSiQIKRb9bA

56 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

57 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

58 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

59 B Robinson, M Raynes (2013) Growing faba bean, Department of Environment and Primary Industries, Victoria. Agnote AG0083, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

60 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

61 D Adcock, R Armstrong, F Best, D Chittleborough, M Imhof, G McDonald, A McNeill, J Nuttall, N Wilhelm (2009) Salinity and sodicity. Identifying, Understanding and Managing Hostile Subsoils For Cropping – A Reference Manual for Neutral-Alkaline Soils of South-Eastern Australia. The Profitable Soils Group. pp 41–50, http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_mgmt_subsoil

62 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

63 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

Table 12: Granular fertiliser application rate calculator, based on phosphorus rates (all rates in kg/ha; ratios relate to the relative amounts of N:P:K:S).

Phosphorus	Some of the fertilisers used on pulses														
	Superphosphate						6 : 16 : 0 : 10 Legume special			10 : 22 : 0 MAP		18 : 20 : 0 DAP		0 : 15 : 0 : 7 Grain legume super	
	Single 8.6% P		Gold Phos 10 18% P		Triple 20% P										
	fertiliser	S	fertiliser	S	fertiliser	S	fertiliser	N	S	fertiliser	N	fertiliser	N	fertiliser	S
10	116	13	50	5	45	0.7	62	4	6	46	5	50	9	69	5
12	140	15	67	7	60	0.9	75	4	8	55	6	60	11	83	6
14	163	18	78	8	70	1.1	87	5	9	64	6	70	13	97	7
16	186	20	89	9	80	1.2	99	6	10	73	7	80	14	110	8
18	209	23	100	10	90	1.4	112	6	11	82	8	90	16	124	9
20	223	25	111	11	100	1.5	124	7	12	91	9	100	18	138	10
22	256	28	122	12	110	1.7	137	8	14	100	10	110	20	152	11
24	279	31	133	13	120	1.8	149	8	15	110	11	120	22	166	12

Source: GRDC (2014)

Birchip Cropping Group trials in Victoria's Wimmera and southern Mallee between 1999 and 2001 found yield responses in faba bean to phosphorus rates up to 18 kg/ha, even in sites with a Colwell P soil test result of 15 ppm or more. In contrast, wheat, barley, canola, lentil and field pea did not respond at sites with a good fertiliser history.[64]

Research in south-western Australia showed that phosphorus application can increase the number of faba bean pods per plant to boost yield by 50–100% on deficient soils. Phosphorus (or zinc) fertiliser did not affect the numbers of seeds per pod and seed weight.[65]

The availability of phosphorus to plants varies with the source of the nutrient. In Australian broadacre organic farming systems, superphosphate fertiliser is not permitted and low soil phosphorus availability commonly limits yield. A comparison of superphosphate with rock phosphate and poultry manure in pulses showed major differences in phosphorus use efficiency between the fertilisers in glasshouse trials, using the equivalent of 50 kg/ha of each fertiliser. Phosphorus uptake in faba bean and field pea grown, in both acidic sandy loam and alkaline clay, was very low (0–1.3%) for rock phosphate, which is sparingly soluble. In contrast, phosphorus uptake ranged from 1.8–12.7% for poultry manure and 6.1–9% for single superphosphate.[66]

Liquid phosphorus uses an efficient and flexible delivery method, but it has the disadvantages of requiring a separate delivery system and being expensive compared with granular phosphorus.

However, the benefits in crop production outweigh the extra expense only on highly calcareous soils and a small number of other cropping areas in southern Australia.[67]

64 BCG (2002) Optimising phosphorus fertiliser rates on alkaline soils. 2001/02 Crop and Pasture Production Manual. Birchip Cropping Group, www.farmtrials.com.au

65 M Bolland, K Siddique, R Brennan (2000) Grain yield responses of faba bean (*Vicia faba* L.) to applications of fertiliser phosphorus and zinc. Australian Journal of Experimental Agriculture 40(6). pp 849–857, www.publish.csiro.au/paper/EA99164.htm

66 G Nachimuthu, P Lockwood, C Guppy, P Kristiansen (2009) Phosphorus uptake in faba bean, field pea, and corn cultivars from different sources: preliminary studies of two options for organic farmers. Crop and Pasture Science 60(2). pp 183–189, https://e-publications.une.edu.au/vital/access/manager/Repository/une:4500

67 GRDC (2012) Crop nutrition fact sheet: Phosphorus management (southern region). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-PhosphorusManagement

Australian researchers have shown variation between different faba bean genotypes (varieties) in their ability to use phosphorus efficiently. In alkaline soil, roots of the most phosphorus-efficient varieties exuded more of an organic compound called malate, which may increase the solubility of soil phosphorus, making it more available to the plant.[68]

6.7.4 Fertiliser placement and fertiliser toxicity

In recent years, Australian researchers have recommended fertilising the subsoil (10–30 cm depth) with phosphorus before sowing faba bean to maximise phosphorus use efficiency. They showed that faba bean responds to extractable subsoil phosphorus concentrations when measuring dry matter production and phosphorus concentration in plant tissue.[69] This is similar to the recommendation for lupin, where deep banding of fertiliser is often preferred as the crop is particularly sensitive to toxic concentrations of fertiliser during establishment and nodulation. Otherwise, growers can broadcast and incorporate, pre-drill or split fertiliser applications so that lower rates or no phosphorus is in contact with the seed.

All pulses can be affected by fertiliser toxicity. Ideally, fertilisers should be banded below or to the side of the seed at sowing. Drilling 10 kg/ha of phosphorus with the seed in 18 cm rows using 10 cm points rarely causes problems.

The use of starter nitrogen such as DAP, banded with the seed has the potential to reduce establishment and nodulation if higher rates are used. On sands, up to 10 kg/ha of nitrogen in 18 cm row spacing can be safely used. On clay soils, do not exceed 20 kg/ha of nitrogen in 18 cm row spacing.

However, the risk of fertiliser toxicity is higher with narrow sowing points or disc seeders with minimal soil disturbance, as well as wider row spacing. These techniques concentrate the fertiliser near the seed in the seeding furrow.

Fertiliser toxicity effects are greater in highly acidic soils, sandy soils and in drier soils at sowing.

Drilling concentrated fertilisers to reduce the product rate per hectare does not reduce the risk of fertiliser toxicity.[70]

6.7.5 AMF: arbuscular mycorrhizae fungi effects on phosphorus and zinc

Some soil fungi form a mutually beneficial relationship with plant roots to help plants more efficiently absorb nutrients such as phosphorus and zinc from soil and fertiliser. They are known as arbuscular mycorrhizal fungi (AMF), previously known as vesicular arbuscular mycorrhiza (VAM).

AMF colonise and build up on the faba bean and broad bean root system. The fungi produce filaments (hyphae) that colonise the root and then grow into the soil, much further than root hairs. Phosphorus and zinc are taken up by the hyphae and transported back for use by the plant.

Many crop species require only half the phosphate concentration in soil when they are colonised by AMF as they do without AMF for the same level of production.

Crops such as faba bean, chickpea, safflower and linseed have a high AMF dependency and promote its accumulation. AMF levels can be severely reduced by long periods of fallow, such as those induced by drought, or the growth of non-host crops. Winter cereals and field pea are less AMF-dependent but do allow AMF to

68 T Rose, P Damon, Z Rengel (2010) Phosphorus-efficient faba bean (*Vicia faba* L.) genotypes enhance subsequent wheat crop growth in an acid and an alkaline soil. Crop and Pasture Science 61(12). pp 1009–1016, http://epubs.scu.edu.au/plantscience_pubs/165/

69 T McLaren, M Bell, I Rochester, C Guppy, M Tighe, R Flavel (2013) Growth and phosphorus uptake of faba bean and cotton are related to Colwell-P concentrations in the subsoil of Vertosols. Crop & Pasture Science. 64. pp 825–833, http://www.publish.csiro.au/?act=view_file&file_id=CP13025.pdf

70 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

MORE INFORMATION

Feri-tech SeedEnhancer VAM™, http://www.fertitech.com/site/DefaultSite/filesystem/documents/FTA%20Ferti%20Seed%20Enhancer%20VAM.pdf

build up. Canola, lupin and extended fallow do not host AMF, so AMF levels are reduced under these crops in rotation.

AMF can be important in faba bean and broad bean production and fertiliser responses. Faba bean and broad bean are considered to have a high crop requirement for phosphorus, and economic fertiliser responses to phosphorus are common.

Uptake of phosphorus can become far less efficient in winter crops with:

- soils with critically low phosphorus levels (below 6 mg/kg) and no history of phosphorus fertiliser application; and
- long fallow situations with low VAM levels (10 months or longer).

AMF products are commercially available as seed treatments, often in association with other seed enhancers that in combination can give the most potent means to ensure a highly successful AMF spore inoculation.

Where soil AMF levels are moderate to high, consistent responses to applied phosphate fertiliser are more likely where soil bicarbonate phosphorus levels fall below 6 mg/kg and are critically low. Double-cropped paddocks or short, 6-month fallows from wheat are more likely to have moderate to high AMF levels.

AMF levels become depleted with long fallows (more than 8–12 months) or after crops such as canola or lupin, which do not host AMF growth. In low-AMF situations, faba bean and broad bean can be very responsive to applied phosphorus and zinc and show a marked growth response to starter fertilisers, which may improve yield.[71 72]

6.8 Potassium

6.8.1 Occurrence of potassium deficiency

As most Australian soils have ample potassium levels, it is feasible for growers to gradually use up some of the soil potassium before needing to replace it. Most clay soils have sufficient reserves of potassium to grow many crops. However, potassium deficiency has been confirmed in SA in grain-cropping regions. As potassium reserves are drawn down with higher yields, potassium replacement may need to be more widely addressed.

Potassium concentration in the stubble of both canola and wheat is higher than in the grain. Research in Canada has shown if the stubble is burnt, 30–40% of this potassium will be lost from the system.[73] If the stubble is retained, much of the potassium will be recycled through the topsoil and, unless the straw is spread, can accumulate under the windrows.[74]

6.8.2 Potassium deficiency symptoms

The older (lower) leave show symptoms of potassium deficiency first. Initially growth is stunted compared with other parts of the paddock with soil of higher potassium levels (for example, in old stubble rows). Older leaves show a slight curling and then a distinct black to grey colour on leaf margins, eventually shrivelling and dying (Photos 7, 8, 9, 10 and 11).[75] Lower leaves may also cup with some purple blotches.[76]

71 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

72 N Seymour (2009) Mycorrhizae and their influence on P nutrition. Australian Grain July–August 2009. pp 23–24, http://www.ausgrain.com.au/Back%20Issues/192jagrn09/23_Mycorrhizae.pdf

73 J Heard, C Cavers, G Adrian (2006) Up in smoke – nutrient loss with straw burning. Better Crops 90(3). pp 10–11, www.ppi-ppic.org/ppiweb/bcrops.nsf/$webindex/896A64C047EA4DE5852571B1006A5BF1/$file/06-3p10.pdf

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

75 M Wurst, W Hawthorne, A Nikandrow, M Ramsey, T Bretag, J Davidson, R Gilbert, W MacLeod, G Murray, K Panagiotopoulos, M Schwinghamer (2002) Winter Pulse Disorders: The Ute Guide. Primary Industries and Resources South Australia.

76 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

The first evidence of potassium deficiency can be observed as poor good growth outside of old header windrows.[77]

Faba bean appear to be more susceptible to potassium deficiency compared with other pulses such as field pea and lupin.

Photo 7: *Potassium deficiency in faba bean. Note the necrosis (dead tissue) of leaf margins and purple blotches.*

Photo: Grain Legume Handbook

Photo 8: *Potassium deficiency in faba bean (left and middle plants), alongside a plant with adequate potassium. Plants were taken from the same paddock but the healthy plant was grown in a windrow of cereal stubble deposited by a harvester.*

Photo: Wayne Hawthorne, formerly Pulse Australia

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

Photo 9: *Potassium deficiency in single faba bean leaflet.*

Photo: Alan Robson; Grain Legume Handbook (2008)

Photo 10: *Potassium deficiency in a faba bean crop showing loss of lower leaves and poorer height and vigour than healthy plants in the same paddock growing in header windrows of canola stubble.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 11: *Faba bean with adequate potassium. Here, plants show better height and vigour in header windrows of canola stubble.*

Photo: Wayne Hawthorne, formerly Pulse Australia

6.8.3 Potassium management

Some Australian cropping soils (usually white sandy soils) respond to potassium and applications may be needed to replace the potassium removed by the crop. Such soils with low or marginal levels of potassium (<50 mg/kg using the bicarbonate, or Colwell K soil test) may respond to applications of potassium fertiliser. When using the ammonium acetate soil test, fertiliser responses are likely where potassium levels fall below:

- 0.25 cmol (+)/kg (milliequivalents/100g) on black earths and grey clays; or
- 0.40 cmol (+)/kg on red earths and sandy soils.

Soil tests for potassium are reliable on sandy soils but less so on heavy soils.

Economic responses to 50–100 kg potassium/ha banded below the seed at sowing are likely where soil tests are below critical concentrations.[78]

For most annual crops, it is usual to apply all the potassium fertiliser at, or before, sowing; the application may be split in highly leaching soils with low nutrient-holding capacity (cation exchange capacity), such as sands. A more specific recommendation for faba bean is to apply potassium fertiliser 6–8 weeks after sowing. Widely used potassium fertilisers are shown in Table 12 (alternatively, consider a blend such as Crop King® 55[79]).

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

79 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

Table 13: Composition of common potassium fertilisers (as percentages).

Fertiliser	Potassium	Magnesium	Sulfur	Nitrogen	Chloride
Muriate of potash	50	–	–	–	46
Sulfate of potash	40–41.5	–	16–17	–	–
Potassium-manganese sulfate	18	11	22	–	–
Potassium thiosulfate	38	–	–	13	–
Potassium nitrate	30	–25	–	–	–

Source: CSIRO (2006) Australian Soil Fertility Manual

The addition of clay or organic matter to sandy soils can increase the capacity of soils to hold nutrients, including potassium.[80]

Responses to potassium are unlikely on most black earths and grey clays. Potassium fertilisers may be warranted on red earths but should be based on soil analysis.

Where soil test levels are critically low, apply 20–40 kg potassium/ha banded 5 cm to the side of, and below the seed row.

Alternatively, consider blends such as Crop King® 55 (13% nitrogen, 13% phosphorus, 13% potassium) at 80–120 kg/ha, where potassium levels are marginal.

6.9 Sulfur

While most other pulse crops remove more sulfur per tonne of grain than cereals, faba bean, like wheat, removes about 1.5 kg/ha of sulfur with each tonne of grain harvested.

6.9.1 Occurrence of sulfur deficiency

Infertile soils such as deep sands and those low in organic matter are more likely to experience sulfur deficiency, particularly in wet seasons. Basaltic, black earths are also prone to sulfur deficiency. Sulfur deficiency is most likely to occur with double-cropping, where available sulfur becomes depleted.

6.9.2 Sulfur deficiency symptoms

Youngest leaves of sulfur-deficient faba bean turn yellow (chlorosis) and plants are slender and small. Chlorosis of leaf edges can progress to necrosis within those chlorotic areas (Photo 11).

80 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Photo 12: *Sulfur deficiency in faba bean shows up as chlorosis (yellowing) of leaf edges (left) and can progress to necrosis (dead tissue) within those chlorotic areas (right).*

Photo: Alan Robson; Grain Legume Handbook (2008)

6.9.3 Sulfur management

Soil sampling to 60 cm is recommended for sulfur tests. A fertiliser response is likely if available sulfate is below 5 mg/kg (KCl-40 test). The level is critically low if less than 3 mg/kg.

Applying 5–10 kg/ha of sulfur will normally correct a sulfur deficiency. A low rate of gypsum is the most cost-effective long-term method of correcting sulfur deficiency where soil phosphate levels are adequate.

Often, a sulfur-fortified fertiliser is applied to pulse crops (Table 11). The 'grain legume' fertilisers provide a good supply of sulfur. However, if the paddock has a good history of single superphosphate, sulfur levels may be adequate, particularly on heavy clay soils. Where double or triple superphosphate has been used over severaL years, the sulfur level in the soil may be inadequate for faba bean.[81 82 83]

MORE INFORMATION

GRDC 2013 Crop nutrition Fact Sheet: micronutrients
www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

MORE INFORMATION

GRDC 2014 Crop nutrition Fact Sheet: Soil testing for crop nutrition (southern region)
www.grdc.com.au/GRDC-FS-SoilTestingS

6.10 Micronutrients (trace elements)

Micronutrients are those elements that plants need in small amounts, for example iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), chlorine (Cl), and molybdenum (Mo).[84] The difference between deficient and adequate (or toxic) levels of some micronutrients can be very small.

Micronutrient deficiencies are best determined by looking at the overall situation: region, soil type, season, crop type and past fertiliser management.

The most likely limiting micronutrients in Australian cropping systems are zinc, boron, copper, manganese and molybdenum. Iron can also be important, especially on strongly alkaline soils. Other micronutrients are important for particular plants in particular situations. Zinc deficiency is a major risk on soil types across all Australian cropping regions. Copper deficiency is also a concern but is less widespread. Pulses are more susceptible to deficiencies of iron, boron, manganese and molybedenum. Micronutrient toxicity and deficiency symptoms of faba bean are listed in Section 6.5 Nutrient disorders.

Soil type is useful in estimating the risk of micronutrient deficiencies. Definitions of soil types can be found in the GRDC Crop nutrition Fact Sheet 'Soil testing for crop nutrition (southern region)' (www.grdc.com.au/GRDC-FS-SoilTestingS). Based on the soil properties, crop are most likely to be at risk of deficiency on particular soils, as follows:

81 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

82 GRDC (2014) Crop nutrition fact sheet: Soil testing for crop nutrition (southern region). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SoilTestingS

83 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

84 Queensland DAF Queensland (2010) Nutrition management. Overview. Queensland Department of Agriculture and Fisheries Queensland, 1 October 2010, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview

- boron deficiency on kurosols, podosols and tenosols;
- copper deficiency on kurosols;
- manganese deficiency on calcarosols;
- molybdenum deficiency on kurosols, podosols and tenosols; and
- zinc deficiency on calcarosols.[85]

In the southern region, calcarosols, sodosols and vertosols have a high risk of zinc deficiency. Manganese deficiency is likely to be a significant risk on soils with more than 60% free calcium carbonate.[86]

Growers can learn about likely soil types on their property with CSIRO's iPad app SoilMapp (https://www.csiro.au/en/Research/AF/Areas/Sustainable-farming/Decision-support-tools/SoilMapp).

Soil pH has an important effect on the availability of micronutrients to plants. Zinc, iron, boron, manganese and copper become less available as the pH increases (more alkaline), while molybdenum (and aluminium) become more available as soils become more alkaline.[87]

6.10.1 Micronutrient application

Traditionally, micronutrient treatment in crops first involved diagnosis of deficiencies and then treatment using solid fertilisers or foliar sprays.

For foliar applications to be effective, a large plant leaf area is required to absorb the product. Multiple applications may be necessary if applying to seedlings.

Growers may apply micronutrients as 'insurance' against possible deficiencies. Rates are generally much lower but will only have economic value if they prevent a deficiency.

Recent changes to micronutrient application include spraying micronutrients into the soil near seed rows in no-till systems. Liquid in-furrow application to the soil offers some advantages with immobile micronutrients (such as copper and zinc), as the distribution in the soil will be better over several years than conventional products. Depending on the soil type, annual applications may not be needed. Growers must take care to avoid germination effects on seeds when applying trace elements this way.

Another new trend is the application of immobile micronutrients to deeper layers of the soil, particularly where infertile A2 (lower topsoil) layers are present. Some sites are showing promising results using this approach.

For nutrients with low residual activity or where soils are likely to strongly bind micronutrients, annual or tactical in-furrow or in-crop foliar applications may be best.

Post-harvest grain nutrient testing can be used to support management decisions but will not provide a conclusive guide to the risk of micronutrient deficiency.

When applying fertiliser to treat a suspected deficiency, leave a strip untreated. Either a visual response or tissue testing can allow you to confirm whether the micronutrient was limiting.[88 89]

85 R Norton (2013) More profit from crop nutrition: micronutrient survey. A scoping study to develop a risk assessment for micronutrient deficiency in the grains industry. Final Project Report. Grains Research and Development Corporation, http://research.ipni.net/page/RANZ-2419

86 GRDC (2013) Crop nutrition fact sheet: Micronutrients (northern, southern and western regions). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

87 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

88 B Hughes (2012) Trace elements in the South East fact sheet. Natural Resources South East, www.naturalresources.sa.gov.au/southeast/land/soil-management/South-East-Soil-Issues

89 GRDC (2013) Crop nutrition fact sheet: Micronutrients (northern, southern and western regions). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

6.10.2 Zinc

Zinc deficiency occurs mostly on highly alkaline soils, very infertile sand and soils with a low zinc fertiliser history. Zinc deficiency in faba bean can be exacerbated by a reaction with herbicide application or residues.[90]

While faba bean can be very responsive to zinc, phosphorus status must be adequate to achieve a response – and vice versa. However, high phosphorus rates can induce zinc deficiency on 'black' soils with pH ($CaCl_2$) of more than 8.0.

Zinc deficiency symptoms

Zinc-deficient faba bean plants are small. The stunted plants have pale green leaves. The areas between veins become mottled yellow, which is worse on the lowest leaves. Middle to lower leaves can have red-brown or pink-brown spots.[91] The top leaves are often smaller, while the older leaves may be wilted and distorted. Maturity may be delayed (Photos 13, 14, 15 and 16).

Photo 13: *Zinc deficiency in faba bean.*

Photo: Grain Legume Handbook (2008)

90 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

91 M Wurst, W Hawthorne, A Nikandrow, M Ramsey, T Bretag, J Davidson, R Gilbert, W MacLeod, G Murray, K Panagiotopoulos, M Schwinghamer (2002) Winter Pulse Disorders: The Ute Guide. Primary Industries and Resources South Australia.

Photo 14: *Zinc-deficient faba bean (left) compared with faba bean grown with adequate zinc applied as solid fertiliser at sowing or early foliar application (right).*

Photo: Grain Legume Handbook

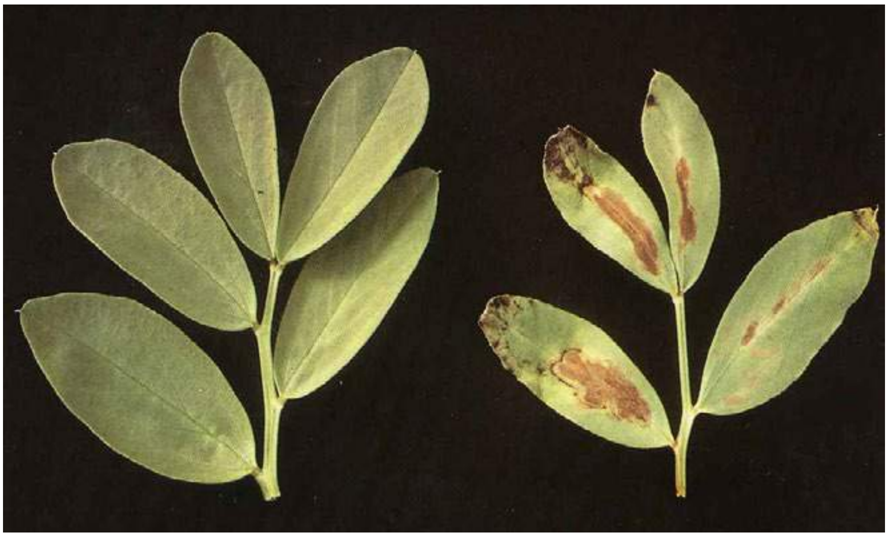

Photo 15: *Zinc-deficient middle leaves of faba bean (right).*

Photo: Alan Robson; Grain Legume Handbook (2008)

Photo 16: *Zinc-deficient leaves of faba bean, (from left) oldest to youngest.*

Photo: Alan Robson; Grain Legume Handbook (2008)

AMF can be extremely important to the zinc nutrition in faba bean, and responses can be expected in situations where AMF levels have become depleted due to long fallows (8–10 months) (see Section 6.7.5 AMF: arbuscular mycorrhizae fungi effects on phosphorus and zinc for more information).

Zinc management

Faba bean has a relatively high demand for zinc, but has evolved highly efficient mechanisms for extracting zinc from the soil.

Leaf tissue testing will determine the plant's zinc status at sampling.[92] Critical values for zinc levels in plant tissue test are shown in Table 5.

Research on zinc responses in faba bean is limited. Fertiliser recommendations are based on a general recommendation used for all crops where DTPA analysis of soil samples in the top 10 cm shows zinc levels:

- below 0.8 mg/kg on alkaline soils; or
- below 0.3 mg/kg on acid soils.

Zinc application is generally advisable for growing faba bean on alkaline soils.

Zinc is usually applied with the fertiliser at sowing or as a foliar spray. Zinc should be applied to the soil every 2–7 years, depending on soil type.

The best method is to spray the zinc onto the soil surface and incorporate by cultivation or use zinc-coated granule fertiliser formulation.[93]

A replicated trial at Rupanyup, in the Victorian Wimmera, in 2001 found no difference in faba bean yields when comparing zinc applied as granular fertiliser, seed dressing or foliar solution – as well as no zinc. This was at a site where zinc had previously been applied in 2 of the previous 5 years. The researchers recommended that granular zinc be applied every 3–4 years in the Victorian Wimmera and Mallee to avoid over-fertilisation, rather than every time a pulse is sown. They also recommended the use of zinc seed dressings or foliar applications only as a 'last resort', to overcome a deficiency in the year it is applied.[94]

Solid zinc fertiliser treatments

Zinc can be applied before sowing or during sowing.

92 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

93 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

94 BCG (2002) Is zinc required every time you sow a crop? Birchip Cropping Group 2001 Research Manual. Birchip Cropping Group, www.farmtrials.com.au

Zinc (and copper) is not mobile in the soil. When applying solid fertiliser, good physical distribution through the soil profile or topsoil is important to ensure roots interact with it. Unlike foliar sprays, solid fertilisers generally provide residual value.

Severe zinc deficiency can be corrected before sowing for 5–8 years with a soil application of 15–20 kg/ha zinc sulfate monohydrate, cultivated into the soil three to four months before sowing (Table 13).

In the first year after application, the pre-sowing soil-applied zinc sulfate monohydrate may not be fully effective and a foliar zinc spray may also be required.

Zinc can also be applied at sowing with a range of phosphate-based fertilisers that contain, or are blended with, a zinc additive.

While cultivation distributes zinc (and copper) through the topsoil, no-till and one-pass sowing equipment provide less physical distribution. Smaller granules of fertiliser, more of them and better placement, will be more effective than a fertiliser with larger granules, even if it is more concentrated.[95 96]

Table 14: Rates of zinc (g/ha) to correct deficiencies in pastures and cereals. (Note: faba bean has a higher demand for copper and zinc than cereals, see Table 1.)

Fertiliser type	Situation	Zinc (g/ha to apply)
Foliar	Confirmed deficiency	330
	'Insurance'	110
Soil-applied	Confirmed deficiency	2,000–2,500
	'Insurance'	500–2,000

Source: Hughes (2012)

Foliar zinc sprays

Foliar application of zinc is common, often fitting in with herbicide or early fungicide applications.[97] Foliar applications of trace elements can cause leaf burning.

A mild zinc deficiency will be corrected with a foliar spray of 1.0 kg/ha zinc sulfate heptahydrate plus 1.0 kg/ha urea with 1,200 mL of a 1,000 g/L non-ionic wetter in at least 100 L water/ha. One to two sprays should be applied within 6–8 weeks of emergence.

Hard water (high in carbonate) will produce an insoluble sediment (zinc carbonate) when the zinc sulfate is dissolved, with the spray mix turning cloudy. Use a buffer – such as L1-700 or Agri-Buffa – if only hard water is available. Zinc oxide products are highly alkaline with a pH of 9.5–10.5.

Zinc seed treatments

Zinc seed treatments may be a cost-effective option in situations where soil phosphorus levels are adequate but zinc is likely to be deficient.

Agrichem Broadacre Zinc® contains 650 g/L of zinc and is applied at 4 L of product per tonne of seed. Pre-mix with 1 L of water before application.

Apply Broadacre Zinc® and then allowed to dry before applying the inoculum, to minimise any damaging effect on rhizobia.

Broadacre Zinc® is compatible with either Thiraflo® or P-Pickel T®; the two products can be mixed to treat faba bean seed in one operation if needed.

95 GRDC (2013) Crop nutrition fact sheet: Micronutrients (northern, southern and western regions). Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

96 J Carter (1999) Faba Bean and Broad Bean Growers Guide: A Guide for the Production of Faba Beans and Broad Beans. D Robey, M Raynes (eds.). Victoria Department of Natural Resources and Environment.

97 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

Teprosyn® Zn (Phosyn) contains 600 g/L of zinc and is applied at 4 L of product per tonne of seed. Pre-mix with 2–3 L of water to assist coverage. Apply inoculum first and allow to dry before applying the Teprosyn®.[98]

6.10.3 Iron

Occurrence of iron deficiency

Iron deficiency is usually observed on alkaline soils with high lime content in cold and wet conditions. It is usually associated with waterlogging after heavy rainfall or irrigation, which interferes with iron absorption and translocation (movement) into the foliage. Iron deficiency in faba bean is often worse in compacted areas, such as wheel tracks (Photo 16).

Plants often recover from iron deficiency as conditions become warmer.

Iron deficiency symptoms

Iron deficiency often appears in young plants. As iron is highly immobile in plants, symptoms may show up in youngest leaves first. Symptoms include a general yellowing of young leaves and poor growth. New leaves and young growth of faba bean may be small and unfolded or barely opened. The chlorotic (yellow) leaves roll along their margins. Symptoms can also include yellowing between leaf veins. Stems become yellow and shortened. Deficiency spreads to older leaves and young growth stops; it can progress to completely yellow plants.

In severe cases, young leaves become distorted, with necrosis (dead tissue) and shedding of terminal (top) leaflets. The leaf tips of severely deficient plants may die.

Iron deficiency symptoms tend to be very transient, with the crop making a rapid recovery once the soil begins to dry out. New growth can recover but symptoms are apparent on the remaining young leaves.

Iron deficiency can be confused with manganese and magnesium deficiency. Contrast in colour between old and new leaves is much stronger with iron deficiency compared with manganese deficiency.

Faba bean varieties show a marked difference in sensitivity to iron chlorosis (yellowing), and major problems with iron deficiency have largely been overcome through the efforts of plant breeders. The broad bean variety Aquadulce is more tolerant of iron deficiency than many faba bean varieties (Photo 17).[99 100 101]

98 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

99 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

100 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

101 M Wurst, W Hawthorne, A Nikandrow, M Ramsey, T Bretag, J Davidson, R Gilbert, W MacLeod, G Murray, K Panagiotopoulos, M Schwinghamer (2002) Winter Pulse Disorders: The Ute Guide. Primary Industries and Resources South Australia.

Photo 17: *Iron deficiency visible in a faba bean crop in wheel tracks. This disorder is often worse in compacted soils.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 18: *Faba bean varieties have different tolerances to iron deficiency. The variety Aquadulce (between the pegs) is more tolerant (but not immune) compared with many other faba bean varieties.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Iron management

An iron deficiency may be corrected with a foliar spray of iron.[102]

As iron deficiency may be transient, foliar iron applications may not necessarily be absorbed into the leaves if symptoms are severe.

102 Queensland DAF (2010) Nutrition management. Overview. Queensland Department of Agriculture and Fisheries, 1 October 2010, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview

6.10.4 Manganese deficiency

Occurrence of manganese deficiency

Manganese deficiency tends to be found on highly alkaline, calcareous soils. It is common in faba bean in the south-east of SA. It is usually associated with dry, loose ('fluffy') soils; wheel tracks or rolled areas may appear healthy while other parts of the paddock show manganese deficiency.

On acidic soils, well-nodulated faba bean crops grown can experience manganese toxicity (see Section 6.5.2 Nutrient toxicity for more information).

Manganese deficiency symptoms

Symptoms of manganese deficiency in faba bean first appear in new leaves, which show mild chlorosis (yellowing) due to a lack of chlorophyll in the leaves. This is followed by small dead spots or purple spotting at each side of the mid-rib and lateral veins of fully and partially opened new leaves and unopened leaves. Many affected new leaves become distorted, as if the margins are growing at different rates, causing twisted leaves. The leaves may turn yellow and die.

Manganese deficiency of faba bean late in the season may lead to discolouration, splitting and deformity of the grain; it can be hollow or have a cavity in its centre (called 'Marsh spot').

Symptoms may vary between plants. While some plants may have only a few brown spots on unopened new growth, for other plants, symptoms may extend to middle leaves and range from blackened tops of leaves and new growth to purple necrosis (dead tissues) over much of the leaf (Photos 19, 20, 21 and 22).[103 104 105 106]

Photo 19: *New, opening leaves of manganese-deficient faba bean (right), compared with healthy leaves (left).*

Photo: Alan Robson; Grain Legume Handbook (2008)

103 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

104 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba bean: The Ute Guide. Primary Industries and Resources South Australia. https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

105 M Wurst, W Hawthorne, A Nikandrow, M Ramsey, T Bretag, J Davidson, R Gilbert, W MacLeod, G Murray, K Panagiotopoulos, M Schwinghamer (2002) Winter Pulse Disorders: The Ute Guide. Primary Industries and Resources South Australia.

106 F Salisbury, C Ross (1985) Mineral nutrition. Plant Physiology. 3rd edn. Wadsworth, Inc.

Photo 20: *New growth of manganese-deficient faba bean.*

Photo: Alan Robson; Grain Legume Handbook (2008)

Photo 21: *Middle leaf of manganese-deficient faba bean.*

Photo: Alan Robson; Grain Legume Handbook (2008)

Photo 22: *Middle leaves of manganese-deficient faba bean (right), compared with healthy leaves (left).*

Photo: Alan Robson; Grain Legume Handbook (2008)

Manganese management

Apply manganese at sowing in the fertiliser, by liquid injection, on the seed, or as a foliar application.

Table 15: Rates of manganese (g/ha) to correct deficiencies in pastures and cereals. (Note: faba bean has a lower demand for manganese than cereals, see Table 1 for details.)

Fertiliser type	Situation	Manganese (g/ha to apply)
Foliar	Confirmed deficiency	1,000
	'Insurance'	500
Soil-applied	Confirmed deficiency	3,000–5,000
	'Insurance'	Not applicable

Source: Hughes (2012)

6.10.5 Copper

Occurrence of copper deficiency

In southern Australia, copper deficiency is most common in sandy soils low in organic matter. Organic soils are also commonly copper deficient. While these soils usually contain reasonable amounts of copper, they hold it so tightly that only small amounts are available to the crop.

While heavy, clay soils are least likely to be copper deficient, grain crops grown on calcareous, alkaline soils in SA at risk of copper deficiency, regardless of texture.

Copper deficiency may also be included in some situations by land-forming operations where the surface soil is removed (for example, for flood irrigation layout). Zinc deficiency can also be brought about this way.

Excessive – but not moderate – liming and the presence of high concentrations of metals in the soil can induce copper deficiency in crops by affecting the availability of copper to plants. Such metals include iron, manganese and aluminium.

Copper is necessary for chlorophyll formation and catalyses several other plant reactions.

It has a role in cell wall constituents of plants, so plants with adequate copper are more resistant to fungal attack.

Copper deficiency symptoms

Copper deficiency does not appear until flowering, so vegetative growth is not particularly affected.

The first symptom of copper deficiency in faba bean is a wilting and rolling of the leaflet ends of fully opened leaves. Wilting is followed by incomplete opening of new leaflets, which in some cases appear puckered and kinked over towards the leaf ends (Photo 23). If deficiency is severe, wilting of fully formed leaves develops into a 'withertip' (Photo 24). Tips of each leaflet become pale green with a dried appearance, and then become twisted and necrotic (dead tissues).

Although flowering is not delayed in faba bean with copper deficiency, in contrast to field pea, few pods and seeds form. Flowers appear quite normal.

Photo 23: *New leaves of copper-deficient faba bean showing 'withertop'.*

Photo: Alan Robson; Grain Legume Handbook (2008)

Photo 24: *Fully opened leaves of copper-deficient faba bean showing 'withertop'.*

Photo: Alan Robson; Grain Legume Handbook (2008)

Management

Copper deficiency can be corrected by soil or foliar application. Copper sulfate is the most common form of copper fertiliser, but copper chelate and copper oxide can also be used.

In crops, copper can be applied to the soil at 2 kg/ha, which can be expected to last five years. Copper is not readily leached and applied copper may have long to very long residual availability of more than 15 years.

Foliar sprays of copper sulfate can also be effective. For pulses, this can be applied 3–5 weeks after emergence (using 2% with respect to volume or 2 kg per 100 L of water). Foliar burn can occur under adverse conditions, such as hot, dry weather.[107 108]

Table 16: Rates of copper (g/ha) to correct deficiencies in pastures and cereals. (Note: faba bean has a higher demand for copper and zinc than cereals, see Table 1.)

Fertiliser type	Situation	Copper (g/ha to apply)
Foliar	Confirmed deficiency	100
	'Insurance'	50
Soil-applied	Confirmed deficiency	2,000
	'Insurance'	500–1,000

Source: Hughes (2012)

6.10.6 Molybdenum

Molybdenum and cobalt are required for effective nodulation and should be applied as needed.

Occurrence of molybdenum deficiency

Molybdenum availability increases as soil pH rises – the opposite of other micronutrients. Deficiencies in Australia are more likely on acid soils.

Sandy soils are deficient more often than finer-textured, heavier soils except for the ferrosols (krasnozems) that are naturally low in molybdenum.

High rates of phosphorus fertilisers increase molybdenum uptake by plants while heavy sulfur applications reduce its uptake.

Molybdenum deficiency symptoms

Molybdenum deficiency symptoms show up as a general yellowing and stunting of the plant, similar to the general symptoms of nitrogen deficiency.

Molybdenum deficiency can cause nitrogen deficiency symptoms in faba bean (see Section 6.5.2 Nutrient toxicity for more information), because the rhizobia require molybdenum to fix nitrogen.

Molybdenum management

Molybdenum deficiencies can be corrected with applications of very small amount of molybdenum fertiliser. To achieve as uniform an application as possible, molybdenum fertilisers should normally be applied with a carrier such as other fertiliser, seed, or in water.

Molybdenum trioxide (60% molybdenum) can be applied as an additive in single superphosphate. Soluble forms of molybdenum such as ammonium molybdate (54% molybdenum) or sodium molybdate (39–41% molybdenum) can be applied in solution directly to the soil or to foliage.

107 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

108 B Hughes (2012) Trace elements in the South East fact sheet. Natural Resources South East, www.naturalresources.sa.gov.au/southeast/land/soil-management/South-East-Soil-Issues

In some field crops, deficiencies can be corrected with soluble molybdenum applied with pre-emergence herbicides. Typical rates are 55–60 g/ha.[109]

6.10.7 Cobalt

Cobalt is required for effective nodulation and should be applied as needed. It is required by rhizobia for efficient nitrogen fixation.

6.10.8 Boron

Pulses have a high demand for boron. Many legumes are highly responsive to boron.

Occurrence of boron deficiency

Boron deficiency is widespread in many parts of the world. In Western Australia the areas most at risk have sandy, acid soils but deficiency is not severe in studied sites.[110] There is little information specific for southern Australia.

Note that boron toxicity (see Section 6.5.2 Nutrient toxicity for more information) is also a problem on some alkaline soils in southern Australia.

Boron deficiency symptoms

Boron-deficient faba bean roots become brown, with lateral extremities showing shortening and thickening. First symptoms are a darkening of leaves and reduced leaf growth with a waxy appearance (Photo 25). This is followed by a folding back of these leaves in an 'umbrella' fashion, leaving the leaflet folded over and twisted.[111] Stem internode length is shortened.

As the deficiency progresses, middle leaves develop a mottled chlorosis (yellowing) that forms between the vein.

As boron becomes deficient, the vegetative growing point of the affected plant becomes stunted, deformed or disappears altogether. When this occurs, side shoots may proliferate resulting in a 'witches broom' condition.

Deformed flowers are a common symptom of boron deficiency. Many plants show reduced flowering and improper pollination as well as thickened, curled, wilted and chlorotic (yellow) new growth.[112]

Photo 25: *Boron-adequate leaflet (left) and boron-deficient leaflets, (left to right) oldest to youngest.*

Photo: Alan Robson; Grain Legume Handbook (2008)

109 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

110 R Bell, K Frost, M Wong, R Brennan (2002) Boron – should we be worried about it? Proceedings Crop Updates 2002: Farming Systems. Western Australian Department of Agriculture. pp 45–46, http://researchrepository.murdoch.edu.au/18874/1/Boron_-_should_we_be_worried_about_it.pdf

111 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

112 Pulse Australia (2016) Agronomy. Southern faba and broad bean best management practices training course manual – 2016. Pulse Australia.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Management of boron deficiency

Use caution when using boron fertiliser and seek specific local advice. Ensure uniform application and use the appropriate rate because there is a narrow range between deficiency and toxicity.

Application rates of boron fertiliser depend on several factors, particularly the availability of soil boron, crop rotation weather conditions, farming practices and soil organic matter.

Boron fertiliser can be broadcast in the dry form to the soil or blended with other fertilisers.

Soluble boron fertilisers can be dissolved in water and applied as liquid. Foliar applications can be applied as one or more sprays.[113]

113 CSIRO (2006) Australian Soil Fertility Manual. 3rd edn. G Price (ed.). CSIRO Publishing.

Weed control

Key points

- **Growing pulses provides the opportunity to use different herbicide groups and target grass weeds, including herbicide-resistant weeds. Preventing weed seedset is a priority for this phase of the rotation.**
- **There are limited options for broadleaf weed control in faba and broad bean. They need to be heavily targeted in the preceding crop or fallow. Pre-emergent herbicides will be required.**
- **Use pre-emergent herbicides carefully to prevent damage to emerging plants. Be wary of herbicide damage from herbicide residues in the soil, drift from outside the crop, or spray tank contamination.**
- **In particularly weedy crops, cutting for hay or silage, or green or brown manuring, provide an opportunity for improved weed control compared to harvesting for grain.**
- **As crops that can be harvested early, faba bean provide a good opportunity for collecting weed seeds at harvest.**

MORE INFORMATION

See Weed ID: The Ute Guide App, https://grdc.com.au/resources-and-publications/app

7.1 Impact/cost of weeds

Weeds cost Australian grain growers $3.3 billion each year.[1] That is, $2.6 billion in control costs and another $745 million in lost yield. The cost to southern growers ranges from $105/ha in the low-rainfall zone, including the South Australian and Victorian Mallee and Upper Eyre Peninsula, up to $184/ha in the higher-rainfall zones including SA's Mid North, Yorke Peninsula and Lower Eyre Peninsula.

Reducing the cost of weed management is one of the grains industry's largest challenges. Good weed control is vital for successful and profitable crop production.

It is a challenge that is also constantly evolving, with changes in weed types and their characteristics, such as herbicide resistance. The use of management techniques such as crop-topping, double-knockdown and narrow windrow burning have increased, with the latter showing rapid recent increases in some areas.

Grasses top the list of the most costly weeds in the southern region (Table 1). Brome grass has increased in importance since the previous rankings were determined in the year 2000.

Planting a pulse crop as a break crop between cereals provides an ideal opportunity to target grass weeds.

Table 1: Weeds in the southern region ranked by area, yield loss and revenue loss.

Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss
1	Ryegrass	3,419,170	Ryegrass	155,332	Ryegrass	$38.9m
2	Wild oats	1,252,299	Wild oats	87,855	Wild oats	$21.7m
3	Brome grass	1,122,207	Brome grass	86,683	Brome grass	$21.0m
4	Wild mustard	822,497	Wild radish	37,169	Wild radish	$10.4m
5	Wild radish	739,339	Wild mustard	15,711	Vetches	$4.9m
6	Wild turnip	586,488	Vetches	11,517	Wild mustard	$3.8m

Source: Llewellyn *et al* (2016) Impact of weeds on Australian grain production

Weeds affect yield and management across all seasons and sometimes the price received for grain.

Weeds may:

- lower crop yields by competing for soil moisture, nutrients, space and light;
- carry diseases and viruses that can infect crops;
- impede harvest;
- contaminate grain; and
- restrict cropping options as there are limited herbicide options in pulse crops.

Weed management aims to reduce the overall number of weeds competing with the crop and in some cases target particular 'hard to manage' weeds such as herbicide-resistant ryegrass. Growers need to select crop rotations that will provide opportunities for the weed control required in each paddock. Crop rotation also allows for rotation of herbicide groups to minimise the build-up of herbicide resistance.

1 R Llewellyn, D Ronning, M Clarke, A Mayfield, S Walker and J Ouzman (2016) Impact of weeds on Australian grain production: The cost of weeds to Australian grain growers and the adoption of weed management and tillage practices. GRDC, https://grdc.com.au/ImpactOfWeeds

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

7.2 Key points for managing weeds in faba bean

Faba and broad bean provide some advantages for weed control including:[2]

- The opportunity to use different herbicide groups, particularly to target grass weeds such as annual ryegrass and wild oats.
- The possibility for delayed sowing in higher-rainfall areas, so there is better opportunity for knockdown weed control before sowing.
- When sowing into dry soil, there is a delay (14–28 days) before beans emerge after germinating rains. This can allow a non-selective knockdown herbicide application to kill weeds that emerge before the beans.
- The opportunity to grow in wider rows in a stubble system, which allows inter-row herbicide application with shielded sprayers.
- The choice to opt for green or brown manure or crop-topping if weed burdens are high.

Particular challenges and problem weeds in faba and broad bean crops include:

- Annual ryegrass that is resistant to Group A products ('Dims' and 'Fops'), particularly where high rates of clethodim are required.
- Annual ryegrass that is resistant to trifluralin.
- Snail and other medic.
- Wild radish: there are no safe treatments for post-emergent control.
- Hoary cress, soursob, vetch, bifora, bedstraw and tares.
- Limited post-emergent control options for broadleaf weeds.
- Bean crops are initially poor competitors with weeds in southern Australia because of slow germination, low plant populations and an extended period before canopy closure.
- Crop-topping to prevent seedset of ryegrass often provides the most effective control before faba bean are sufficiently mature and will reduce yield and quality. Broad bean consistently matures too late for crop-topping.
- Bean crops are often sown early or into dry soil limiting the opportunity for knockdown weed control before seeding and growers need to rely on herbicides and low weed numbers for in-crop weed control.

7.3 Using pulse crops for strategic weed control

The impact of weeds on bean yield is not well quantified. As bean crops are often thin during early development weeds don't necessarily inhibit bean growth at this stage. Tall, bulky crops are good competitors against later-germinating weeds.

Growers need to focus on limiting weed seedset and ensuring that green weed material does not delay harvest or reduce grain quality.

Research at Tamworth in 2001–03 found that faba bean had a similar competitiveness against weeds to canola, and was less competitive than wheat, but more competitive than chickpea.[3] In general, better weed management is required to grow faba bean than to grow wheat. In these trials faba bean, chickpea and canola stubble provided poor groundcover after harvest when compared with cereals.

2 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

3 WL Felton, BM Haigh and S Harden (2004) Comparing weed competition in chickpea, faba bean, canola and wheat. 14th Australian Weeds Conference, Wagga Wagga, New South Wales, pp. 304-307, http://caws.org.au/awc/2004/awc200413041.pdf

MORE INFORMATION

For details on annual ryegrass, see https://grdc.com.au/resources-and-publications/iwmhub/common-weeds-of-cropping/annual-ryegrass

GRDC has produced Fact Sheets on Wild radish: https://grdc.com.au/Resources/Factsheets/2014/07/Wild-radish and Brome grass: https://grdc.com.au/Resources/Factsheets/2011/05/Brome-Grass

7.3.1 Grass weeds

Pulse crops provide a good opportunity to control grass weeds that have been difficult to manage in cereals. Preventing weed seedset is a priority for pulse rotations, particularly where there are resistant weeds.

Grass-control herbicides can control most grass weeds in pulses, and volunteer cereals can also be controlled with some of these herbicides. Effective control of grass weeds will reduce root disease carry-over and provide a true break crop.

Where grass weeds have herbicide resistance faba bean can provide the opportunity to use alternative herbicide groups or to use other techniques such as crop-topping or green or brown manuring.

7.3.2 Broadleaf weeds

A weakness of pulse crops is the limited options for broadleaf weed control. In faba bean, chickpea and lentil there are few effective broadleaf post-emergent herbicides available.[4] It is important to have a 'plan of attack', which is likely to include the use of a pre-emergent herbicide.

Broadleaf weeds need to be heavily targeted in the preceding crop and/or fallow. The broadleaf weed risk is based on

- grower's experience;
- the previous crop and herbicides used; and
- an assessment of winter weeds germinating in the fallow year prior to planting.

Paddocks with substantial populations of wild radish, musk weed or vetch should be avoided.

Wild radish is a particular problem weed. Western Australian trials showed that 10 wild radish plants per square metre can reduce faba bean yields by 36%.[5]

In WA, 60% of wild radish is resistant to herbicides.[6] As southern region growers move to a more intensive cropping system, with fewer sheep and more herbicide applications the number of resistant wild radish populations are increasing. More than 90% of seed can be captured at harvest for destruction or removal.

4 GRDC (2014) Integrated Weed Management Hub. GRDC, https://grdc.com.au/weedlinks

5 AH Cheam *et al* (2008) Managing wild radish and other brassicaceous weeds in Australian cropping systems. CRC for Australian Weed Management.

6 GRDC (2013) Emerging Issues with Diseases Weeds and Pests. GroundCover™ Supplement, Issue 102, January–February 2013, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102

7.4 Integrated weed management (IWM)

An integrated weed management (IWM) system combining all available methods is the key to successful control of weeds. IWM includes both herbicidal and non-herbicidal options (Table 2).

Table 2: Weed control options for integrated weed management (IWM).

	Herbicidal	Non-herbicidal
Crop phase	• Use knockdown herbicides e.g. double-knock before sowing • Occasionally it may be possible to delay sowing to get maximum weed control before sowing • Use selective herbicides before and/or after sowing but ensure escapes do not set seed • Avoid high resistance-risk herbicides • Crop-topping • Brown manure crops	• Rotate crops • Rotate varieties • Grow a dense and competitive crop • Use cultivation • Delay sowing • Green manure crops • Cut crops for hay/silage • Burn stubbles/windrows • Collect weed seeds at harvest and remove/burn • Destroy weed seeds harvested e.g. use Harrington Seed Destructor
Pasture phase	• Spray-topping • Winter cleaning • Use selective herbicides but ensure escapees do not set seed	• Good pasture competition • Cut for hay/silage • Cultivated fallow • Grazing

Source: Pulse Australia (2016) [7]

MORE INFORMATION

GRDC booklet *Integrated weed management in Australian cropping systems*, see http://www.grdc.com.au/IWMM

GRDC booklet *Summer fallow weed management: A reference manual for grain growers and advisers in the southern and western grains regions of Australia*, http://www.grdc.com.au/GRDC-Manual-SummerFallowWeedManagement

7.4.1 Strategy – paddock choice and crop rotation

It is preferable to sow faba bean into paddocks with a low burden of grass and broadleaf weeds. Those with a severe broadleaf weed problem should be avoided.

A well-managed rotation of crops in each paddock provides the opportunity to target different weeds and can prevent a build-up of particular weed species. Grasses are easier to control in broadleaf crops such as pulses.

7.4.2 Good agronomic practice

Of the pulses, faba bean have a medium competitive ability, similar to field pea, and better than chickpea, lentil and lupin.

Getting the agronomy right means a more competitive crop. Use weed-free seed and sow on time. Faba bean in particular should not be sown after their optimum sowing date. Plant at optimal plant populations and use adequate nutrition with careful placement of fertiliser.

7.4.3 Pre-plant weed control

All weeds growing in a paddock should be controlled before the crop emerges.

Tillage is a valuable method for killing large, mature weeds and preparing seedbeds. There are varying combinations of mechanical and chemical weed control to manage fallows or stubbles. Large, advanced weeds not controlled prior to or during the sowing operation are difficult if not impossible to control with in-crop herbicides.

Knockdown herbicides are generally used instead of cultivation for fallow commencement, as well as for pre-planting weed control in the autumn. Knockdown

7 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

VIDEO

AHRI video: Narrow row spacing: more crop, fewer weeds https://www.youtube.com/watch?v=qM-PI4vMliw

MORE INFORMATION

GRDC Integrated Weed Management hub, https://grdc.com.au/weedlinks

herbicides benefit soil structure and provide more timely and effective weed control. However, it is important to understand and manage the risk of herbicide resistance.

Cultivation can spread grass weed seeds such as ryegrass, wild oat and brome grass through the soil profile and prolong their seedbank dormancy.[8] For these weeds a light cultivation with an autumn tickle (1–3 cm deep) can encourage germination and can assist in depleting the seedbank. This needs to be combined with delayed sowing and is more appropriate for faba bean in seasons with a very early break.

7.4.4 In-crop weed control

A wide range of pre emergent and early post-emergent herbicides are available for grass weed control in faba and broad bean. However, post-emergent options are very limited for broadleaf weeds.

Weeds should be removed from crops early, and certainly no later than 6 weeks after sowing, to minimise yield losses. The yield response will depend on weed species, weed and crop density and seasonal conditions.

The growth stage of the weed and the crop are vital factors to consider to successfully use post emergent herbicides. The growth stages of faba bean are detailed in Section 5 Plant growth and physiology. Read herbicide labels carefully for these details and information on the best conditions for spraying.

The risk of crop damage from herbicide application should be balanced against the potential yield loss from weed competition. In heavy weed infestations, some crop damage can be tolerated, as it is easily offset by the yield loss avoided by reducing weed competition.

7.4.5 Selective grazing

Although no longer a common practice, grazing weeds and crop contaminants in pulses can be useful where selective herbicides are not available. There may still be limited opportunities in crop salvage situations. This will not provide a disease break as the host weeds are not killed by selective grazing.

Plants vary in their palatability. When the stocking rate is light, animals will selectively graze the more palatable plants. This may be useful with volunteer crop weeds when herbicides are not available or their use would damage the sown crop, e.g. graze field peas in a faba and broad bean crop.

The relative palatability for some crops was determined by the University of Adelaide (Table 3). Palatability was rated as highly palatable – most of the crop eaten, through to low palatability – very little of the crop eaten.

Table 3: Relative palatability of various crops to sheep.

Highly palatable	Moderately palatable	Low palatability
Nine weeks after sowing		
Field pea, lathyrus, fenugreek, lentil, canola, wheat, safflower, lupin, common vetch	Chickpea	Coriander, faba bean, narbon bean
Thirteen weeks after sowing		
Field pea, lathyrus, canola	Lentil, lupin, mustard, safflower	Chickpea, coriander, faba bean, narbon bean, fenugreek

Source: Grain Legume Handbook (2008)[9]

8 GRDC (2012) Herbicide-resistance Fact Sheet, Southern Region, GRDC, May 2012, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

9 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

For best results:

- Introduce sheep early, before crop canopy closes.
- Use older sheep.
- Use low stocking rates.
- Spray weeds along fence lines to concentrate sheep in crop.
- Remove sheep before they do too much damage to crop.
- Remove sheep before flowering.
- Observe grazing withholding periods if any chemicals are used in crop.

7.4.6 Managing weeds at harvest

Managing weeds at harvest is an effective way to reduce carryover of problem weeds, particularly those with herbicide resistance.

Most southern Australian cropping weeds have seed that does not shatter before harvest. This major biological weakness provides the potential to remove the weed seed from cropping systems at harvest.[10]

Research by the Australian Herbicide Resistance Initiative (AHRI) found that ryegrass, wild radish, brome grass and wild oats all retained at least 75% of weed seeds at the first opportunity to harvest wheat. As faba bean can be harvested before wheat this presents an excellent opportunity to reduce the weed seedset.[11]

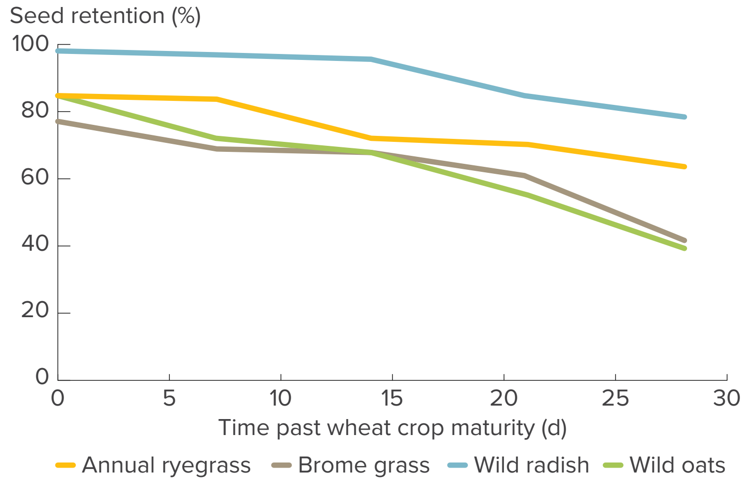

Figure 1: *Weed seed retention in WA measured from the date of wheat crop maturity.*

Source: Australian Herbicide Resistance Initiative (2014) [12]

These same weeds will shed between 0.8 and 1.5% of their seeds each day that harvest is delayed. To improve control of problem weeds, harvest weedy crops first and remove chaff.

MORE INFORMATION

For information on managing weeds at harvest, please see https://grdc.com.au/resources-and-publications/iwmhub/section-7-managing-weeds-at-harvest

The WeedSmart website has details on capturing weed seeds at harvest, see http://www.weedsmart.org.au/10-point-plan/capture-weed-seeds-at-harvest/

The AHRI Web site has 'Rules of thumb for weed seeds', please see http://ahri.uwa.edu.au/rules-of-thumb/

VIDEO

Harvest the time to get on top of resistant weeds https://youtu.be/uURyKaaq-_I

10 M Walsh, P Newman (2013) Cart, crush or cremate weed seeds to manage resistance. Herbicide Resistance, GRDC GroundCover™ Supplement, Issue 104, May–June 2013, pp. 8-9, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

11 Australian Herbicide Resistance Initiative (2014) Rules of thumb. Australian Herbicide Resistance Initiative, http://ahri.uwa.edu.au/rules-of-thumb/

12 Australian Herbicide Resistance Initiative (2014) Rules of thumb. Australian Herbicide Resistance Initiative, http://ahri.uwa.edu.au/rules-of-thumb/

VIDEO

GRDC Video: Harvest weed-seed control for the high-rainfall zone, https://youtu.be/RrvQQYqSmdE

Options for removing weed seeds in the chaff include:

- removing the weed-laden chaff via baling;
- tow a chaff cart and burn the heaps;
- concentrate the chaff into narrow windrows for burning;
- pulverising the chaff to crush and destroy the weed seeds before they exit the harvester – this can be achieved with the Integrated Harrington Seed Destructor; and
- in controlled-traffic farming, funnel chaff onto tramlines, confining weeds to a hostile environment separate from the crop.

Another weakness of weeds in southern Australian is that for many their seed does not remain viable in the soil for very long and seedbanks decline rapidly if not replenished each year.[13]

Harvest weed-seed control methods can lower a very large seedbank of more than 1,000 seeds/m^2 to 100 seeds/m^2 in only 4 years.[14] In paddocks with low ryegrass burdens harvest weed-seed methods reduced ryegrass emergence by as much as 90%.[15] Paddocks with high ryegrass burdens (>2,000 seeds/m^2) were less responsive, with a 30–40% reduction in ryegrass emergence. This means that harvest weed seed management will take longer to lower ryegrass populations in highly infested paddocks where the residual seedbank is still being exhausted.

Trials in SA and NSW showed that narrow windrow burning and the chaff cart proved as effective as the Harrington Seed Destructor at removing ryegrass seed and cost a similar amount per hectare to destroy ryegrass seed [16]

7.4.7 Alternatives to harvesting the crop

Operations such as cutting hay or silage, or green or brown manuring provide an opportunity for improved weed control when compared with harvesting crops for grain. These techniques are particularly valuable where herbicide-resistant weeds are a problem. When timed well they can prevent almost all seedset.

Additional benefits of manuring include boosting soil nitrogen and conserving soil moisture to benefit yield in subsequent years.

While green and brown manuring cost money without providing an income, the benefits for subsequent years can make it worthwhile. Manuring is usually suited to longer-seasoned forage crops, crop-topping for earlier-maturing grain crops. If income is important, crop-topping and grain harvest may be a more economically viable option even though yield may be reduced by topping.

Green manuring uses cultivation and brown manuring uses chemical control to stop the growth of both crop and weed.

The best crops for manuring are those with good early vigour that are effective at suppressing weed growth. As faba bean provide poor early groundcover, they are not as good as field pea or vetch, but they are better than chickpea. Total biomass is important to maximise the nitrogen benefit so choose a variety that is most likely to produce the highest biomass.

If the growth of the crop is reduced by disease, weeds, drought or sowing time then the nitrogen benefit will also be reduced.

Some in-crop herbicides are still required to maximise crop competitiveness and prevent weeds from getting too large to control. When aiming to control weed

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13 M Walsh, P Newman (2013) Cart, crush or cremate weed seeds to manage resistance. Herbicide Resistance, GRDC GroundCover™ Supplement, Issue 104, May–June 2013, pp. 8-9, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

14 M Walsh, P Newman (2013) Cart, crush or cremate weed seeds to manage resistance. Herbicide Resistance, GRDC GroundCover™ Supplement, Issue 104, May–June 2013, pp. 8-9, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

15 C Aves (2013) Mechanical options. Herbicide Resistance, GRDC GroundCover™ Supplement, Issue 104, May–June 2013, pp. 12, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

16 C Aves (2013) Mechanical options. Herbicide Resistance, GRDC GroundCover™ Supplement, Issue 104, May¬–June 2013, pp. 12, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

seedset, a later sowing date with pre-sowing knockdown will be more advantageous for weed control than sowing on time.

To maximise the effectiveness of herbicide-resistant-weed control, it is important to make sure they are controlled before seedset i.e. before the milky dough stage of the target weed. This may be before the peak dry matter and nitrogen fixing potential of the crop.

A second knockdown herbicide may be required to control weeds that were shielded from the first spray by the crop. Also check for and control regrowth after cutting.

7.5 Decision-support tools

Managing weeds is complicated and requires a long-term strategy. Decision-support models can be useful to assist with planning weed management strategy.

The Weed Seed Wizard (https://www.agric.wa.gov.au/weed-seed-wizard-0) is a computer simulation tool to help you understand and manage weed seedbanks for a range of different weeds and is relevant to all Australian grain-growing areas. It uses farm management records to simulate how different crop rotations, weed control techniques, irrigation, grazing and harvest management tactics can affect weed numbers, the weed seedbank and yields.

Ryegrass Integrated Management (RIM) (http://ahri.uwa.edu.au/research/rim/) is a decision-support tool to evaluate the long-term profitability of strategic and tactical ryegrass control methods. It allows you to test your ideas for reducing ryegrass populations while improving profitability.

7.6 Free alert services for weeds

MORE INFORMATION

More information about free weed information services is available on eXtensionAus, extensionaus.com.au

IN FOCUS

Growers can subscribe to newsletters that provide local pest and weed updates. The services listed below are all free.

National

- GrowNotes™ Alert on the latest weed, pest and disease issues in your area delivered via App, SMS, voice, email, social media or web portal (or a combination of preferred methods). Subscribe to this service on the GRDC website. (https://grdc.com.au/resources-and-publications/grownotes/alerts).

Victoria

- General grains information is available on the @VicGovGrains Twitter account (www.twitter.com/VicGovGrains), hosted by Agriculture Victoria. Additional services by Agriculture Victoria can be subscribed to on the GRDC website.

MORE INFORMATION

APVMA webpage: Registration database, https://portal.apvma.gov.au/pubcris

APVMA webpage: Permits database, https://portal.apvma.gov.au/permits

APVMA app: Permit app for iOS, http://apvma.gov.au/node/10831#iphone_app

Pulse Australia webpage: Permits for pulses, http://pulseaus.com.au/growing-pulses/crop-protection-products

Grain Producers booklet: *Safely managing risks with crop inputs and grain on-farm*, http://grainsguide.grainproducers.com.au/

CropLife Australia, Herbicide Mode of Action Groups 2017, https://www.croplife.org.au/resistance.../2017-herbicide-mode-of-action-group

7.7 Using herbicides

Herbicides that are registered for use in faba and broad bean can be found using the Australian Pesticides and Veterinary Medicines Authority (APVMA) database. An iOS app is also available. Seek the advice of your local agronomist or reseller.

Make sure you have the current information on the registration status, rates of application and warnings related to withholding periods, OH&S, residues and off-target effects before making decisions on which pesticide to use.

Use a herbicide that is legally registered for the particular use in the particular crop at the listed label rates. Using products off-label risks reduced efficacy, exceeded maximum residue limits (MRLs) and litigation.

Always read the product label and Safety Data Sheet (SDS) before using herbicides.

Residue limits in any crop are at risk of being exceeded or breached where pesticides are applied:

- at rates higher than the maximum specified;
- more frequently than the maximum number of times specified per crop;
- within the specified withholding period (i.e. within the shortest time before harvest that a product can be applied); and
- where they are not registered for the particular crop.

The National Residue Survey (NRS) is part of an Australian Government and industry strategy to minimise chemical residues and environmental contaminants in Australian food products. NRS programs support primary producers and commodity marketers by confirming Australia's status as a producer of clean food and facilitating access to key domestic and export markets. The compliance rate for pulses in 2013-14 was 99.5%.[17]

7.7.1 Residual and non-residual herbicides

Residual herbicides remain active in the soil for an extended period of time (i.e. months) and can act on successive weed germinations. Residual herbicides must be absorbed through either the roots or the shoots, or through both. Examples of residual herbicides include imazapyr, chlorsulfuron, atrazine and simazine.

The persistence of residual herbicides is determined by a range of factors including application rate, soil texture, organic matter levels, soil pH, rainfall or irrigation, temperature and the herbicide's characteristics. Persistence will affect enterprise sequence (e.g. a rotation of crops such as wheat–barley–chickpeas–canola–wheat).

Non-residual herbicides, such as the non-selective paraquat and glyphosate, have little or no soil activity and are quickly deactivated in the soil. They are either broken down or bound to soil particles, becoming less available to growing plants. They also may have little or no ability to be absorbed by roots.

7.7.2 Post-emergent and pre-emergent

These terms refer to the target and timing of herbicide application. Post-emergent refers to foliar application of the herbicide after the target weeds have emerged from the soil, while pre-emergent refers to application of the herbicide to the soil before the weeds have emerged.

17 National Residue Survey (2014) Residue results for 2013-14. Australian Government, Department of Agriculture and Water Resources, http://www.agriculture.gov.au/ag-farm-food/food/nrs/nrs-results-publications

MORE INFORMATION

CropLife webpage: Herbicide mode of action table, http://www.croplife.org.au/resistance-strategy/2017-herbicide-moa-table/

CropLife webpage: Herbicide-resistant weeds in Australia, http://www.croplife.org.au/resistance-strategy/2017-herbicide-resistant-weeds-list/

GRDC Fact Sheet: Herbicide resistance, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

CropLife booklet: *Herbicide-resistance management strategies*, http://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/

Webpage: WeedSmart, The Big 6, https://weedsmart.org.au/the-big-6/

Website: Australian Glyphosate Sustainability Working Group, http://www.glyphosateresistance.org.au/

App: WeedSmart to estimate paddock risk (iOS only), https://grdc.com.au/resources-and-publications/app

7.7.3 Current minor use permits (MUP)

Some products may be available under permit, with conditions attached, until enough data is generated for full registration. In other cases, a temporary permit may be granted when there is a particular seasonal issue.

Pulse Australia holds several minor use permits (MUP) on behalf of the pulse industry and is actively involved in the pursuit of new permits and label registrations to meet industry needs.[18]

The current minor use permit for herbicides is:

- **PER14726**
  Imazamox for use in faba bean to control grass and broadleaf weeds.
  Current to 30 September 2019.

7.8 Herbicide-resistant weeds

Herbicide resistance continues to develop and become more widespread. It is one of the biggest agronomic threats to the sustainability of our cropping systems. In 2014 there were 39 weed species in Australia with resistance to one or more herbicide modes of action.[19]

The main reason resistance has developed is because of the repeated and often uninterrupted use of herbicides with the same mode of action (Table 4). Selection of resistant strains can occur in as little as 3–4 years if no attention is paid to resistance management. The resistance risk is the same for products that have the same mode of action.

All herbicides sold in Australia are grouped by mode of action, which is clearly indicated by a letter code on the product label.[20]

GROUP	A	HERBICIDE

Resistance can be managed through good crop rotation, rotating herbicide groups, and by combining both chemical and non-chemical methods of weed control.

The WeedSmart App (https://grdc.com.au/resources-and-publications/app) is a simple tool to assess the weed management for a specific paddock. By answering nine short questions about a paddock's farming system, the tool will assess herbicide resistance and weed seedbank risk. It is currently only available for iOS.

18 Pulse Australia (2016) Crop protection products. Pulse Australia website, http://pulseaus.com.au/growing-pulses/crop-protection-products

19 GRDC (2014) Integrated Weed Management Hub. GRDC, https://grdc.com.au/weedlinks

20 CropLife Booklet: Herbicide resistance management strategies http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/

Table 4: Herbicide modes of action.

Resistance group	Mode of action
High resistance risk	
GROUP A	Inhibitors of acetyl co-enzyme A carboxylase (inhibitors of fat synthesis/ACC'ase inhibitors)
GROUP B	Inhibitors of acetolactate synthase (ALS inhibitors), acetohydroxyacid synthase (AHAS)
Moderate resistance risk	
GROUP C	Inhibitors of photosynthesis at photosystem II (PS II inhibitors)
GROUP D	Inhibitors of microtubule assembly
GROUP E	Inhibitors of wmicrotubule polymerisation
GROUP F	Bleachers: inhibitors of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)
GROUP G	Inhibitors of protoporphyrinogen oxidase (PPOs)
GROUP H	Bleachers: inhibitors of 4-hydroxyphenyl-pyruvate dioxygenase (HPPDs)
GROUP I	Disruptors of plant cell growth (synthetic auxins)
GROUP J	Inhibitors of lipid synthesis (not ACCase inhibitors)
GROUP K	Inhibitors of cell division / inhibitors of very long chain fatty acids (VLCFA inhibitors)
GROUP L	Inhibitors of photosynthesis at photosystem I via electron diversion (PSI inhibitors)
GROUP M	Inhibitors of 5-enolpyruvyl shikimate-3 phosphate (EPSP) synthase
GROUP N	Inhibitors of glutamine synthetase
GROUP O	Inhibitors of cell wall (cellulose) synthesis
GROUP P	Inhibitors of auxin transport
GROUP Q	Bleachers: inhibitors of carotenoid biosynthesis unknown target
GROUP R	Inhibitors of dihydropteroate synthase (DHP inhibitors)
GROUP Z	Herbicides with unknown and probably diverse sites of action

Source: CropLife Australia (2016) Herbicide mode of action table, CropLife website, http://www.croplife.org.au/resistance-strategy/2016-herbicide-moa-table/

Herbicide resistance evolves following the intensive use of herbicides for weed control.

In any weed population there are likely to be a small number of individuals that are naturally resistant to herbicides due to genetic diversity, even before the herbicides are used. When herbicide is used, these individual weeds survive and set seed, whereas the majority of susceptible plants are killed. Continued use of one herbicide, or herbicide group, will eventually result in a significant fraction of the weed population with resistance.

MORE INFORMATION

AHRI decision-support tool: Ryegrass Integrated Management (RIM), http://ahri.uwa.edu.au/research/rim/

Australian Glyphosate Sustainability Working Group www.glyphosateresistance.org.au

GRDC Updates 2015: Herbicide-resistance management, a local, in-field perspective, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/07/herbicide-resistance-management-a-local-infield-perspective

VIDEO

GRDC Video: Glyphosate-resistant weeds, https://youtu.be/Ke8klYNQzI8

VIDEO

See GRDC GroundCover™ TV Episode 19 for more about glyphosate resistance in feathertop Rhodes grass, https://youtu.be/Yk95mS_hvhM8

There are four main factors that influence the evolution of resistance:

1. The intensity of selection pressure.

This refers to how many weeds are killed by the herbicide. It is good practice to use labelled rates of herbicides to control weeds, as this will lead to the highest and most consistent levels of weed control. Failure to control weeds adequately will lead to increases in weed populations and put pressure on all herbicides used.

2. The frequency of use of one herbicide or mode of action group.

For most weeds and herbicides, the number of years of herbicide use is a good measure of selection intensity. The more often herbicide is applied the higher the selection pressure and the higher the risk of herbicide resistance developing.

3. The frequency of resistance present in untreated populations.

If the frequency of resistant genes in a population is relatively high, such as with Group B herbicides, resistance will occur quickly. If the frequency is low, such as with Group M herbicides, resistance will occur more slowly.

4. The biology and density of the weed.

Weed species that produce large numbers of seed, and have a short seedbank life in the soil, will evolve resistance faster than weed species with long seedbank lives.

Weed species with greater genetic diversity are more likely to evolve resistance.

Resistance is also more likely to be detected in larger weed populations.

7.8.1 Glyphosate (Group M)

Continued reliance on glyphosate is leading to increased resistance. The loss of glyphosate will increase the cost of weed management. Glyphosate-resistant weeds have a lower fitness and are more vulnerable to IWM techniques. Controlling weeds using integrated weed management will be more costly, but will have long-term benefits of delaying the development of resistance and reducing weed seedbanks.

Resistance mainly occurs in situations where glyphosate has been used as the main weed-control tactic, no other effective herbicides are used and few other weed-management practices are employed. These include chemical fallows, fence lines, irrigation channels, vineyards and roadsides.

In 2017 glyphosate resistance was present in populations including annual ryegrass, awnless barnyard grass, liverseed grass, brome grass, red brome grass, windmill grass, flaxleaf fleabane, milk/sow thistle, wild radish, winter grass, willow-leaved lettuce, tridax daisy, feathertop Rhodes grass, sweet summer grass and prickly lettuce.[21]

Growers are encouraged to use paraquat for crop-topping in pulses rather than rely on glyphosate, which is frequently used for topping in other crops. However, paraquat resistance is also increasing so weeds should be tested before planning a management strategy.

7.8.2 Paraquat (Group L)

In 2017 paraquat-resistant weeds included capeweed, northern barley grass, barley grass, annual ryegrass, small square weed, silvergrass, cudweed, blackberry nightshade, crowsfoot grass and flaxleaf fleabane.

Ryegrass that is resistant to both glyphosate and paraquat has been found in South Australia.

21 GRDC (2014) Integrated Weed Management Hub. GRDC, https://grdc.com.au/weedlinks

7.8.3 Other herbicides

Annual ryegrass in Australia is now resistant to 8 different herbicide groups.[22] The major herbicides are Group A (>20,000 sites in Australia), Group B (>20,000 sites) and Group D (>5,000 sites). Resistance to trifluralin (Group D) and the Dims (Group A) is increasing in southern Australia.[23]

Annual ryegrass is highly competitive against faba bean.

Clethodim (Group A) resistance is a major issue in pulse production. Clethodim is the last Group A herbicide that provides effective control of herbicide-resistant ryegrass. There are no highly effective alternatives to clethodim for controlling annual ryegrass in faba bean or canola. Medic, vetch and tares may also be resistant to clethodim.

Wild oats in some areas have a high rate of resistance to all of the Group A herbicides (Fops, Dims and Dens).

In trials with clethodim-resistant ryegrass at Roseworthy, South Australia, the sole reliance on pre-emergent herbicides failed to adequately manage annual ryegrass and there were large yield penalties for faba bean.[24] Early competition by ryegrass reduced bean yield. Tank-mixing butroxydim (Factor®) with clethodim gave improved ryegrass control and protected yield. Simazine pre-emergent combined with clethodim + butroxydim post-emergent are the most effective of the current registered options.

7.8.4 Managing herbicide resistance

Weedsmart (http://www.weedsmart.org.au/10-point-plan/) lists 10 ways to weed out herbicide resistance:

1. Act now to stop weeds from setting seed.
2. Capture weed seeds at harvest.
3. Rotate crops and herbicide modes of action.
4. Test for resistance to establish a clear picture of paddock-by-paddock status.
5. Never cut the rate.
6. Don't automatically reach for glyphosate.
7. Carefully manage spray events.
8. Plant clean seed into clean paddocks with clean borders.
9. Use the double-knock technique.
10. Employ crop competitiveness to combat weeds.

Annual ryegrass has higher levels of resistance than any other weed. Preventing ryegrass from setting seed and removing weed seeds at harvest before they fall to the ground is the top priority. Aim for 3 years with no weed seedset. Techniques to manage resistant ryegrass include:

- Know your resistance status. What herbicides are the ryegrass resistant to?
- Use crop rotation to access different treatment options
- Avoid cultivation that will bury ryegrass seed. Seed on the soil surface is more likely to be burnt, rot naturally or be controlled by pre-emergent herbicide. Cultivation is more suited to large mature weeds in fallow.
- Use double-knock before seeding
- Consider crop-topping even if yield will be reduced.
- Consider green or brown manuring or cutting for hay.
- Capture and destroy weed seeds at harvest.
- Control ryegrass in non-crop areas such as fence lines, channel banks, etc.

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22 CropLife Australia (2016) Herbicide-resistant weeds, CropLife website, http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistant-weeds-list/

23 G Brooke, C McMaster (2016) Weed control in winter crops 2016. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops

24 C Preston, P Boutsalis, S Kleemann, R Saini and G Gill (2015) Managing resistant ryegrass in break crops and new herbicides for resistant ryegrass. GRDC Update Papers, 28 July 2015, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/07/managing-resistant-ryegrass-in-break-crops-and-new-herbicides-for-resistant-ryegrass

Ryegrass Integrated Management (RIM) (http://ahri.uwa.edu.au/research/rim/) is a decision-support tool to evaluate the long-term profitability of strategic and tactical ryegrass control methods. It allows you to test your ideas for reducing ryegrass populations while improving profitability.

7.8.5 Herbicide-resistance testing

There are two types of commercial tests for herbicide resistance.

Seed testing is suitable for pre- and post-emergent herbicides and takes 4–5 months. This requires 3,000 seeds of each weed – approximately 1 cup of annual ryegrass seed or 6 cups of wild radish pods.

The **quick test** for post-emergent herbicides only uses live plant seedlings and results are available within 6 weeks. This requires 50 plants (or 20 large, tillering plants) for each herbicide tested.

There are two testing services in the southern region:

- **Plant Science Consulting** offers both seed testing and the quick test.
  22 Linley Avenue, Prospect, SA 5082.
  Ph: 0400 66 44 60
  Email: info@plantscienceconsulting.com.au
  http://www.plantscienceconsulting.com.au/
- **Charles Sturt University** offers the seed test only.
  Herbicide Resistance Testing, School of Agricultural and Wine Sciences, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW, 2678.
  Ph: John Broster 02 6933 4001 or 0427 296 641
  Email: jbroster@csu.edu.au
  https://www.csu.edu.au/weedresearchgroup/herbicide-resistance

7.9 Risk of herbicide damage

Herbicide damage can result from:

- residues in the soil;
- drift from outside the crop;
- pre- and post-emergent herbicides applied to the crop; and
- spray tank contamination.

Damage from pre- and post-emergent herbicides can be minimised by careful application and by understanding the tolerance of bean varieties.

Plants weakened by herbicide injury are more susceptible to diseases, especially chocolate spot. The most common problems come from residual herbicides applied to prior cereal crops, but non-residual herbicides have also been implicated.

MORE INFORMATION

Agriculture Victoria, Avoiding crop damage from residual herbicides, http://agriculture.vic.gov.au/agriculture/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

7.9.1 Herbicide residues

Pulse types differ in their sensitivity to residual herbicides used in earlier crop or fallow situations. Check the re-cropping period on the label of each herbicide used.

Group B:

- Lentil and chickpea are most vulnerable to sulfonylurea residues (e.g. chlorsulfuron, Logran®), with field pea, faba and broad bean the least. Residues persist longer in high pH soil. Moisture favours breakdown and residues will persist longer in dry conditions.
- At low pH (<6.5 pH in water) faba and broad bean are more sensitive to Monza® residues (sulfonylurea) than chickpea, lentil, lupin and field pea. All are sensitive at higher pH (>6.5 pH in water).
- Faba and broad bean, lentil and lupin are more sensitive to sulfonamide residues (e.g. Broadstrike®) particularly on shallow duplex soils where breakdown is slower.
- Chickpea, field pea, faba and broad bean are least sensitive to the imidazolinones (IMIs e.g. Spinnaker®, Raptor®, Midas®). Lentil is most sensitive. Lupin and vetch are intermediate.
- Raptor® (IMI) has no minimum re-cropping interval if field pea is being sown.
- IMI herbicides persist longer in heavy soils and under dry conditions.
- When Group B residues are present, there is an increased risk of damage from using another Group B herbicide in-crop.

Group I:

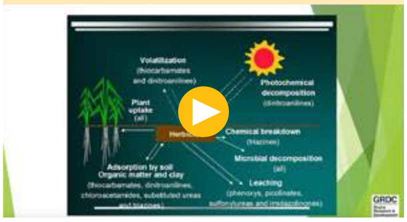
- All pulses are vulnerable to pyridine residues (e.g. clopyralid/Lontrel®) but beans are more vulnerable than lupin. Lontrel® is more likely to persist in stubble-retention systems.
- Spikes (e.g. dicamba, 2,4-D) used on late summer weeds or added to knockdown sprays may persist under dry conditions and can reduce pulse crop establishment. Some plant-backs require 15 mm of rain before the re-cropping period commences. Faba bean and lentil are not listed on label for these herbicides.
- Picloram and aminopyralid (e.g. Grazon Extra® and Tordon 75D®) applied to previous summer fallows are more likely to persist and damage crops under dry conditions. Residues from spot spraying of picloram can show up as bare patches in faba bean crops.
- Group I herbicides can accumulate on stubble and also persist longer under dry conditions.

VIDEO

GRDC Video: Pre-emergent herbicides – solubility and binding, https://youtu.be/s63GYYyfIzw

VIDEO

GRDC Webinar: Stubble & soil binding of pre-emergent herbicides for annual ryegrass control in winter crops, https://youtu.be/mrJvg5ZmdOU



VIDEO

WeedSmart webinar: Understanding pre-emergent herbicides, http://weedsmart.org.au/webinars/setting-crops-up-for-success/

Group C:

- Triazine herbicides (e.g. simazine, cyanazine, terbuthylazine) applied in-crop can potentially cause crop damage in some circumstances. This also applies to diuron and metribuzin.
- They are more likely to persist in soil that is high pH, heavy or duplex.
- All residual herbicides require moist soil to break down. Where dry conditions have persisted between herbicide application and sowing, there will be a higher risk of residual herbicide damage.

7.9.2 Drift

All herbicides are capable of drifting from neighbouring paddocks. Pulses are particularly vulnerable to damage from volatile ester formulations of phenoxy herbicides (Group I) that are more prone to drift as a vapour during or after application.

7.9.3 Spray tank contamination with sulfonylurea herbicides

Traces of sulfonylurea herbicides (Group B, e.g. chlorsulfuron, metsulfuron or triasulfuron) and carfentrazone (Group G, e.g. Affinity®) in spray equipment can cause severe damage to faba and broad bean and other legumes when activated by grass-control herbicides.

It is vitally important to properly clean and decontaminate spray equipment before applying herbicides. See product labels for specific product recommendations on decontamination.

7.9.4 Minimising damage from pre- and post-emergent herbicides

Herbicide damage does not always result in reduced grain yield. Damage may be very obvious, such as scorched leaves, or it may be subtle, such as poor establishment or delayed maturity. Symptoms can easily be confused with symptoms produced by other causes, such as frost, disease or nutrition.

The risk of crop damage from a herbicide should be balanced against the potential yield loss from weed competition. In heavy weed infestations, some herbicide crop damage can be tolerated as this is easily offset by the yield loss avoided by removing competing weeds.

Some precautions for using pre-emergent residual herbicides can reduce the likelihood of crop damage:

- Do not apply if rain is imminent.
- Plant seed at least 7.5–10 cm deep.
- Avoid leaving a furrow or depression above the seed that could allow water (and chemical) to concentrate around the seed/seedling.
- Avoid leaving an exposed, open slot over the seed with disc openers and avoid a cloddy, rough tilth with tyned openers.

If herbicide is applied to dry soils, the risk of movement and crop damage is increased greatly after rainfall, particularly if the soil is left ridged and herbicide washes into the seed row. It may be more appropriate to use incorporation by seeding (IBS), or splitting the application between IBS and post-sowing pre-emergent (PSPE) to minimise risk.

Metribuzin leaches at almost 3 times the rate of simazine and 7 times the rate of diuron. The relative tolerance of the crop type and variety will also affect crop damage from these herbicides. For more specific details on soil-active herbicides and the risk of crop damage in your cropping situation seek advice from an experienced agronomist.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

MORE INFORMATION

GRDC GrowNotes™ Spray Application manual for grain growers, https://grdc.com.au/GrowNotesSprayApplication

VIDEO

GRDC Video: Spray application workshop, https://youtu.be/UskthCWjeug

VIDEO

GRDC Webinar: Spray application in summer fallows, https://youtu.be/kDuz6ADMjA0

Some spray oils used with post-emergent selective-grass herbicides can cause minor leaf spotting and/or burning, which should not be confused with disease symptoms.

7.9.5 Symptoms of herbicide damage

Pulses have narrow crop safety margins to most registered herbicides.

Group A

Group A herbicides can occasionally cause leaf spotting in faba and broad bean (Photo 1). This is usually associated with either frost or high temperatures soon after spray application. Unlike with disease, new growth does not show spots (Photo 2).

Photo 1: *Group A grass herbicide. Chemical leaf spotting from oils in a group A herbicide applied post-emergent. Note that spots are numerous, small, irregular in shape and differ on top and bottom sides of leaf.*

Photo: R. Kimber, SARDI

Photo 2: *Group A grass herbicide. Chemical leaf spotting on lower leaves after application of a grass herbicide. Do not confuse this with Cercospora or Ascochyta leaf diseases.*

Photo: R. Kimber, SARDI

MORE INFORMATION

GRDC App: Herbicide injury: the Ute Guide, http://www.uteguides.net.au/UteGuides

Obtain a copy of the GRDC *Field Crop Herbicide Injury: The Ute Guide*, https://grdc.com.au/resources-and-publications/all-publications/bookshop

Group B

Seedlings may emerge and grow normally for several weeks before plants become stunted. Group B herbicides cause yellowing sometimes with a red-purple tinge (Photo 3). Damage is more common on areas where there has been overlapping such as headlands. Roots are often pruned and this leads to other symptoms such as nutrient deficiency (often zinc) and greater risk of disease development. Symptoms can be more severe in compacted soil.

IMI products that are registered for use in faba bean can still cause problems under dry conditions, when residues remain in the soil and where there is spray overlap.

Photo 3: *Group B imazethapyr (Spinnaker®) damage.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Group C

The group C chemistry applied post sowing pre-emergent in low-rainfall areas and on light soils can often lead to crop damage reducing establishment and plant growth. This mainly occurs when rainfall washes herbicide applied to dry soils into the seed furrow, or on calcareous soils where these herbicides are highly soluble.

Initial symptoms are stunting and chlorosis and then as the herbicide accumulates in the tips and margins there is bleaching and necrosis (Photo 4).

Photo 4: *Group C simazine. High rates of simazine can damage faba bean. Lower leaves turn black and die back from the edge.*

Photo: Allan Mayfield, Grain Legume Handbook (2008)

Group D

Trifluralin can cause stunted plants (Photo 5). Emergence may be intermittent with plant shoots are shortened or unable to emerge. Emerging leaves can be twisted and distorted. Roots can be shortened and thickened.

Photo 5: *Group D trifluralin. Trifluralin injury (left) causing stunted growth. It can also cause development of multiple growing points.*

Photo: C. Preston, Univ. of Adelaide

Group F

Diflufenican (e.g. Brodal®) damage is usually white to yellow spots 3–4 days after application (Photo 6). Plants turn light green and whole leaves to yellow to cream in colour. Effects disappear as new growth develops.

Photo 6: *Group F diflufenican. Symptoms of Brodal® (diflufenican) damage: white to pale yellow leaves with yellow blotches.*

Photo: Allan Mayfield, Grain Legume Handbook (2008)

Group G

Carfentrazone is a contact herbicide causing leaf spotting (Photo 7). Numerous white spots develop within 1–2 days of spraying. It can lead to desiccation and death in bean crops.

Photo 7: *Group G carfentrazone. Leaf spotting from spray droplets of Affinity® (carfentrazone).*

Photo: C. Preston, Univ. of Adelaide

Group I

Typical symptoms of Group I herbicides is twisting of the leaf and stem (Photo 8). The less obvious symptoms of residues may be slow growth, thickening and callusing of the stem and a proliferation of short lateral roots.

Spray drift can lead to less obvious symptoms such as narrow leaves with crinkled edges (Photo 9). Leaf spotting from MCPB can be confused with Ascochyta or chocolate spot (Photo 10).

Photo 8: *Group I. Beans are susceptible to Tordon® or Lontrel® residue in soil. Note the stem distortion and severe leaf curl.*

Photo: Allan Mayfield, Grain Legume Handbook (2008)

Photo 9: *Group I, 2,4-D. Spray drift causing narrow leaves with crinkled edges.*

Photo: Allan Mayfield, Grain Legume Handbook (2008)

Photo 10: *Group I, MCPB. Leaf spotting caused by MCPB herbicide can be confused with Ascochyta and chocolate spot infections in beans.*

Photo: Allan Mayfield, Grain Legume Handbook (2008)

Group J

Symptoms appear underground or as plants emerge with reduced or poor seedling emergence. Symptoms include pruned roots with stubby root knobs and shoots that are swollen and bright green.

Group K

Visual symptoms appear as the crop emerges with reduced or poor seedling emergence (Photo 11). In most cases weeds do not appear. Seedlings are malformed and twisted, with transitory crop yellowing.

Photo 11: *Group K damage (left) from Dual Gold® (metalachlor).*

Photo: C. Preston, University of Adelaide

Group L

Paraquat and diquat are contact herbicides and cause necrotic spots (Photos 12 and 13). Symptoms appear within hours of application. There may also be wilting and interveinal yellowing followed by browning and blackening of the leaf edges.

Plants shrivel up within 4 days of application if damage is severe. Signs are often worse on one side of the plant or stem. Effects disappear as new growth develops.

Photo 12: *Group L paraquat. Leaf spotting from spray droplets of paraquat.*

Photo: C. Preston, University of Adelaide

Photo 13: *Group L paraquat and diquat. Leaf damage and plant set-back from post-emergent application of SpraySeed® (paraquat plus diquat).*

Photo: Wayne Hawthorne, formerly Pulse Australia

Group M

Glyphosate typically causes yellowing of the leaves (Photo 14).

Photo 14: *Group M glyphosate. Limp leaves and yellowing after glyphosate application. Young leaves are stunted and twisted.*

Photo: C. Preston, University of Adelaide

MORE INFORMATION

For herbicide-tolerance trials, see NVT Online, http://www.nvtonline.com.au/herbicide-tolerance/

7.9.6 Herbicide tolerance trials

Faba and broad bean varieties differ in their herbicide tolerance, depending on season, soil type and rate of application. Herbicide labels generally do not reflect these subtleties.

Herbicide-tolerance trials in South Australia (alkaline sandy loam soils) demonstrate some of the varietal differences (Table 5).

Table 5: Herbicide tolerance of faba bean varieties to commonly used herbicides, South Australia.

Herbicide		Boxer Gold®	Diuron®	Outlook*	Simazine	Simazine	Lexone ®	Spinnaker®	Raptor®*	Status®*	Terbyne®
		Prosulfocarb + S-metolochlor	Diuron	Di-methenamid-P	Simazine	Simazine	Metribuzin	Imazethapyr	Imazamox	Clethodim	Terbuthylazine
Variety	Years	2015	2000-2015	2011-2013	2000-2015	2001-2008	2003-2010	2000-2015	2003-2015	2014	2009-2015
PBA Samira	2013-2015	✓(1)	✓(3)	✓(1)	✓(3)	-	-	✓(3)	30-35 (2/3)	✓(1)	✓(3)
Farah	2002-2008	-	✓(7)	-	N (1/7)	6-18 (3/7)	✓(6)	28-39 (2/3)	N (3/6)	-	-
Fiesta	2000-2007	-	N (1/8)	-	18 (1/8)	21 (1/7)	✓(5)	11-32 (2/8)	N (4/5)	-	-
Fiord	2000-2002	-	N (1/3)	-	N (2/3)	N (1/2)	-	18-30 (2/3)	-	-	-
PBA Rana	2009-2011	-	✓(3)	✓(1)	✓(3)	-	N (1/2)	14 (1/3)	18 (1/3)	-	N (1/3)
Nura	2003-2015	✓(1)	✓(12)	✓(2)	N (2/12)	N (1/7)	✓(8)	10-53 (8/12)	8-20 (4/12)	✓(1)	10 (4/6)
Rates (product/ha)		2.5 L	1 kg	1 L	1 kg	1.5 L	280 g	85 g	45 g	1 L	1 kg
Crop stage at spraying		IBS	PSPE	IBS	PSPE	6 weeks	PSPE	PSPE	3-4 leaf	3 node	PSPE

* Denotes an off label use. This use is not endorsed by this data and no responsibility will be taken for its interpretation.

The sensitivity of the variety is summarised, using the following symbols based on the yield responses across all trials:

- \- not tested or insufficient data
- ✓ (z) no significant yield reductions at recommended rates or higher than recommended rates in (z) trials
- N (w/z) narrow margin, significant yield reductions at higher than recommended rate, but not at recommended rate, significant event occurring w years out of z years tested Eg (2/5) = tested for 5 years, 2 returning a significant yield loss
- x% (w/z) yield reduction (warning) significant yield reduction at recommended rate in 1 trial only in z years of testing
- x-y% (w/z) yield reductions (warning) significant yield reductions at recommended rate in w years out of z years tested.

Always follow label recommendations. All pesticide applications must accord with the currently regisetered label for that particular pesticide, crop, pest and region. Any research regarding pesticides of their use reported in this website does not consititute a recommedation for that particular use by the authors, the author's organisations of ACAS. It must be emphasised that crop tolerance and yield responses to herbicides are strongly influenced by seasonal conditions.

Source: NVT Online (2016)

All varieties exhibit some yield loss to imazathapyr (Group B, IMI), but Nura[ⅆ] appears to be more sensitive than others.

Raptor® (imazamox, Group B) has a narrow safety margin in all faba bean varieties. It can be applied post-emergent under APVMA permit. Field experience is that damage is more severe under moisture stress and conditions of slow growth. It should be considered a salvage option rather than a routine application.

Simazine (Group C) applied post emergence can be more damaging than when applied PSPE, especially with the variety Farah[ⅆ]. Simazine does have a narrow safety margin or some yield loss (to 21%) at standard rates.

Diuron (Group C) has been safe in Farah[ⅆ] and Nura[ⅆ] over 7 or more trials, but check current registration status with broadacre crops.

Broad bean are not evaluated in the tolerance trials, but visual observations from PBA breeding trials in the high-rainfall zone suggest that PBA Kareema[ⅆ] and Aquadulce have a similar tolerance to registered herbicides as faba bean.

VIDEO

Watch GRDC Video: Pulse herbicide tolerance, https://youtu.be/j7JEfzclUfg

7.9.7 Breeding for improved tolerance

Faba bean lines with tolerance to imidazolinone herbicides (Group B) are currently being evaluated with potential for commercialization in 2018–19.[25] There is some cross-tolerance to other Group B herbicides in some of the lines.

Screening techniques have been developed for metribuzin tolerance (Group C). Low level tolerance has been identified in faba bean genetic resources and will be incorporated into breeding programs to improve the safety margin to currently registered use rates.

7.10 Knockdown herbicides

The most important part of the pulse weed-control strategy is to control the majority of weeds before seeding, either by cultivation or with knockdown herbicides such as glyphosate (Group M) or Spray Seed® (Group L).

Group I herbicides used pre-sowing as spikes (e.g. dicamba) in knockdown sprays may persist under dry conditions and can reduce pulse crop establishment. Dicamba plantbacks require 15 mm of rain before the re-cropping period commences. Faba bean and lentil are not listed on the label. Alternative products with lesser or no residual may be more appropriate such as carfentrazone-ethyl, oxyfluorfen or flumioxazin (Group G).

A technique used with varying success by growers has been to sow faba and broad bean and then use a knockdown herbicide tank mixed with a pre-emergent herbicide to control germinating weeds just before the crop emerges. Faba and broad bean crops may take up to 28 days to emerge under cool, drying soil conditions, but under favourable warm, moist soil conditions may emerge after 7–10 days. Growers considering this option should sow deeper and carefully check their paddocks for the emergence of the faba and broad bean immediately before spraying. Done well, this can be an effective weed-control option.

Double-knock is the sequential application of two different weed-control tactics where the second tactic controls survivors from the first. A common technique is to apply glyphosate (Group M), followed 2–10 days later by paraquat/diquat (Group L). Non-chemical options such as burning or grazing may also be used.

It may be necessary to delay sowing for up to 2 weeks after rain to enable a greater percentage of annual weeds to emerge and so is not suitable for faba bean unless there is an early break (see Section 7.10 Knockdown herbicides for more information).

Please see the GRDC Update paper for details on optimising the impact of glyphosate, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/optimising-the-impact-of-glyphosate

The GRDC has produced a video on double-knock timing, please see https://grdc.com.au/Media-Centre/GroundCover-TV/2013/05/GCTV10/tNNRziB3MKc

Watch GRDC video: IWM: Double-knock applications – double-knock strategies for resistant weed populations, https://youtu.be/bL0sbdQAYK0

Watch GRDC Video: Double knock-applications – a grower's experience, https://youtu.be/pElEGsQDzBg

25 D Mao, J Paull, C Preston, S Yang, T Sutton and L McMurray (2016) Developing improved herbicide tolerance in pulse crops. GRDC Update Paper, 9 February 2016, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/developing-improved-herbicide-tolerance-in-pulse-crops

MORE INFORMATION

GRDC booklet *Soil behaviour of pre-emergent herbicides in Australian farming systems*, https://grdc.com.au/SoilBehaviourPreEmergentHerbicides

7.11 Pre-emergent herbicides

Pre-emergent herbicides are essential because there are limited post-emergent options for broadleaf weed control in faba bean.

Pre-emergent herbicides control weeds at the early stages of the life cycle, between radicle (root shoot) emergence from the seed and seedling leaf emergence through the soil.

Some pre-emergent herbicides also have post-emergent activity through leaf absorption and can be applied to newly emerging weeds.

The residual activity of a pre-emergent herbicide controls the first few flushes of germinating weeds while the crop is too small to compete. As a result, pre-emergent herbicides are often excellent at protecting the crop from early weed competition.

With the continued development of Group A, Group B and Group D resistant populations of annual ryegrass and wild oats, growers are returning to older products to rotate herbicide-resistance groups.

Pre-emergent herbicides will not adequately control large weed populations by themselves and need to be used in conjunction with paddock selection, crop rotation and pre-seeding weed control.

Pre-emergent registrations for use on faba and broad bean include:

- Group B: imazethapyr (e.g. Spinnaker®)
- Group D: trifluralin (e.g. TriflurX®) and pendimethalin (e.g. Stomp®)
- Group J: triallate (e.g. Avadex®)
- Group C: cyanazine (e.g. Bladex®), simazine, terbuthylazine (Terbyne®), metribuzin (Sencor®) and some diuron brands (e.g. Diurex ®)
- Groups J+K: prosulfocarb + S-metolachlor (e.g. Boxer Gold®).

Outlook® (dimethenamid, Group K) and Sakura® (Pyroxasulfone, Group K) are registered in some pulses to provide control options for ryegrass that is resistant to other herbicide groups. However, Outlook® and Sakura® **ARE NOT REGISTERED FOR USE IN FABA BEAN** because they are too damaging. Most pre-emergent chemicals are very dependent on rainfall soon after application. They provide inconsistent or partial weed control under drier conditions.

Crop tolerance of several pre-emergent herbicides (i.e. trifluralin, prosulfocarb) is often related to spatial separation of the young crop from the herbicide. This depends on the level of solubility and potential movement in the soil of the herbicide, the crop establishment process, the level of soil displacement over the crop row, follow-up rainfall and physical nature of the seed furrow.

Incorporation by sowing (IBS) is generally considered safer on the crop than post-sowing pre-emergent (PSPE) in no-till sowing systems. There is little protection within the sowing row, or else there is potential for crop damage if soil is thrown into the seeding furrow.

To avoid PSPE damage, sow deep. Apply to moist soil, not dry, and do not apply if there is heavy rain forecast. Apply to level soil surface to limit the possibility of herbicide concentrating in the furrow. Use lower rates on lighter soils.

7.11.1 Imazethapyr (Group B)

Imazethapyr is registered for the pre-emergent weed control in faba and broad bean and may be mixed with simazine. Listed weeds include deadnettle, Indian hedge mustard, wild radish and wireweed.

Do not use on faba bean on light, sandy soils. The risk of crop damage may be increased on alkaline soils in adverse growing conditions.

7.11.2 Trifluralin and pendimethalin (Group D)

Both trifluralin and pendimethalin are used on annual ryegrass and provide partial control of wild oats. They are also effective on a range of broadleaf weeds including wireweed.

When using trifluralin and pendimethalin on faba and broad bean, avoid shallow planting (below 2.5 cm). Very deep planting (below 5 cm) is usually safe. Be aware though that deep planting may also cause problems if the emerging shoots absorb greater quantities of the chemical. Affected shoots tend to swell and deform, and can result in a weak, patchy plant stand.

7.11.3 Triallate (Group J)

Triallate provides control of wild oats and assists in the control of trifluralin-resistant ryegrass when used in a mixture with trifluralin.

7.11.4 Cyanazine (Group C)

Cyanazine is recommended in combination with trifluralin or pendimethalin for control of annual ryegrass and wireweed.

7.11.5 Simazine (Group C)

Simazine alone controls a range of broadleaf weeds including capeweed, fumitory, mustards and geranium. It is often mixed with trifluralin or other products to provide a broader spectrum of both broadleaf and grass weed control including annual ryegrass and wild oats.

If grass weeds are present at application, consider tank-mixing with glyphosate or SpraySeed®.

Avoid shallow planting as tolerance of faba and broad bean is based on physical separation. Sow the crop at least 5 cm deep. Avoid overlapping when applying simazine, and double spraying on headlands. Simazine damage is more likely on lighter soils.

7.11.6 Terbuthylazine (Group C)

Terbuthylazine controls a wide range of broadleaf weeds, with some suppression of grasses, particularly if there is good soil moisture. It is generally safer on crops than the older triazine herbicides, atrazine and simazine.

7.11.7 Metribuzin (Group C)

Metribuzin is effective against grass and broad leaf weeds and has foliar and root uptake. However, activity is highly variable depending on soil type and environmental conditions such as light intensity, temperature, soil moisture and humidity.

Metribuzin is commonly used in pulse crops as a post-sowing-pre-emergent application, or in some cases as a post-emergent. However, it often results in crop damage and needs to be used with care.

7.11.8 Diuron (Group C)

Not all diuron brands are registered for use in faba and broad bean. As well, the APVMA is currently reviewing use of diuron with the intent of removing it from use. Some brands of diuron (e.g. Diurex®, some proprietary diurons) are currently registered for use IBS or PSPE in faba and broad bean in all states. Weeds controlled include capeweed, crassula, doublegee, erodium, wild radish, wild turnip, toad rush.

If applied IBS, diuron should be applied to bare soil prior to or at sowing and incorporated by the sowing operation. For PSPE, apply as a post-plant application to moist soil before weed and crop emergence. Use the lower rate on light, sandy soils

MORE INFORMATION

NSW DPI booklet *Weed control in winter crops 2017* can be found at: http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops

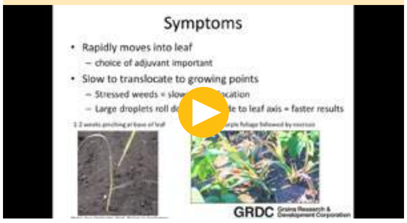
GRDC Fact Sheet: In-crop herbicide use, https://grdc.com.au/GRDC-FS-InCropHerbicideUse

VIDEO

GRDC video: Spray application: Group A herbicides, https://youtu.be/ev75wYd1lRg

VIDEO

A GRDC Webinar (Video/slides) on Grass weed control with Group A herbicides is at https://www.youtube.com/watch?v=HlkxBITNs1c



and do not apply to excessively ridged or waterlogged soils. Sow the crop at least 5 cm deep. Trifluralin or imazethapyr can be tank mixed at the recommended rates.

7.12 Post-emergent herbicides

Selective post-emergent herbicides give high levels of control (often >98%) when applied under recommended conditions on susceptible populations. When used early in crop development, the yield benefit provides significant economic returns.

Application of post-emergent herbicides to stressed crops and weeds can result in reduced levels of weed control and increased crop damage.

Stress from waterlogging, frost or dry conditions results because crops cannot produce sufficient levels of the enzymes that normally break down the herbicide.

7.12.1 Broadleaf herbicides (Group B)

Imazamox (e.g. Raptor® WG) is the only broadleaf herbicide currently approved under permit for post-emergence use, and it is only used to a very limited extent. It is effective on cruciferous weeds (turnip etc).

Imazamox can result in significant crop damage in our environment, particularly where dry conditions are experienced after application. It usually causes some transient crop yellowing and can cause reddish discolouration and height suppression. Flowering may be delayed resulting in yield suppression. Stunting also causes stunting (Photo 15).

It is used mainly in salvage situations (as a last resort) and even then should only be applied under good growing conditions.

Photo 15: *Raptor® stunting. Raptor® in broad bean post-emergent (left) shows crop shortening but broadleaf weed control compared with untreated plot (right). Raptor® post-emergent can be damaging in beans, especially if dry conditions with growth under moisture stress.*

Photo: Wayne Hawthorne, formerly Pulse Australia

7.12.2 Grass herbicides (Group A)

Faba and broad bean are not highly competitive crops and early post-emergent grass control is often still required.

Control of grass weeds with post-emergent Fop or Dim (Group A) herbicides is often variable depending on the rate used and the level of herbicide resistance. This particularly applies where marginal rates of the Group A herbicides are being used because of cost constraints.

It is important to know your resistance status before selecting a grass herbicide.

Getting the spray application right is very important with Group A herbicides. They do not translocate readily so good coverage is needed. Larger droplet sizes that roll down the leaf blade into the leaf axis can provide faster results. Keep the nozzle pressure up when using oil-based adjuvants. If the pressure drops, the droplet can collapse resulting in large droplets with poor coverage.

Only spray grass herbicides when weeds are actively growing. Group A herbicides often fail to kill weeds if applied too soon after a frost. Other stresses such as drought and low nitrogen will reduce herbicide uptake and translocation resulting in less effective control.

Group A herbicides can occasionally cause leaf spotting in faba and broad bean. This is usually associated with either frost or high temperatures soon after spray application.

Traces of sulfonylurea herbicides that contaminate spray equipment used to apply post-emergent grass herbicides can cause significant damage to faba and broad bean crops. It is vitally important to properly clean and decontaminate spray equipment before applying herbicides. See product labels for specific product recommendations on decontamination.

The application of grass-selective herbicides also renders the crop more sensitive to damage from residues of herbicides applied previously.

7.13 Directed sprays

With the shift to cropping faba and broad bean on wide rows, weeds will have more time to become established between the rows, but it also provides the opportunity to use inter-row spraying.[26] This can be combined with fertiliser banding at sowing to favour the crop over the weed.

Shielded sprayers are becoming increasingly common in or around the cotton-growing areas, as they provide very cheap grass and broadleaf weed control with glyphosate.

The use of directed sprays of glyphosate and other chemicals, either alone or in tank-mixes with simazine, largely avoids the problem of crop damage and improves weed control through the ability to safely add wetters or mineral oils to the spray mix.

Some disadvantages of shielded spraying are the potential to damage crop plants, particularly the lower branches, and the ability of weeds within the row to escape control and set seed.[27]

While faba and broad bean do have a degree of tolerance to glyphosate during the vegetative stage, caution is still required as the branches arising from the base and main stem contribute a large proportion of the total faba and broad bean yield. Shorter plants will be more susceptible to damage.

26 WL Felton, BM Haigh and S Harden (2004) Comparing weed competition in chickpea, faba bean, canola and wheat. 14th Australian Weeds Conference, Wagga Wagga, New South Wales, pp. 304-307, http://caws.org.au/awc/2004/awc200413041.pdf

27 S Kleemann, G Gill (2012) Herbicide Application Strategies for the Control of Rigid Ryegrass (*Lolium rigidum*) in Wide-Row Faba Bean (*Vicia faba*) in Southern Australia. Weed Technology 26, pp 284-288.

Propyzamide is NOT currently registered for use on faba bean. However, the following trials have been conducted.

Field trials at Roseworthy, South Australia, looked at herbicide application strategies for herbicide-resistant annual ryegrass (*Lolium rigidum*) in wide row (54 cm) faba bean. Annual ryegrass is extremely competitive against faba bean particularly in wide rows.[28]

Standard farmer practice of PSPE simazine + post-emergent clethodim in the wide row achieved ≥96% control and had the best yield benefit for bean. In conventional row spacing (18 cm), this combination provided 84–95% control of ryegrass.

PSPE propyzamide alone provided 79–88% control, but is NOT REGISTERED FOR USE ON BEANS. PSPE propyzamide + shielded inter-row glyphosate or paraquat provided ≥93% control and reduced spike density (≤20 spikes/m^2), but were unable to reduce spike density within the crop row (20–54 spikes/m^2). Shielded spraying resulted in a 13–29% yield reduction (compared to propyzamide alone) that could be a result of spray drift onto the lower leaves. Improvements in timing, crop safety, and integrating with other early season control methods are still required for shielded spraying to become more effective. Some studies showed a greater damage from inter-row glyphosate than paraquat – this study did not.

7.14 Crop-topping

Faba bean provide the opportunity to crop-top for ryegrass and other weed seedset control. However, topping before physiological maturity of beans will reduce yield and may damage quality. Not all faba bean crops will be sufficiently mature at the right crop-top timing for the target weed.

As a later maturing crop, broad bean is not suited to crop-topping to prevent seedset in weeds.

However, when there is a sizeable population of problem weeds such as resistant ryegrass, any yield or grain quality reduction from crop-topping may be an acceptable compromise to achieve a reduction in ryegrass seedset.

Crop-topping should be used as part of an integrated weed management strategy with techniques such as seed capture at harvest to maximise the effectiveness.

Further information is available in Section 12 Harvest.

7.15 Selective sprayer technology

As a result of an increase in the use of no-till cropping and the incidence of summer weeds many growers have adopted a spray fallow system that predominantly uses glyphosate over summer to remove weeds and conserve moisture for the next crop.

To reduce the risk of glyphosate resistance developing in fallow weeds some growers are using weed-detecting technology to detect individual weeds that have survived the glyphosate application and spraying these with an alternative knockdown herbicide.

The key to successful resistance management is killing the last few individuals, but this becomes rather difficult on large-scale properties. Left uncontrolled, these last few weeds result in significant seed production and a resetting of the weed seedbank.

The introduction of weed-detecting technology is timely as it is well suited to detecting patches of weeds across large areas.

The technology uses optical sensors to turn on spray nozzles only when green weeds are detected, greatly reducing total herbicide use per hectare. The units have their own light source so can be used day or night.

28 S Kleemann, G Gill (2012) Herbicide Application Strategies for the Control of Rigid Ryegrass (*Lolium rigidum*) in Wide-Row Faba Bean (*Vicia faba*) in Southern Australia. Weed Technology 26, pp 284-288.

Rather than spray a blanket amount of the herbicide across a paddock, the weed-detecting technology enables the user to apply higher herbicide rates (per plant), which results in more effective weed control as well as saving on herbicide costs.

Photo 16: *Selective sprayer technology uses optical sensors to turn on spray nozzles only when green weeds are detected.*

Photo: McIntosh Distribution, 2016
Source: http://www.mcintoshdistribution.com.au/machinery/show/weedseeker-australia

7.15.1 Permits for herbicides using weed detectors

Weed-detecting technology (via WeedSeeker®) is being used to manage glyphosate-resistant grasses in northern NSW fallows with the aid of a minor use permit. This allows growers in the region to use selective-grass herbicides and higher rates of paraquat and diquat (bipyridyl herbicides, Group L). The permit (PER11163) is in force until 28 February 2019 and is for all Australian states.

This permit allows the use of about 30 different herbicides from groups with seven modes of action. Additional modes of action are likely to be added to the permit over time.

Some herbicide rates have been increased to enable control of larger or stressed weeds. For example, glyphosate (450 g of glyphosate per litre) rates range from 3–4 L/ha (using a set water rate of 100 L/ha), which far exceeds the label blanket rates of 0.4–2.4L/ha. Similar increases in rate have also been permitted for paraquat (e.g. Gramoxone®).

The WeedSeeker® permit system is a great help for zero and minimum-tillage systems battling glyphosate-resistant weeds as it represents a more economical way to carry out a double-knock and avoids the need to cultivate for weed-seed burial. It also results in significant savings in chemical costs.

The new technology also has the potential to map troublesome weed patches so that these areas can be targeted with a pre-emergent herbicide before sowing.[29]

29 T Cook (2013) Selective spraying to cut costs. GRDC GroundCover™ Supplement, 6 May 2013, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104/Selective-spraying-to-cut-costs

MORE INFORMATION

For details on branched broomrape, please see the Plant Health Australia website: http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Branched-broomrape-FS.pdf

7.16 Exotic weeds of faba bean

7.16.1 Branched broomrape (*Orobanche ramosa*)

Description and life cycle

Branched broomrape is a serious parasitic pest of lentil and faba bean in the Middle East.[30]

Orobanche spp., commonly known as broomrape, is a parasitic plant that attacks the roots of a considerable number of plant species. This includes a wide range of vegetables, pulses and pasture legumes.

Suitable hosts in Australia include lentil, faba bean, broad bean, chickpea, vetch, field pea, clover, cabbages, canola, capsicums, carrots, cauliflowers, celery, eggplant, lettuce, melons, potato, and tomato. Major crops attacked overseas include sunflowers and tobacco.

Orobanche spp. drains its hosts of nutrients, causing anything from 10–70% yield losses. Lentil and chickpea, for example, can suffer up to 50% yield loss, with remaining seed being of poor quality.

Of the 20 or so *Orobanche* spp. worldwide, five are particularly weedy. These are *O. aegyptiaca*, *O. cernua* var. *cernua*, *O. crenata*, *O. cumana* and *O. ramosa*. Only three *Orobanche* spp. are known to be present in Australia. O. *cernua* var. *australiana* is a native that does not attack crops.

Lesser broomrape (*O. minor*) is a common minor weed. An infestation of *O. ramosa*, or branched broomrape exists in South Australia. One *O. ramosa* plant can produce up to 500,000 seeds. As well as parasitising a range of pulse and vegetable crops, O. *ramosa* is the only broomrape to attack *Cannabis sativa*.

All *Orobanche* spp. are Australian Quarantine and Inspection Service (AQIS) prohibited imports. However, the seeds are very small, like dust, and could enter the country undetected.

The seeds can be spread in contaminated soil, on machinery, or by livestock. Even if these parasites become established in one location, Australian export markets could be affected as many of our trading partners prohibit *Orobanche* spp.

As *Orobanche* spp. has been identified as a major exotic threat, development of an emergency response is a priority.

The life cycle is shown in Figure 2.

30 M Owen, C Preston, S Walker (2013) Resistance rising across Australia. Herbicide Resistance, GRDC GroundCover™ Supplement, Issue 104, May–June 2013, pp. 6-7, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

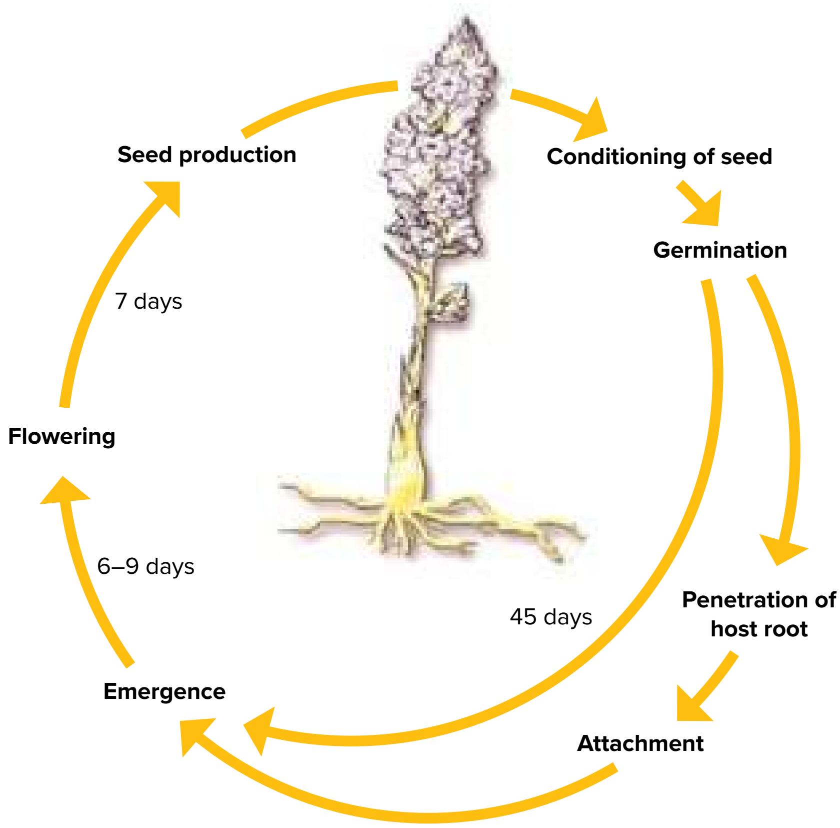


Figure 2: *Life cycle of branched broomrape.*

Source: Grain Legume Handbook (2008)

Photo 17: *Flowering branched broomrape.*

Source: Grain Legume Handbook (2008)

Photo 18: *Branched broomrape setting seed on capeweed.*

Source: Grain Legume Handbook (2008)

Flowers/seed head

Flowers: pale blue, tubular and two-lipped. Lower lip three-lobed and upper lip shallowly two-lobed. An erect spike of flowers appears in spring and summer (Photo 17).

Description

Mature plants are about 20 cm tall with several branches from ground level. Stems have dense, soft, woolly hairs on the upper part. Leaves are reduced to a few brown scales to 8 mm long. The capsule is enclosed in persistent corolla. Seeds are pepper-like, up to 40,000 per plant.

Distinguishing features

Branched yellow-brown glandular-hairy stems; absence of green parts; blue flowers.

Dispersal

Spread by seed (Photo 18).

Confused with

Other species of *Orobanche* in Australia; see a specialist to confirm identification.

Surveillance

As symptoms may be characteristic of a number of seedling weeds of lentil, plant samples of unknown or suspicious looking weeds should be sent for diagnosis.

Entry potential

High. Entry through seed, debris or soil contamination.

Establishment and spread potential

High as is a fine powder-like seed. Also spread by soil and debris to become problematic.

Economic impact

High. Yield and possible market losses could occur.

Overall risk

High

Pest management

Key points

- The key pests of faba bean in southern Australia are Helicoverpa punctigera (native budworm), snails, slugs and aphids. Mites, lucerne flea, locusts and H. armigera are occasional pests, while many other minor pests can affect faba bean.
- Integrated pest management (IPM) is an ecological approach aimed at significantly reducing use of pesticides while managing pest populations at an acceptable level.
- IPM involves planning, monitoring, recording, identifing, assessing options, controlling/managing and reassessing.
- Monitoring for beneficial species is important.
- Exotic bruchids and leaf miners pose a biosecurity threat.

MORE INFORMATION

GRDC Fact Sheet: Integrated pest management, https://grdc.com.au/__data/assets/pdf_file/0031/225877/integrated-pest-management.pdf.pdf

MORE INFORMATION

A GRDC Fact Sheet on pest-suppressive landscapes, 'Pest management using native vegetation', is at www.grdc.com.au/GRDC-FS-PestSuppressiveLandscapes

IPM guidelines for grains website: http://ipmguidelinesforgrains.com.au/

8.1 Integrated pest management (IPM)

8.1.1 IPM definition

Integrated pest management (IPM) is an integrated approach of crop management to reduce chemical inputs and solve ecological problems. Although originally developed for agricultural insect pest management, IPM programs have now been developed to encompass diseases, weeds, and other pests that interfere with the management objectives of sites.

IPM is an ecological approach aimed at significantly reducing the use of pesticides while managing pest populations at an acceptable level. IPM uses an array of complementary methods including mechanical and physical devices, as well as genetic, biological, cultural and chemical management. It uses strategies of prevention, observation and intervention with the primary goal of significantly reducing the use of pesticide. Benefits include the reduction in cost, contamination, residues and resistance to the pesticide.

8.1.2 Problems with pesticides

IPM does not mean abandoning pesticides – they are still the basis for pest control – but the impact on natural enemies is considered when selecting a pesticide. Regular monitoring needs to observe the pest and beneficial species dynamics. Beneficial species can provide control of most pests if they are present. By reducing the use of non-selective pesticides, the aim is to foster predators and parasites to stabilise pest populations and reducing the need to spray.

Overuse of pesticides can hasten pesticide resistance developing. It can also lead to a resurgence of pests, create new pests, potentially increase pesticide residues in grain and lead to off-target contamination including of wildlife reserves and waterways.[1]

8.1.3 IPM, organics and biological control

IPM is not the same as organic pest management, although many organic options are compatible with IPM. IPM is sometimes confused with classic biological control. While they are not the same, IPM plays an important role in maximising the success of biological control by reducing the use of non-selective sprays, boosting the survival of biological control agents.[2]

IN FOCUS

Native remnant vegetation can support beneficial predatory insects. Pest-suppressive landscapes are those that have the right mix of habitats that support beneficial insects and allow them to move into crop fields, while discouraging the build-up of pest insect species.

8.1.4 Soft *v.* hard pesticides

The terms 'soft' and 'selective' are terms used to describe pesticides that kill target pests but have minimal impact on parasites and predators attacking these pests. Parasites and predators are often called 'beneficials'.

1 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

2 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

Pesticides that impact on beneficial species are termed 'hard', 'non-selective' or 'broad-spectrum'.

In practice, there are varying degrees of softness, and many products may be hard on one group of beneficial species but relatively soft on another. (See Section 8.7 Beneficial species)

Insecticides that are less toxic to beneficial insects should be used where possible. For example, using pirimicarb (which is registered for broad bean) for aphid control may mean fewer repeat applications compared with synthetic pyrethroids, because beneficial insects are preserved.

Synthetic pesticides are generally only used as required and often only at specific times in a pest's life cycle.

Many newer pesticide groups are derived from plants or naturally occurring substances.[3] Examples are nicotine, pyrethrum and insect juvenile hormone analogues. Further 'biology-based' or 'ecological' techniques are being evaluated.[4]

8.1.5 IPM process

The process in managing insect pests to reduce damage in a profitable manner is:

1. Planning.
2. Monitoring and recording.
3. Identification.
4. Assessing options.
5. Controlling/managing.
6. Reassessing.

Regular monitoring, with accurate pest identification, is the key to IPM. For insects, monitoring for beneficial organisms and predators is important too. Record-keeping is essential, as is knowledge of the behaviour and reproductive cycles of target pests. For more information on monitoring, see Section 8.1.7 Monitoring methods.

Use the information gathered from monitoring to decide what sort of control action (if any) is required. Make spray decisions based on a combination of economic threshold information and your experience. Insecticide resistance and area-wide management strategies may also affect spray recommendations.

If a control operation is required, ensure application occurs at the appropriate time of day. Record all spray details including rates, spray volume, pressure, nozzles, meteorological data (relative humidity, temperature, wind speed and direction, inversions and thermals) and time of day.

Assess crops after spraying and record data. Post-spray inspections are important in assessing whether the spray has been effective.[5]

3 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

4 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

5 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

8.1.6 IPM system

An IPM system is designed around some basic components:

- acceptable pest levels;
- preventative cultural practices;
- monitoring the crop;
- biological and environmental control; and
- responsible chemical use.

Acceptable pest levels

Emphasis is on control, not eradication. IPM programs work to establish acceptable pest levels (action thresholds) and then apply controls if those thresholds are exceeded.

The most common threshold used is an economic threshold, which involves control at a density that will prevent the pest numbers from reaching an economically damaging population. The aim of pest management is to keep pest populations below the economic threshold.

Guideline thresholds based on research exist for some pests but most thresholds fluctuate depending upon a number of factors. Monitoring and sampling of crops is essential to determine these factors and their influence on where the threshold lies. Growers who maintain a close watch on pest activity through regular crop inspections and thorough sampling are best placed to decide if and when treatment is needed.

Preventative cultural practices

Use varieties best suited to local growing conditions and maintain healthy crops. Mechanical methods may be possible under some circumstances, such as burning, rolling or cabling for snail control.

If faba bean is the first crop in the rotation after a pasture phase there can be a range of pests that occur naturally in pastures that can cause problems.

Blue oat mite will often be present in the pasture phase and attack lentil seedlings. A long fallow (September to April) with clean cultivation and good weed control before the faba bean crop can prevent this pest. Weedy fallows can provide resources and shelter for pests as well as taking soil moisture that could be used by the crop later in the season.

Monitoring faba bean crops

All faba bean crops should be scouted for insects at regular intervals, usually once per week prior to pod-set and 2–3 times a week from pod-set onwards.[6]

This includes monitoring for beneficial organisms and predators is important. Record-keeping is essential.

Prior to sowing, paddocks should be checked for signs of insect presence.

After sowing, monitor as the crop emerges, to check if the plant population has emerged as expected and there are not gaps from attack by insects or slugs. These can leave large bare patches which may need replanting, as they can affect yields and leave spaces for weeds later.

Monitoring weekly during the vegetative stages, looking for evidence of caterpillar or aphids. Beneficial species such as lady beetles, hoverflies and wasps are often seen during this phase as well and can be a good indicator to check for the pest species.

As crops close over before flowering, monitor each week to for pests.

6 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

Aphids will target stressed crops. They will move and can build up overnight. Monitoring needs to be completed more often. Many beneficial species will follow the aphid colonies.

When faba bean crops become dense, monitoring becomes more difficult.

Some paddocks are set out with 'tram tracks' that may be possible to navigate, otherwise monitoring is done along the edge of the crop at a number of sites. This is often acceptable as many pest insects move in from the edges.

Use a beat sheet or sweep net and a standardised protocol for each sample to compare numbers with previous counts.

Record results in a diary or spreadsheet to enable objective decisions.

Biological and environmental control

A range of organisms and environmental processes can provide control, with minimal crop damage, and often at low cost. The main focus is on promoting beneficial organisms that target pests. See Section 8.7 Beneficial species.

There is a lag period between when a pest is present and when the beneficial species affect the pest population. Predators destroy their prey and leave little evidence of their actions, so these effects are often underestimated. Some biological control agents are very prolific, relatively predictable and able to keep the pests at low levels so they do not impact on crop production.

In broadacre crops the best strategy is to preserve and encourage these beneficial organisms that are naturally occurring. Grow a diverse range of plant species around the farm, preserving native habitat near crop paddocks and reduce the use of broad-spectrum insecticides.

Use biological insecticides, derived from naturally occurring microorganisms (*Bt*, Viva Gold®, entomopathogenic fungi and nematodes) and chemicals specific to pest species where possible.

Responsible chemical use

Synthetic pesticides are generally only used as required and often only at specific times in a pest's life cycle. Many newer pesticide groups are derived from plants or naturally occurring substances.

Insecticides that are less toxic to beneficial insects should be used where possible. For example, pirimicarb for aphid control may mean less repeat applications compared with the use of synthetic pyrethroids because beneficial insects are preserved.

8.1.7 Monitoring methods

Sweep net monitoring

The easiest and quickest way to determine the number of grubs in a crop is to 'sweep' the crop with an insect sweep net. It is impossible to accurately determine numbers by simply looking in the crop.[7] Sweep-net sampling of faba bean can seriously underestimate the density of larvae, particularly smaller larvae. A visual inspection of faba bean terminals, flowers and buds is very important for smaller larvae estimates of *Helicoverpa* spp.[8]

A standard sized net (38 cm in diameter) can be purchased from most chemical suppliers.

- Take 10 sweeps of the net through the crop canopy while walking slowly through the paddock. A standard sweep of the net needs to be about 2 m.
- Empty the contents into a tray or bucket and count the caterpillars of various sizes. It is important to look very carefully for small caterpillars as these have the most potential to cause damage.
- Repeat this process at least 12 places throughout the paddock to obtain an average insect density.

VIDEO

To watch a video on how to use a sweep net to sample for insect pests, see: www.youtube.com/watch?v=fwesXzQ1pCc

Crop inspection

Sampling flowers and leaves in the crop can tell you much more than a sticky trap including:

- levels of non-flying juvenile stages (eggs, larvae, pupae);
- levels of non-flying adult insects (mites, snails etc); and
- early stages and extent of pest damage.

This information is much more powerful for assessing pest levels, accurately predicting trends and checking the effectiveness of control measures. It is essential for making decisions and following up on the results.

Depending on the pest, where it feeds, hides and breeds, you will need to check flowers, leaves, pods and stems. The pattern, frequency and level of sampling depend on the crop, pests of concern and beneficial insects of interest and the time of year.

Weeds near to your farm or crop will build up large numbers of pests in spring. Inspecting the weeds can keep you in touch with how the local pest pressure is building up. Ideally, remove the weeds before the pests build up on them.

7 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

8 M Miles, P Grundy, A Quade and R Lloyd (2015) Insect management in faba beans and canola recent research. GRDC Update Paper, 25 February 2015, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/insect-management-in-fababeans-and-canola-recent-research

Yellow sticky traps or cards

Sticky traps are useful as a way of monitoring flying pests like thrips, whitefly and aphids. They attract these insects because of their colour. They are a useful way of sending samples away for identification of thrips species. However, they do not give a complete picture of pest dynamics in the crop. Adult insects may settle into the crop after flying in and juvenile non-flying stages may survive spray applications but will not show up on the traps.

Sticky traps should be changed or checked at least weekly. They need to be placed just above the growing tips of the plants to catch insects hovering above them and to avoid getting stuck and lost in the crop.[9]

Quadrats

Use quadrats to sample snails. See Section 8.3.2 Snails.

Tiles, hessian bags and slug traps

Use either a tile, hessian bag or slug trap left in the paddock over night to count snail or slug numbers. See Section 8.3.3 Slugs (Deroceras reticulatum, Milax gagates and others) Monitoring of slugs.

8.2 Identifying pests

8.2.1 Correct identification of insect species

It is important to be able to identify the various insect present in your crop, whether they are pest or beneficial species, and their growth stages.

Sending insect samples for diagnostics

SARDI Entomology Unit provides free insect diagnostic services for subscribers of PestFacts South Australia and western Victoria newsletter.

CESAR (University of Melbourne), SARDI and NSW DPI will identify insects for a fee. For more information: contact CESAR (03 9349 4723 or www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/insect-identification-service/) or SARDI (www.pir.sa.gov.au/research/services/crop_diagnostics/insect_diagnostic_service) (prices available on application).

Agriculture Victoria does not offer a routine insect identification service.[10]

9 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

10 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

MORE INFORMATION

The GRDC has an App on insects:'Insect ID: the Ute Guide App', https://grdc.com.au/Resources/Ute-Guides/Insects/

8.2.2 Insect ID: The Ute Guide

While many resources are available, the primary insect identification resource for grain growers is 'Insect ID: The Ute Guide', a digital guide for smartphones and tablets that is progressively updated as new information becomes available (Figure 1).

Insect ID is a comprehensive reference guide to insect pests commonly affecting broadacre crops and growers across Australia, and includes the beneficial insects that may help to control the pests.

Photos have been provided for multiple life-cycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored and other pests that they may be confused with.[11]

Not all insects found in field crops are listed in this app, so further advice may be required before making management decisions.

Figure 1: *Screenshots from the iOS edition of 'Insect ID: The Ute Guide' app.*

Source: https://grdc.com.au/resources-and-publications/app

MORE INFORMATION

See https://grdc.com.au/GrowNotes™alert for alerts from the GRDC

8.2.3 GrowNotes™ Alerts

GrowNotes™ Alerts is a free, early warning system that notifies you of any emerging disease, pest and weed threats, specific to the user's chosen area. It provides real-time information from experts across Australia.

A GrowNotes™ Alert can be delivered via app, SMS, voice, email, social media or web portal (or a combination of preferred methods). The urgency with which they are delivered can help reduce the impact of weed, pest and disease costs. GrowNotes™ Alerts improves the relevance, reliability, speed and coverage of notifications on the incidence, prevalence and distribution of weed, pest and diseases.

11 GRDC (2014) Northern faba bean GrowNotes™, https://grdc.com.au/Resources/GrowNotes™

8.3 Key pests of faba bean

The key pests of faba bean in southern Australia are *Helicoverpa punctigera* (native budworm), snails, slugs and aphids. See sections 8.3.1 (*Helicoverpa punctigera* (native budworm), 8.3.2 (snails), 8.3.3 (slugs) and 8.3.4 (aphids) for more information). Table 1 shows the timing of damaging effects of the key and other pests in faba bean crops.

Table 1: Key and other pests of faba bean crops.

Pest	Crop stage				
	Emergence/ seedling	Vegetative	Flowering	Podding	Grain fill
Helicoverpa spp.		Present	Damaging	Damaging	Damaging
Slugs and snails*	Damaging	Damaging			
Aphids (virus vectors)	Damaging	Damaging	Present	Present	
Earth mites	Damaging	Present	Present		
Lucerne flea	Damaging	Present			
Cutworms	Damaging				
Thrips		Present	Present		

* Snails may also cause grain contamination at harvest

Present: Present in crop but generally not damaging

Damaging: Crop susceptible to damage and loss.

Source: Queensland Department of Agriculture and Fisheries (2016)

8.3.1 *Helicoverpa* species: native budworm and corn earworm (*Helicoverpa punctigera* and *H. armigera*)

The larva of native budworm (*Helicoverpa punctigera*) is the main insect pest of faba bean and broad bean late in the season in southern Australia.

Helicoverpa punctigera is different from the species *H. armigera*, which is commonly known as corn earworm or cotton bollworm.

Helicoverpa spp. are commonly referred to as helicoverpa, heliothis or 'helis'. It is technically more correct to refer to them as "*Helicoverpa* species" to distinguish them from true *Heliothis* sp.

Distribution of *Helicoverpa* spp.

Most *Helicoverpa* in southern Australia from September to early November will be *H. punctigera*. *H. punctigera* is native to Australia. It is more common in inland regions and southern Australia.

H. punctigera (native budworm) breeds over winter in the arid inland regions of Queensland, South Australia, Western Australia and New South Wales on desert plants before migrating into southern agricultural areas in late winter or spring. They can migrate as far south as Tasmania.[12]

H. armigera may become more problematic in summer crop irrigation areas. It rarely occurs in significant numbers in Victorian crops.[13] Although summer pulses are at greatest risk from *H. armigera*, spring outbreaks are possible.

12 G McDonald (2015) Native budworm. Pest Notes Southern. CESAR and South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0005/274181/Native_Budworm.pdf

13 G McDonald (1995) Native budworm. Agnote Ag0417. Agriculture Victoria, June 1995, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/native-budworm

H.armigera is present in Europe, Asia, Africa and Australasia. While it is present in all Australian states, it is more common in the tropics and subtropics.[14] It is a major pest of chickpea and other pulses in northern Australia.[15]

Pest status of *Helicoverpa* spp.

Helicoverpa spp. are major pests and can severely damage all crop stages and all plant parts of all summer and winter pulses. Both species of *Helicoverpa* may be found in faba bean.[16]

While significant numbers of *H. armigera* are rare in Victoria, it is still an important pest when it does occur in large numbers, as it may be resistant to many of the commonly used insecticides.[17]

MORE INFORMATION

GRDC app: Insect ID: The Ute Guide, https://grdc.com.au/resources-and-publications/app

Identification of *Helicoverpa* spp. eggs and larvae

The adult moths lay round eggs singly on the host plant. Eggs are pale cream or white when laid, 0.6 mm diameter, ribbed and globular. Fertile eggs develop a red or brown ring after 1–2 days and become brown or black before hatching. They hatch 2–5 days after being laid.

The two *Helicoverpa* species can be differentiated for eggs and small larvae with a Lepton™ test.

Photo 1: *(From left) fresh white eggs of Helicoverpa, 1–2-day-old eggs showing brown ring and eggs close to hatching showing black larval head.*

Source: Northern Faba Bean GrowNotes™

Newly hatched larvae are pale with tiny dark spots and dark heads.

Medium larvae are usually brown and the darker spots become more obvious.

Medium larvae develop lines and bands running the length of the body in variable colours.[18]

14 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

15 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

16 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

17 G McDonald (1995) Native budworm. Agnote Ag0417. Agriculture Victoria. June 1995. http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/native-budworm

18 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/Resources/Ute-Guides/Insects

Large larvae can reach 45 mm. Darker specimens are more common in high density populations. Large larvae vary from green, yellow, orange, pink and red-brown to black.[19]

Photo 2: *It is important to be able to identify the different larval instars of Helicoverpa spp. The six larval instars and two eggs are shown. Helicoverpa spp. have four abdominal prolegs. Insecticides are more effective on smaller larvae.*[20]

Photo: Gabriella Caon, SARDI

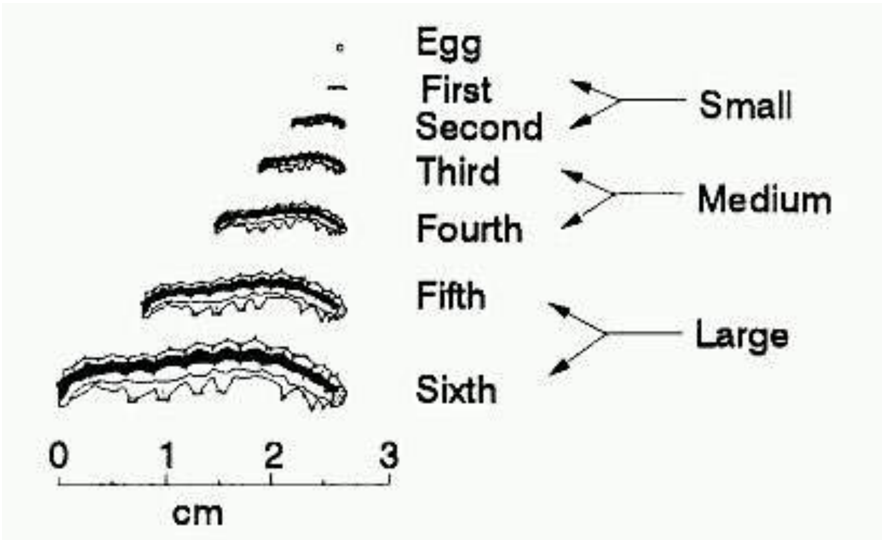


Figure 2: *Approximate sizes of the six instars of Helicoverpa spp.*

Source: G McDonald (1995), Agriculture Victoria

Sometimes the two *Helicoverpa* spp. can be identified by visually examining the larvae. Small *H. armigera* (third instar) have a saddle on the fourth segment but *H. punctigera* do not. While this method can be difficult in the field and is not completely reliable, it may provide a good guide.

In larger (fifth and sixth instar) larvae, hair colour in the segment immediately behind the head is a good species indicator. These hairs are white for H. *armigera* and black for *H. punctigera* (Photo 3).[21]

19 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

20 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

21 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

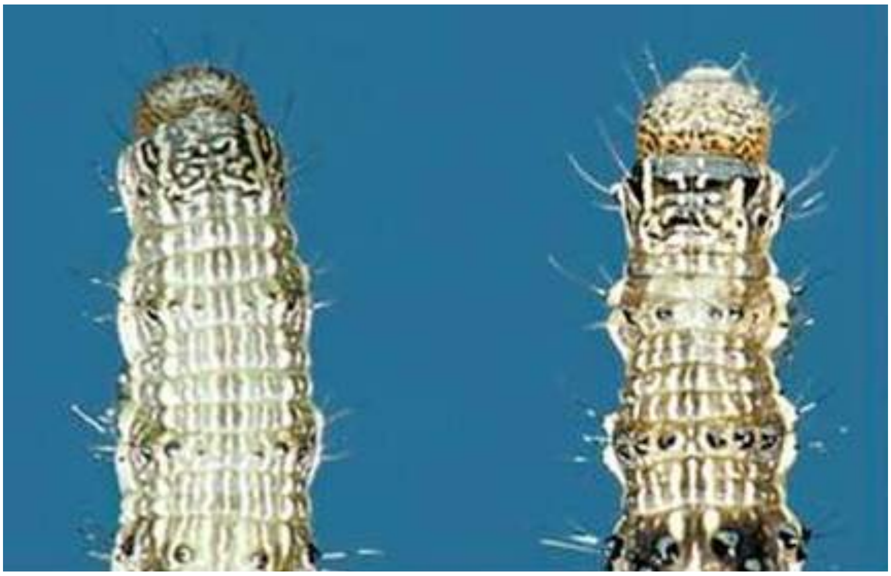


Photo 3: *H. punctigera with black hairs from head (left) and H. armigera with white hairs and 'saddle' on fourth abdominal segment (right).*

Photo: L Turton & M Cahill

Distinguishing *Helicoverpa* spp. from other caterpillars

Helicoverpa spp. larvae can be easily identified, despite the colour variation, by a broad yellow stripe along the body.[22] Young larvae (<10 mm) prefer to feed on foliage; older larvae prefer to feed on pods.

In southern Australia, other larvae that look like native budworm may be found in a pulse crop, e.g. southern armyworm and pink cutworm. These are primarily grass feeders and rarely do any damage to pulses.[23]

H. punctigera larvae have black hairs around the head, no dark 'saddle' and light-coloured legs. In contrast, medium larvae of *H. armigera* have white hairs around the head, a dark 'saddle' on the fourth segment back from the head and dark-coloured legs. Pupae of *H. armigera* are readily separated from *H. punctigera* which have spines that are close together.

Medium and large larvae, pupae and adult of *Helicoverpa* spp. can be distinguished visually. Both species of *Helicoverpa* larvae have a group of four pairs of 'legs' in the back half of the body; loopers can have a group of two, three or four pairs of legs at the rear and loop when walking. *Helicoverpa* spp. larvae do not taper noticeably towards the head, as do loopers.

Armyworm larvae can be distinguished by the lack of hairs and by bodies that taper at both ends.

Medium *H. armigera* larvae may also be confused with cluster caterpillar (*Spodoptera litura*) but are more hairy and lack the cluster caterpillar's distinctive spots and hump behind the head. To view images of cluster caterpillar, visit: www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/cluster-caterpillar.

Helicoverpa eggs are paler than looper eggs, which have a green tinge and are squatter.[24,25]

22 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

23 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

24 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

25 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/Resources/Ute-Guides/Insects

Identification of *Helicoverpa* spp. moths

Helicoverpa spp. moths have a 30–45 mm wingspan with stout bodies. Moths are a dull light brown with dark markings.

Adult moths of *H. punctigera* are usually active during the evening and night and are rarely seen during the day. For native budworm (*H. punctigera*), the forewings are buff-olive to red-brown with numerous dark spots and blotches. The hind wings are pale grey with dark veins and a dark band along the lower edge. The hind wings have a dark, broad band on the outer margin.

Photo 4: Helicoverpa punctigera *(native budworm) moths, showing female (left) and male (right).*

Photo: SARDI

H. armigera has a small light or pale patch in the dark section of the hindwing while the dark section is uniform in *H. punctigera*.[26 27 28 29 30]

26 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

27 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

28 G McDonald (1995) Native budworm. Agnote Ag0417. Agriculture Victoria, June 1995, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/native-budworm

29 D Hopkins, M Miles (1998) Insects: the Ute Guide, Southern Region. Primary Industries and Resources SA.

30 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/Resources/Ute-Guides/Insects

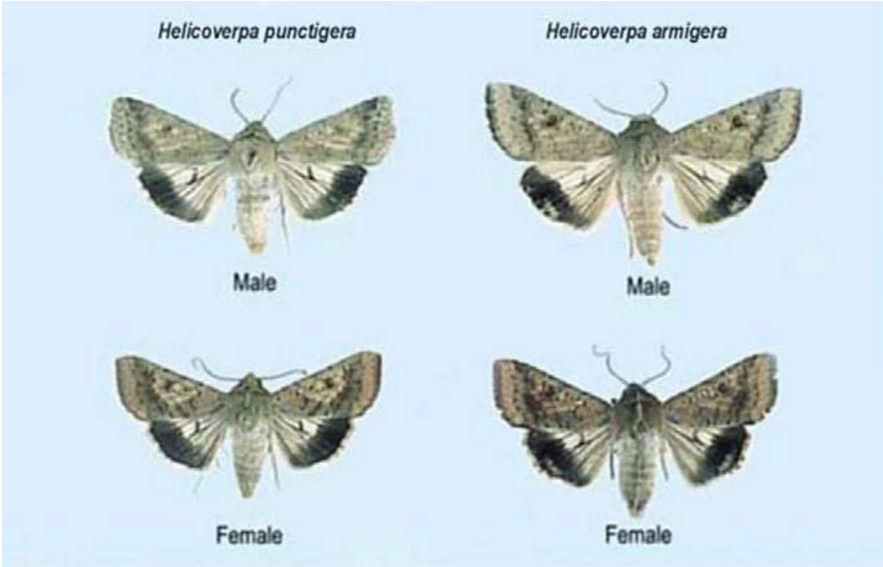


Photo 5: *Helicoverpa punctigera (native budworm) and H. armigera moths. The two species are distinguished by the presence of a pale patch in the margin of the hindwing of H. armigera. Most Helicoverpa in southern Australia from September to early November will be H. punctigera.*

Source: Pulse Australia (2016), Southern faba and broad bean management practices training course 2016. Pulse Australia

Life cycle of *Helicoverpa* spp.

Each female *helicoverpa* can lay more than 1,000 eggs. In southern Australia, native budworm may produce up to five generations a year. The eggs hatch 1–2 weeks after laying in spring (or 2–6 days in summer) and the larvae feed in crops for 4–6 weeks.

Once larvae are fully grown, they crawl to the base of the plant, tunnel into the soil and form a chamber in which they pupate. During spring, summer and early autumn, the pupae develop quickly and a new generation of moths emerges after about two weeks. As with all insect development, the duration of pupation is determined by temperature, taking longer in spring and autumn. Diapausing pupae take much longer to emerge.

The moth emerges, feeds, mates and is then ready to begin the cycle of egg laying and larval development.

Native budworm eggs and holes on soursob (oxalis) petals are signs of native budworm activity in the area.

The spring generation causes the most damage, especially to pulse crops.

During winter, native budworm enters a resting period as a pupa in the soil. Adult moths emerge from these over-wintering pupae in August and September and live for about 2–4 weeks.[31 32 33]

Diapause in *Helicoverpa* spp.

Both species of *Helicoverpa* survive winter as pupae in the soil, when host plants and thus food sources are scarce. *H. punctigera* are capable of over-wintering in southern cropping regions, but only a few are ever found. By contrast, substantial numbers of over-wintering *H. armigera* pupae can be found under late summer crops, particularly when *Helicoverpa* activity has been high late into March.

31 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

32 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

33 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

Not all pupae that form in late summer go into diapause; a proportion continue to develop, perhaps emerging during winter, or early in spring.

Over-wintering pupae can be killed without use of chemicals. Pupae in the soil are susceptible to soil disturbance and disruption of the emergence tunnel. Cultivation is enough to create this disturbance.[34]

Damage by ***Helicoverpa*** spp.

Helicoverpa spp. attack most major field crops as well as many horticultural crops.1 They attack all above-ground plant parts. Once crops reach flowering, larvae focus on buds, flowers and pods.

Native budworm (*H. punctigera*) larvae bore into the faba bean pods and usually destroy several seeds in each pod. A single larva may attack 4–5 pods before reaching maturity. The amount of damage to each seed varies considerably, but the damaged area has jagged edges.

Helicoverpa spp. cause most damage from pod-set to maturity, and can reduce grain yield and quality. Whilst important, insect damage does not constitute the majority of defective faba bean grain.

It is important to control larvae while they are still very small (<7 mm). Ninety per cent of all feeding (and therefore damage) by *Helicoverpa* is done by larvae from the third instar (small–medium larva that are 8–13 mm long) onwards. Large *Helicoverpa* larvae (>24 mm) are the most damaging stage, since larvae consume about 80% of their diet in the fifth and sixth instars.

Photo 6: *Native budworm on faba bean. Helicoverpa spp. attack all above-ground parts of plants.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 7: *Native budworm damage to faba bean pods. Helicoverpa spp. larvae focus on buds, flowers and pods once the crop has reached flowering.*

Photo: Landmark

34 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

Photo 8: *Native budworm damage to faba bean grain downgrades its quality. Affected grains are classified as defective.*

Photo: Landmark

While the feeding behaviour of *H. armigera* and *H. punctigera* are expected to be the same, no research has been undertaken to assess this.

No studies have compared the behaviour of larvae in drought-stressed crops compared with crops with adequate moisture. Consequently there is no certainty about whether there is more, or earlier, flower and pod feeding when foliage appears to be less attractive.[35,36,37,38]

Monitoring *Helicoverpa* spp. larvae

Regularly monitor the faba bean crop for insect pests and/or damage to make timely decisions on control. It is important to target small larvae.

Begin monitoring crops for *Helicoverpa* larvae when crops start flowering and continue until late maturity. One recommendation is to inspect crops weekly for before pod-set, then 2 or 3 times a week until late podding. Another recommendation is to monitor crops every 3 or 4 days from the beginning of flowering. Moth flight activity can provide an early warning for egg laying and potential future larval activity in the crop, and also signals the time to start monitoring crops for larvae.

Growers also need to take into account beneficial species and populations, as there may be a very high predation rate in faba bean. See Section 8.7 Beneficial species.

Experienced agronomists suggest that *Helicoverpa* numbers alone do not always give an accurate assessment of damage. In some situations (for example, if the crop is severely moisture stressed), monitoring crop damage will assist in assessing the accumulating yield loss.

While the quickest and easiest method of sampling most crops is to use a 38 cm diameter sweep net, it may be less efficient in tall, dense crops of faba bean. Repeat the sweeping process of 10 sweeps in at least 12 places throughout the paddock to obtain an average caterpillar density. For more details, see Section 8.1.7 Monitoring methods.

Sweep-net sampling of faba bean severely underestimates the density of larvae, and particularly the smaller larvae. A visual inspection of faba bean terminals, flowers and buds is very important for smaller larvae estimates.

35 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

36 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

37 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

38 M Miles, P Grundy, A Quade and R Lloyd (2015) Insect management in fababeans and canola recent research. GRDC Update Paper, 25 February 2015, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/insect-management-in-fababeans-and-canola-recent-research

VIDEO

For more information in beat sheet sampling, watch: GCTV16: IPM beatsheet demo. Mung bean, https://www.youtube.com/watch?v=MwtqG6IC49E

Beat sheet sampling is the preferred sampling method for medium to large *Helicoverpa* larvae. The beat sheet sampling method is providing a better estimate of larval density than sweep nets, but is still poor overall, as it markedly underestimates larva density in faba bean, particularly smaller larvae. Scout for small larvae by opening vegetative terminals, buds and flowers. Sample 6 widely spaced locations per paddock and take five 1-metre long samples at each site with a standard beat sheet. Convert larval counts per metre to larvae per square metre by dividing the counts by the row spacing, in metres.[39 40 41]

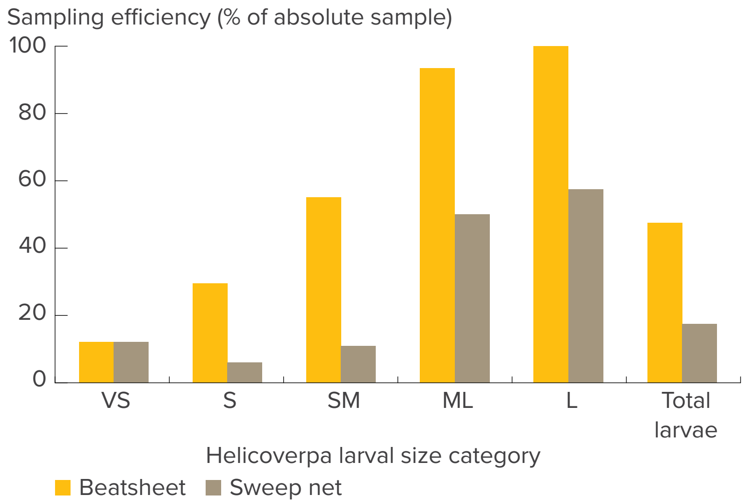


Figure 3: *A simple conversion from sweep-net sampling to beat-sheet sampling is not currently possible because the two methods are not equally effective at collecting different larval sizes. Larger larvae are more easily dislodged with both methods, but smaller larvae are more difficult to assess accurately.*

Source: Miles *et al* (2015) [42]

A basic approach to monitoring is to sample each of 10 widely separated sites, by laying a 0.5 m^2 piece of white fertiliser bag between the rows. Beat the plants on each side over the bag and count the number of 4–9 mm long larvae that fall.

Helicoverpa eggs are difficult to see, so egg counts are an unreliable indicator of control thresholds. Egg survival to larvae can also be highly variable. If an egg count is taken, use it as an indication of an egg-lay event and determine the potential development rate of the *Helicoverpa*. Rates of native budworm (*H. punctigera*) development have been estimated for South Australia, based on meteorological data (Table 2); eggs laid on 20 August will take about 3 weeks to hatch, while eggs laid 1 month later will take 13 days. In some seasons, a second spray is needed.

39 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

40 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

41 D Lush (2013) Time to watch for native budworm. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-106-Sept-Oct-2013/Time-to-watch-for-native-budworm

42 M Miles, P Grundy, A Quade and R Lloyd (2015) Insect management in fababeans and canola recent research. GRDC Update Paper, 25 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02

Table 2: Estimated developmental rate (number of days between stages) for native budworm in South Australia. Development is faster in spring than winter. In some years, a second spray is required. Based on former Victorian Department of Primary Industries estimates using DARABUG software using moth counts, larvae developmental stages and weather pattern information. These are a guide only.

Stage	August 20	August 30	September 10	September 20	September 30
Egg laying to egg hatch	21	18	16	13	13
Egg hatch to larvae 7–10 mm	32	30	28	27	24
Egg laying to larvae 7–10 mm	53	48	44	40	37

Source: Budworm Watch program – more than monitoring, (2003), www.regional.org.au/au/apen/2003/abstracts/p-37.htm

It is difficult to estimate the number of very small larvae hatched in the previous 24 hours. Often they are low in the canopy. When using a beat sheet, they often remain on leaflets, making them very difficult to see and count. Very small larvae do no economic damage to the crop, their feeding confined to leaves. Early research on *Helicoverpa* has shown high mortality of very small larvae; their value in monitoring is potential activity of larger larvae in a week or two.

In studies of *Helicoverpa* larval feeding behaviour in soybean, large larvae were found to cause the majority of damage, in the order of 80%, with medium larvae contributing about 15% and other instars, the remainder.[43 44 45 46]

Monitoring *Helicoverpa punctigera* (native budworm) moth flights

Helicoverpa punctigera (native budworm) moths migrate to southern Australia from breeding grounds in the northern pastoral and desert areas after winter rainfall.

Large numbers of native budworm moths usually fly into cropping areas during late winter and spring, with infestations commencing in the northern cropping areas.

Moths are attracted to traps containing a chemical sex-attractant (pheromone), specific to the species so only the *Helicoverpa* is caught.

Photo 9: *Pheromone traps can be used as a guide to identifying and monitoring moth numbers.*

Photo: Unknown

43 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

44 Matthews, P. and Marcellos, H. (2003) Faba bean. AgFact P4.2.7 Second Edition, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/157732/faba-bean-pt2.pdf

45 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

46 L Breen (2003) Budworm Watch program – more than monitoring. Australasia Pacific Extension Network 2003 Forum, Hobart, 26-28 November 2003, www.regional.org.au/au/apen/2003/abstracts/p-37.htm

Take note of news of *Helicoverpa* moth flights and inspect crops for the presence of caterpillars when crops are flowering and podding.

Growers should begin monitoring crops when moths are detected in their region. However, as there is no established relationship between the numbers of moths trapped and the resulting caterpillar population in nearby crops, growers cannot determine the need for sprays by the moth traps.[47]

Control thresholds for *Helicoverpa* spp.

An economic control threshold is the number of caterpillars that will cause more financial loss than the cost of spraying. Further research is needed into control thresholds for *Helicoverpa* in faba bean.

The thresholds used for *Helicoverpa* are based on yield loss rather than quality; however, in faba bean, the quality threshold (defective grain) is probably reached before significant yield loss. Even in low numbers, *Helicoverpa* can affect the marketability of grain while not economically affecting yield, meaning that control measures may be needed before economic thresholds are reached. For large grains such as faba bean, growers should consider treating the moment any budworm larvae are detected.

The control thresholds used in the southern region are those developed for Western Australia. This threshold is the only one used in Australia that may be derived from research, rather than 'best guesses', and assumes 90 kg/ha yield loss per larva in 10 sweeps (Table 3). In southern Australia, the original threshold was two larvae per 10 sweeps.

In New South Wales, a threshold for spraying is determined when the average number of small larvae (<10 mm) exceeds 2–4 larvae/m^2, but if the crop is used for human consumption, a lower threshold of 1 larvae/m^2 is advised.[48 49 50]

Note that the Western Australian thresholds are only a guide for the southern region. To calculate the threshold, use the formula:

Economic threshold for grubs in 10 sweeps = C ÷ (K x P)

Where:

C = control cost ($/ha), i.e. chemical plus application costs per hectare

K = 90 kg/ha faba bean grain eaten for every one caterpillar netted in 10 sweeps or per square metre

P = price of grain per kg, i.e. price per tonne ÷ 1,000

For example, with faba bean:

P = $280/t, (i.e. $0.28/kg) Therefore: ET = 10 ÷ (90 x 0.28)

C = $10/ha

K = 90 kg/ha

47 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

48 P Mangano, S Micic (2016) Management and economic thresholds for native budworm control. Department of Agriculture and Food, Western Australia, www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

49 M Miles, P Grundy, A Quade and R Lloyd (2015) Insect management in fababeans and canola recent research. GRDC Update Paper, 25 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02

50 D Lush (2013) Time to watch for native budworm. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-106-Sept-Oct-2013/Time-to-watch-for-native-budworm

Table 3: Examples of economic thresholds for native budworm control in faba bean for Western Australia.

	P	C	K	Economic thresholds	
Grain price per tonne ($)	Grain price per kg ($)	Control costs including application ($/ha)	Loss per grub in each of 10 sweeps (kg/ha/grub)	Grubs in 10 sweeps	Grubs in 5 lots of 10 sweeps (5x previous column)
280	0.28	10	90	0.4	2
560	0.56	10	90	0.2	1

Note: These thresholds are a guide only, as no thresholds have been developed for south-eastern Australia.[51] They are based on yield loss only, not loss of quality. Source: P Mangano, S Micic (2016) Management and economic thresholds for native budworm control. Department of Agriculture and Food, Western Australia, www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

Helicoverpa punctigera (native budworm) control

Few control options are currently available other than the use of chemical insecticides or biopesticides for above-threshold populations of larvae in a crop.

Spray promptly once the threshold are exceeded. *Helicoverpa punctigera* (native budworm) larvae are easily killed by all registered products, including products to which *H. armigera* is resistant.

Because *H. punctigera* moths migrate annually into eastern Australian cropping regions, any resistance that might be selected for, because of exposure to insecticides in crops, is lost among the larger susceptible population. In other words, as new *H. punctigera* moths appear each year, insecticide resistance is unlikely to be a threat to pulse production in southern and western regions of Australia.

Commonly used insecticides registered for use on native budworm are shown in Table 7 with details in Table 8 .

Aim to control larvae less than 10 mm long, because bigger larvae require higher rates of insecticides. The larvae must be sprayed before they burrow into the seed pods or they will be shielded from insecticides and will continue to damage seed.[52,53]

Helicoverpa armigera control

H. armigera has developed resistance to synthetic pyrethroids, organophosphates and carbamates. Unlike *H. punctigera*, populations tend to remain local, so their resistance to insecticides is maintained in the population from season to season.

If *H. armigera* is the dominant species, spray with carbamates or pyrethroids may fail because of resistance. The biopesticides Helicoverpa nucleopolyhedrovirus (NPV) and *Bacillus thuringiensis* (*Bt*) currently have no known resistance problems.

Before flowering, biopesticides are recommended in preference to chemical insecticides in all pulses, particularly older, less selective products, for integrated pest management.

After flowering, control is recommended only for small larvae 5–7 mm long, depending on the product and if resistance levels are within acceptable limits for the region.

If using a product that is effective only against early-instar larvae, another spray may be necessary during flowering to prevent large larvae damage at pod-set.

Where newer, more selective pesticides, such as spinosad and indoxacarb, are used for *H. armigera*, the number of spray applications per crop is restricted (usually to one) for resistance management. Because of this, and because they are often more

51 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited

52 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

53 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

MORE INFORMATION

GRDC Fact Sheet: Snail management, www.grdc.com.au/GRDC-FS-SnailManagement

Comprehensive information on snail management is available in the publications:

- Snail Bait Application: GRDC Fact Sheet, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application
- *Bash 'Em, Burn 'Em, Bait 'Em: Integrated snail management in crops and pastures*, www.grdc.com.au/GRDC-Snails-BashBurnBait
- *Snail Identification and Control: The Back Pocket Guide*, www.grdc.com.au/BPG-SnailIdentificationAndControl

expensive, new chemical pesticides are best reserved for 'at risk' flowering and podding stages.

For best results, all 'ingestion' products (including biopesticides) require thorough plant coverage. The addition of Amino Feed® or equivalent is strongly recommended for biopesticides.[54 55]

8.3.2 Snails

While snail populations do not build up as readily under faba bean as under field pea, they can still be a problem. Snails climb onto faba bean plants and standing cereal stubble. They can enter the grain sample at harvest with or without having climbed onto the faba bean plant. Snail numbers can explode in seasons with wet springs, summers and autumns.[56 57] **Particular attention must be paid to slugs under no-till and stubble retention**.[58]

White snails or round snails (*Cernuella virgata* and *Theba pisana*)

Two species of white (or round) snails exist: the vineyard or common white snail (*Cernuella virgata*) and the white Italian snail (*Theba pisana*). They are found throughout the agricultural districts of South Australia, and the Victorian Mallee and Wimmera. They also occur in Western Australia, New South Wales and Tasmania.

Both species have similar shapes: white coiled shells up to 20 mm diameter, which may have brown bands around the spiral. The common white snail has an open umbilicus whereas the umbilicus of the Italian snail is partly closed. The umbilicus of a white snail is the hollow space on the underside of the shell.

Photo 10: *Vineyard or common white snail. Note the umbilicus (hollow space) is open.*

Photos: SARDI

54 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

55 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

56 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

57 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

58 J Kirkegaard (2017) Opportunities and challenges for continuous cropping systems, GRDC Update Paper, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/opportunities-and-challenges-for-continuous-cropping-systems

Photo 11: *White Italian snail. Note the umbilicus (hollow space) is partly closed.*

Photos: SARDI

Conical snails or pointed snails or (*Cochlicella acuta* and *Cochlicella barbara*)

Two species of conical snails exist: conical snails (*Cochlicella acuta*) and small conical snails (*C. barbara*).

Conical snails are also known as pointed snails. They have fawn, grey or brown shells. Mature conical snails have shells 12–18 mm long whereas the shells on the small conical snails are 8–10 mm long.

Highest numbers of conical snails (*C. acuta*) are found on the Yorke Peninsula in South Australia. Isolated populations are also present in other parts of SA, Victoria, NSW and Western Australia.

The small conical snail, *C. barbara*, occurs throughout SA, but is most abundant in higher-rainfall areas (>500 mm). It is also widely spread in Victoria, NSW and WA.

The ratio of shell length to base diameter is always greater than two for conical snails and less than two for small conical snails.[59 60 61]

59 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

60 GRDC (2011) Snail Identification and Control: The Backpocket Guide. www.grdc.com.au/BPG-SnailIdentificationAndControl

61 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Fact heet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

Photo 12: *Conical snail, also known as pointed snail. The shell length is always more than double the base diameter. Mature conical snail shells are 12–18 mm long.*

Photo: SARDI

Photo 13: *Small conical snail, also known as small pointed snail. The shell length is always less than double the base diameter. Mature small conical snail shells are 8–10 mm long.*

Photo: SARDI

Damage by snails

White snails mainly damage crops during establishment and harvest. Both common white and Italian snails may feed on young crops and destroy substantial areas, which then need re-sowing. In late spring, snails climb plants. The juveniles, in particular, contaminate the grain at harvest.

Conical snails, *Cochlicella acuta*, contaminate grain at harvest, especially cereals and canola. They feed mostly on decaying plant material but can damage cereal and canola seedlings.

The small conical snail, *C. barbara*, feeds on growing plants and can contaminate grain. Lucerne is a favoured plant.

The contaminated grain may be downgraded or rejected and live snails in grain pose a threat to exports. Grain will be rejection if more than half a dead or one live snail is found in a 0.5 L wheat sample or 200 g pulse sample (Grain Trade Australia). Check with your buyers for specific regulations or visit: www.pulseaus.com.au/marketing/receival-trading-standards

Crushed snails clog up machinery causing delays during harvest. Modify headers and clean grain to eliminate snail contamination of grain. For more details see Section 12.9 Managing snails.

Life cycle of snails

Snails appear to build up most rapidly in canola, field pea and faba bean. However, they can feed and multiply in all crops and pastures. White snails are dormant in summer. Young snails hatch about 2 weeks after eggs are laid. They feed and grow through the winter and spring and then climb fence posts or plants in late spring or summer where they go into summer dormancy. Snails live for 1–2 years, and move only short distances. They are spread in hay, grain, machinery or by vehicles.

Conical snails have a similar life cycle to white snails. Conical snails may over-summer under stones as well as on posts and plants.

Small conical snails over-summer on the ground in the leaf litter and under stones and stumps.[62 63 64]

Monitoring snails

Monitor snails regularly to establish their numbers, types and activity, as well as success of controls. Monitoring and early baiting before eggs are laid is critical for snail control.

Look for snails early morning or in the evening when conditions are cooler and snails are more active.

The key times to monitor snail populations are:

- summer to pre-sowing – check numbers in stubble before and after rolling, slashing or cabling;
- 3–4 weeks before harvest, to assess need for harvester modifications and cleaning; and
- after summer rains: check if snails are moving from resting sites.

A wide range of snail sizes in an area indicates that snails are breeding there; if most snails are the same size, snails are moving in from other areas. Size range of snails is important as juveniles don't take baits.

Various monitoring techniques are recommended for snails. Methods include:

- Sampling with 10 x 10 cm quadrats at 50 locations across the paddock. Take samples from the perimeter to the interior of the paddock and note density in different areas.
- Sampling with a 0.1 m^2 (32 x 32 cm) quadrat. Place the quadrat on the ground and count all live snails within it. Take five counts along the fence at approximately 10 m apart, then five counts into the paddock every 10 m.
- Sampling with a 30 x 30 cm quadrat at 50 locations across the paddock.

When sampling at 50 locations, take five sampling transects in each paddock. One transect is taken at 90 degrees to each fence line, and the fifth transect runs across the centre of the paddock. Take five samples (counts), 10 m apart along each transect. Record the size and number of the snails in each sample. Average the counts for each transect and multiply this figure by 10 to calculate the number of snails per square metre in that area of the paddock.

If two snails groups are present (round and conical), record the number of each group separately.

62 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Fact Sheet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

63 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

64 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

Place the snails in a simple sieve box and shake gently to separate into larger snails and those smaller than 7 mm. Round snails and small conical snails (<7 mm) are unlikely to be controlled by bait. Record two size groups (juveniles <7 mm and adults >7 mm). Sieve boxes can be constructed from two stackable containers, such as sandwich boxes. Remove the bottom from one and replace by a punch hole screen. Suggested screen size is 7 mm round or hexagonal.

When looking for snails, check under weeds, and shake and thresh samples of mature crops onto a small tarp or sack, to see if snails are in the portion of crop that will enter the harvester.

Record live snails before and seven days after baiting or the paddock operation and calculate the reduction in numbers.

Snail control

To control snails, you will need to apply a combination of treatments throughout the year.

The keys to snail management and control are:

- Stubble management:
  - cabling or rolling in summer;
  - slashing in summer; and
  - burning in autumn.
- Summer weed control.
- Baiting in autumn.
- Harvest and delivery:
  - reducing snail intake during harvest (windrowing, brushes, bars);
  - header settings; and
  - cleaning after harvest.

Snail control starts in the summer before sowing. Stop baiting 8 weeks before harvest to avoid bait contamination in grain. Juvenile snails (<7 mm) cannot be controlled after sowing. If pulse crops have more than 5 snails/m^2, growers are likely have grain contamination at harvest.

While control measures for conical snails are the same as those used on white snails, they are generally less effective as conical snails can shelter in cracks in the ground or under stones. Dragging harrows or a cable before burning improves the control of conical snails by exposing more snails to burning.

The best control is achieved by stubble management on hot days or burning, followed by baiting in autumn before egg laying.

Rolling, harrowing or dragging a cable over stubble on hot days reduces snail numbers by knocking snails to the ground to die in the heat (air temperature >35°C). Some snails may also be crushed by rollers.

Burning in autumn can reduce snail numbers by up to 95%, provided there is sufficient stubble for a hot and even burn. Note that wind or water erosion become a risk on burnt stubble.

It is important to understand the factors that determine baiting efficacy. Bait in autumn when snails have commenced activity following rain and must be done before egg laying. Baiting may be necessary to reduce damage to young crops. Fence line baiting can also be vital to prevent re-infestation of the paddock. Do not bait within 2 months of harvest.

Timing and choice of controls will depend on the season. Three bait types are available for snail control: methiocarb, metaldehyde and iron chelates, which are similar in efficacy. (However, methiocarb is not registered for use in faba bean.) The metaldehyde rate used depends on the product used.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

MORE INFORMATION

For more information on managing snails at harvest, see Section 12.9 Managing snails.

Most spreaders are designed for fertiliser. A trial has shown that snail and slug bait is not spread as widely as expected and can become fragmented. Ute spreaders give uneven coverage. For optimal coverage, calibrate spreaders especially for snail bait.[65]

Windrowing can reduce white snail numbers harvested. Snails are knocked from the crops during windrowing, and most re-climb the stalks between the windrows rather than in the windrow.

Biological controls are not yet available for white snails. Native nematode species have shown promise against the four pest snail species but commercially trialled with limited success.[66]

Grain can be cleaned on-farm where snail contamination is so high that grain will be downgraded or rejected.[67 68 69]

8.3.3 Slugs (*Deroceras reticulatum*, *Milax gagates* and others)

Slugs are a growing problem in the high-rainfall zones with zero-till and stubble retention. Faba bean tolerates slug damage better than many other crops.

Although slugs reproduce very poorly on faba bean in laboratory trials, this is not observed in paddocks. This may be due to the microhabitat in faba bean crops favouring slug populations. This is possibly related to soil moisture relative to other crops that dry out the soil more. No single control method will provide complete protection; an integrated approach is best. Slug populations are regulated by moisture. Cool, wet summers and heavy stubble provide ideal conditions for slugs, as they need moisture and shelter to thrive.

MORE INFORMATION

Details of other species can be found in *Slugs in Crops: the Back Pocket Guide*, www.grdc.com.au/GRDC-BPG-Slug

A slug identikit is available at Ground Cover™ Radio, go to https://grdc.com.au/Media-Centre/Hot-Topics/Slugging-slugs/Details

Slug species identification

The two main pest species are the grey field (or reticulated) slug (*Deroceras reticulatum*) and the black keeled slug (*Milax gagates*). The grey field slug is the most common slug species in southern Australia. Brown field slugs (*D. invadens* or *D. laeve*) can also pose a serious threat.

Adult grey field slugs are usually grey and about 2–5 cm long. They may have dark brown mottling and range from light grey to fawn. The black keeled slug is uniform black to grey, with a ridge down its back, and 4–6 cm long. The brown field slug is 25–35 mm long, and usually brown all over with no distinct markings.

The brown field slug is mainly surface active but can burrow to shallow depths.

Grey field slugs are mainly active on the surface while the black keeled slug can burrow up to 20 cm underground to escape the heat. For this reason, black keeled slugs may become active in emerging crops later than grey field slugs, as the autumn break develops. This means the optimal timing of control will differ for the two species.

As black keeled slugs are a burrowing species, they are considered better suited to drier environments.

65 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Fact Sheet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

66 M Nash (2013) Slug control – new insight. GRDC Update paper. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Slug-control-new-insights

67 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

68 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

69 Queensland Department of Agriculture and Fisheries (2016) http://ipmguidelinesforgrains.com.au/pests/slugs-and-snails/snails-in-seedling-crops/

Photo 14: *The two main slug species in southern Australia are the grey field slug (Deroceras reticulatum) (top) and the black keeled slug (Milax gagates) (bottom).*

Photo: Peter Mangano, DPIRD

Damage by slugs

Slugs will attack all plant parts. Seedlings are the most vulnerable and can suffer major economic damage. Faba bean is more tolerant of slug damage than many other crops.

Slugs can be underestimated as pests because they are nocturnal and shelter during dry conditions.

Although slugs can cause major damage to emerging pulse, canola and wheat crops in high rainfall areas, they have also caused damage in lower-rainfall areas in wetter years. Damage is usually greater in cracking clay soils.

Photo 15: *Slug damage on a faba bean seedling.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Life cycle of slugs

Slugs are hermaphrodites, that is, individuals are both male and female. Slugs will breed whenever moisture and temperature conditions are suitable – generally from mid-autumn to late spring. Both individuals of a mating pair lay eggs in batches. Each individual can lay about 100 eggs; some species can produce about 1,000 eggs per year.

Eggs are laid in moist soils and will hatch within 3–6 weeks, depending on temperature. Juveniles look like smaller versions of the adult.

Moisture is essential for slug survival and some species, such as the black keeled slug, may move down the soil to depths of 20 cm or more in dry periods and reappear when conditions improve.

Photo 16: *Slug eggs hatch within 3–6 weeks of laying. Some species can produce up to 1,000 eggs per year.*

Photo: Michael Nash

Monitoring of slugs

Use surface refuges, such as 30 x 30 cm pavers, to monitor slugs. This represents approximately 1 m^2 for slugs. Ideally, use a minimum of 10 tiles per 10 ha placed evenly across the entire paddock.

Growers can also use either a tile, hessian bag or slug trap left in the paddock over night to count snail or slug numbers. There are many types of slug traps available for home garden use. Use surface traps baited with layer's mash and check them early in the morning, as slugs move out of the traps as the day starts to warm up.

Slug control

When slugs are actively breeding, no current control measure will reduce populations below established thresholds. Particular attention must be paid to slugs under no-till and stubble retention.[70]

Cultivation and rolling, and burning stubble after weed control will reduce slug populations. Rolling the soil immediately after sowing can also markedly reduce slug damage. Shallow discing may reduce populations of grey field slugs by 40–50%. While burning may help control surface active species, it will not control the burrowing black keeled slugs.

If anticipating crop damage from slugs, bait after sowing, before crop emergence. Differences in biology between species can affect control options and chemical efficacy.

Always use the highest possible label rates or adjust the rate to the perceived size of the slug population. Bait is commonly applied at 4–5 kg/ha, but be aware that the density of bait points needs to be at about 25–30 bait points/m^2 for a paddock population of 20 slugs/m^2, giving 80% chance of slugs encountering the baits. Spreading bait with fertiliser spreaders can lead to poor distribution of bait.[71]

Preliminary trials found the effective bait life is between 2–3 weeks. More than one bait application may be necessary, particularly with wet winters. Cheaper options give similar results if baiting occurs monthly.

Buried bait is less effective than bait on the soil surface.

MORE INFORMATION

GRDC Fact Sheet: Slug identification and management, see www.grdc.com.au/GRDC-FS-SlugControl

70 J Kirkegaard (2017) Opportunities and challenges for continuous cropping systems. GRDC Update Paper, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/opportunities-and-challenges-for-continuous-cropping-systems

71 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Fact Sheet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

Three types of baits are registered for the control of slugs. They are based on:

- metaldehyde;
- methiocarb (Mesurol®) (although this is not registered for us in faba bean); and
- iron EDTA (iron chelate) complex (Multiguard®).

Metaldehyde and iron chelates are considered by some as the most effective baits. Metaldehyde damages the mucous-producing cells, so it is less affected by cold and wet conditions. Rates of up to 10 kg/ha may be necessary. Baiting will generally only kill half of the slug population at any one time. Details of slug baits are shown in Table 4.

Table 4: Notes on the three groups of slug baits for use in crops in southern Australia.

Bait base	Product	Notes
Metaldehyde	Many products	• Some products are registered for all slugs and some for grey field slugs only • Black keeled and brown slugs appear more tolerant of baits containing metaldehyde • Highly toxic to birds and mammals • Spread evenly to avoid off-target damage
Methiocarb	Mesurol®	• Highly toxic to carabid beetles, one of the few predators of slugs
Iron EDTA complex	Multiguard®	• Registered for grey field slugs only • Snail and slug-specific • Low toxicity to mammals and birds • No impact on predatory insects • The recommended IPM option in Europe

Source: GRDC (2013) Slug control: Slug identification and management Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SlugControl

Consider placing baits with the seed when sowing when black keeled slugs are present.

For grey field slugs, broadcasting baits is more effective.

Predators may provide some regulation of slug populations. The carabid or ground beetle, *Notonomus gravis*, reduces grey field slug numbers but not below damage thresholds.[72 73 74 75 76]

72 M Nash, H Brier, P Horne, J Page, S Micic, G Ash, A Wang (2013) Slug control: Slug identification and management Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SlugControl

73 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

74 M Nash, M Richards, H De Graff, G Baker (2016) New insights into slug and snail control. GRDC Update Paper, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/New-insights-into-slug-and-snail-control GRDC (2014) Slugging Slugs: findings from recent GRDC High Rainfall Zone (HRZ) trials. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Hot-Topics/Slugging-slugs/Details

75 GRDC (2014) Slugging Slugs: findings from recent GRDC High Rainfall Zone (HRZ) trials. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Hot-Topics/Slugging-slugs/Details

76 M Nash (2013) Slug control – new insight. GRDC Update paper. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Slug-control-new-insights

MORE INFORMATION

GRDC Fact Sheet: Aphids and viruses in pulse crops, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

IPM guidelines for grains website: http://ipmguidelinesforgrains.com.au/

8.3.4 Aphids

Aphids are a pest of faba bean chiefly because they spread viruses during feeding, which can reduce crop yields, especially when infection is extensive in early crop stages. A few aphids can cause substantial damage if they are spreading viruses, especially early in the season.

It takes large numbers of aphids to damage crops by direct feeding. This happens in hot spots, where aphids are concentrated at the growing tips of plants, causing wilting stunting and, sometimes, tip death.

Aphids and virus transmission

Viruses are a problem in faba bean crops in some seasons. Viruses such as Pea seed-borne mosaic (PSbMV), Bean leaf roll virus (BLRV) and Beet western yellows virus (BWYV) are not seed-transmitted but become established after aphid-vector activity.

Different aphid species transmit different viruses to particular crop types; species identification is important because management strategies can vary.

Aphids, and the viruses they spread, have alternative hosts between growing seasons. Summer rain and early autumn breaks favour the early build-up in aphids, as well as the volunteer plants that host viruses. It is important to use integrated management practices to control aphid populations early in the season.

Aphids can spread viruses persistently or non-persistently (Table 5). Once an aphid has picked up a persistently transmitted virus, it carries the virus for life, infecting every plant where it feeds. Aphids carrying non-persistently transmitted viruses, carry the virus temporarily and only infect new plants in the first one or two probes.

For more information on viruses, refer to Section 9 Diseases.

Table 5: Examples of transmission of some persistent and non-persistent viruses by four aphid species affecting pulse crops.[77]

Aphid	Cucumber mosaic virus (CMV)	Pea seed-borne mosaic virus (PSbMV)	Beet western yellows virus (BWYV)
	non-persistent	non-persistent	persistent
Green peach aphid	Yes	Yes	Yes
Pea aphid	Yes	Yes	No
Cowpea aphid	Yes	Yes	Yes
Bluegreen aphid	Yes	No	No

Source: Pulse Australia (2016) Faba bean: integrated disease management. Australian Pulse Bulletin. Pulse Australia, www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/idm-strategies

Persistent viruses can be transmitted while visiting faba bean crops, so it is important to protect crops against aphid invading from surrounding areas.[78 79 80]

77 GRDC (2010) Aphids and viruses in pulse crops. Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

78 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes™

79 GRDC (2010) Aphids and viruses in pulse crops, Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

80 Pulse Australia (2016) Faba bean: integrated disease management, Australian Pulse Bulletin, 15 January 2016, Pulse Australia, www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/idm-strategies

MORE INFORMATION

PestNotes Southern has more details on cowpea aphids, please see http://www.pir.sa.gov.au/__data/assets/pdf_file/0003/275826/Cowpea_Aphid.pdf

Cowpea aphid (*Aphis craccivora*)

The cowpea aphid is a widespread and common pest of pulses. They have a wide range of host plants and can tolerate warm, dry weather conditions that cause many other aphid species to suffer.

Cowpea aphid is the only black aphid. All stages have black and white legs. Adults are shiny black, up to 2.5 mm long and may have wings. Nymphs are slate grey.

Superficially, nymphs of the brown smudge bug look like cowpea aphid nymphs.

Photo 17: *Cowpea aphids can transmit a number of viruses to faba bean crops. Note the different aphid ages: the older aphids are shiny black. The white cast is a skin, shed as the aphid grows.*

Photo: SARDI.

Photo 18: *Cowpea aphid colony damaging a faba bean plant.*

Photo: Gordon Cumming, formerly Pulse Australia

The cowpea aphid is the most common species to infest faba bean. Before they colonise a faba bean crop, cowpea aphids can transmit viruses (Table 6).

Table 6: Some persistent and non-persistent viruses spread by cowpea aphid that affect faba bean. This list is not exhaustive and the viruses may be spread by other aphid species.

Persistent	Non-persistent
Bean leaf roll virus (BLRV)	Pea seed-borne mosaic virus (PSbMV)
Sub clover red leaf virus (SCRLV)	Bean yellow mosaic virus (BYMV)
Sub clover stunt virus (SCSV)	Cucumber mosaic virus (CMV)
Beet western yellows virus (BWYV)	Alfalfa mosaic virus (AMV)

Source: Southern Faba Bean Best Management Practices Training Course Manual, (2016), Pulse Australia

A cowpea aphid infestation is generally patchy at first but will spread through the crop if the weather is fine and warm.

Infestations start when winged females colonise a few plants in a crop and give birth to wingless nymphs that live in colonies. This may occur from early winter onwards. As the plant deteriorates, the aphids move to neighbouring plants, increasing the area of infested patches within the crop.[81 82 83]

Bluegreen aphid (*Acyrthosiphon kondoi*)

Adult bluegreen aphids grow up to 3 mm, may have wings and vary from matte blue-green to grey-green. They are oval, with long legs and antennae. They have two large cornicles (tubes) that extend beyond the base of the abdomen. Nymphs are similar to adults but smaller.

MORE INFORMATION

Details on bluegreen aphids can be found in PestNotes Southern, please see http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

Photo 19: *Bluegreen aphid.*

Photo: Grain Legume Handbook

81 P Umina, S Hangartner (2015) Cowpea aphid, Pest Notes Southern, cesar and the South Australian Research and Development Institute, www.pir.sa.gov.au/__data/assets/pdf_file/0003/275826/Cowpea_Aphid.pdf

82 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

83 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Photo 20: *Bluegreen aphids of various ages. The brown insects are dead bluegreen aphids which have been parasitised by wasps.*

Photo: Grain Legume Handbook

Bluegreen aphids can colonise faba bean plants and transmit important viruses including the non-persistent viruses Cucumber mosaic virus (CMV) and Bean yellow mosaic virus (BYMV).

Bluegreen aphids do not transmit Pea seed-borne mosaic virus (PSbMV).

Bluegreen aphids cause feeding damage to upper leaves, stems and terminal buds of host plants. Heavy infestations can cause damage to plants by direct removal of nutrients. In general, aphids have the greatest impact on crops when soil moisture is limited.

Bluegreen aphids prefer cooler weather (10°C–18°C) for breeding. Females produce **up to 100 young at a rate of approximately 7 per day**. Winged aphids develop when infestations become crowded; they fly or are blown by wind to start new infestations elsewhere.

Natural enemies are: hoverfly larvae, aphid parasites, green lacewing larvae, brown lacewing, ladybirds.[84 85 86]

Monitoring aphids

Aphids invade faba bean crops from adjacent crops and pastures.

The literature varies in recommendations for aphid monitoring early in the season.

One method is to inspect faba bean crops and sample leaves for winged aphids from early winter onwards. A second source encourages monitoring faba bean and surrounding crops and pastures at all crop stages, including frequent monitoring of seedlings and establishing plants to detect rapid increases of aphid populations.

In contrast, other literature states that the early monitoring of aphids in faba bean crops for virus control has limited benefits. This is firstly because non-colonising aphids may be found. Secondly, even when colonising aphids are found, the virus may have already spread by the time they are observed.

In spring and early summer, inspect faba bean crops for aphid colonies Monitor crops and neighbouring areas regularly and identify the species of aphid present and their numbers.

Branch samples may give useful estimates of aphid density for bluegreen aphid.

84 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia

85 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

86 P Umina, W Kimber (2015) Bluegreen aphid, Pest Notes Southern. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

VIDEO

For more information of insecticide resistance and management of green peach aphid and TuYV (formerly BWYV), watch: www.youtube.com/watch?v=1MIRtsfydkc

Sticky traps might assist in identifying early aphid activity, as well as the presence of beneficial insects including hoverflies, lacewings, ladybirds and parasitic wasps. These species will attack aphids.

Beneficial insects can help reduce virus spread and spring feeding damage, but some virus spread will have occurred before aphid numbers subside.

Aphid control for viruses

Control the aphids if virus spread and direct feeding damage is of concern.

Thresholds for managing aphids to prevent the incursion of aphid-vectored viruses have not been established and will be much lower than any threshold to prevent yield loss via direct feeding.

While no specific thresholds are available for cowpea aphid, in the southern region growers are encouraged to treat low levels of cowpea aphids in faba bean to prevent virus transmission early in the season.

Monitor faba bean and surrounding crops and pastures from early winter, and spray if plants with cowpea aphid can be found easily.

Use an integrated management approach to reduce the risk of virus transmission by aphids. **Particular attention must be paid to pests that develop resistance to available pesticides, such as green peach aphid.**[87]

The best protection against aphid infestation and virus spread in faba bean is to preventing aphids landing in the crop.

While beneficial insects can help reduce virus spread (and spring feeding damage), some virus spread will have occurred before aphid numbers subside.

The risk of non-persistently transmitted viruses can be reduced before sowing using a range of management measures, as follows:

- Eliminate summer weeds and volunteer pulses (the ‘green bridge’) that host viruses and provide refuge for aphids.
- Monitoring in nearby crops and pastures early in the season.
- Sow directly into cereal stubbles, (preferably standing) and encourage rapid canopy cover through early planting and high planting density as bare soil is more attractive to some aphid species. Minimum-tillage with inter-row sowing is ideal to discourage aphid landings.
- Consider using seed-applied insecticide dressings; Gaucho 600 Red Flowable® is now registered and when applied as seed treatment will help protect faba bean seedlings from early season aphid attack and reduce spread of the persistently transmitted viruses BLRV and BWYV early in the season, as well as Subterranean clover red leaf virus (SCRLV), Subterranean clover stunt virus (SCSV) and Beet western yellows virus (BWYV).
- Possibly use foliar insecticides soon after crop emergence to help control persistently transmitted viruses. These are of little benefit against non-persistently transmitted viruses. A prophylactic insecticide spray is not desirable. Several insecticides for aphid control are highly toxic to bees and should not be applied while bees are foraging or pollinating faba beans.
- Possibly use an aphicide to reduce aphid numbers; e.g. pirimicarb targets aphids but leaves beneficial insects unharmed. Pirimicarb is registered for faba bean in Victoria and Tasmania.
- Rotate pulse crops with cereals to reduce virus and vector sources and, where possible, avoid close proximity to perennial pastures (such as lucerne) or other crops that host viruses and aphid vectors.
- Purchase virus-tested seed or have farmer seed virus-tested. Sow tested seed with less than 0.1% virus infection.

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87 J Kirkegaard (2017) Opportunities and challenges for continuous cropping systems. GRDC Update Paper, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/opportunities-and-challenges-for-continuous-cropping-systems

Foliar application of synthetic pyrethroids (SP) for aphids is under debate. It is recommended to prevent BLRV transmission by preventing early colonising of crops by pea aphids. However, discouraging colonisation may increase the spread of aphids and, potentially, virus through a crop.

Synthetic pyrethroid (SP) insecticides should not be used to control green peach aphid, an important vector of BWYV, as most populations are resistant to SPs.

A commonly used insecticide registered for use on bluegreen aphid is shown in Table 7 with details in Table 8 (see Section 8.8 Registered insecticides, commonly used).

Pulse Breeding Australia (PBA) is increasing its emphasis on developing pulse crop lines with increased virus resistance. Faba bean lines with resistance to BLRV and field pea with resistance to BLRV and PSbMV have been identified and should be commercially available in the future.

Aphid control for direct feeding damage

Limited threshold information on aphid numbers is available, to determine whether it is economically worthwhile to apply insecticides to prevent damage caused by feeding.

For bluegreen aphid, the economic control threshold in faba bean in Victoria is 10% of plants infested.

When determining economic thresholds for aphids, it is critical to consider several other factors before making a decision. The availability of moisture and the incidence of predators and parasitoids will affect the decision to control aphids. Crops that are not moisture stressed have a greater ability to compensate for aphid damage and will generally be able to tolerate far higher infestations than moisture stressed plants before a yield loss occurs.

When damage is evident, it may be necessary to control bluegreen aphid. Faba bean suffers some mechanical damage from this pest.

For bluegreen aphid, spray with insecticide only where damage to growing points is obvious. Broad-spectrum insecticides should be avoided to assist with conservation of natural enemies.

If bluegreen aphid is the predominant pest, use insecticides that do not kill aphid parasites and predators; for mixed infestations, systemic chemicals that control aphids and mites should be used.

Routine spraying of SP insecticides should be avoided as repeated applications of these insecticides can result in resistance developing in other aphid species and will also kill many natural insect predators.

A border spray can provide sufficient control earlier in the season when aphids move into crop edges.

A 'soft' insecticide such as pirimicarb is an option for controlling direct feeding damage when aphid populations are increasing.[88 89 90 91 92 93]

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88 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

89 GRDC (2014) Northern faba bean GrowNotes™. https://grdc.com.au/Resources/GrowNotes

90 GRDC (2010) Aphids and viruses in pulse crops, Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

91 P Umina, W Kimber (2015) Bluegreen aphid, Pest Notes Southern. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

92 Pulse Australia (2015) Managing viruses in pulses. Australian Pulse Bulletin, 20 November 2015, Pulse Australia, www.pulseaus.com.au/growing-pulses/publications/manage-viruses

93 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

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8.4 Other pests of faba bean

A range of other pests are also potentially major pests in some pulses, including faba bean. These should not be ignored in crop monitoring and management of faba bean.

Pests like lucerne flea compete for food and resources with other agricultural pests such as redlegged earth mite and blue oat mite. Control strategies that only target one species may not necessarily reduce the overall pest pressure because other pests can fill any gaps. It is important to assess the complex of pests before deciding on the most appropriate control strategy.

To avoid developing multiple pesticide resistance, rotate chemical classes across generations rather than within a generation of a pest.[94]

8.4.1 Redlegged earth mite (*Halotydeus destructor*)

MORE INFORMATION

For more information on redlegged earthmites, please see the Agnote, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

VIDEO

Or watch GRDC (2012) GCTV9: https://www.youtube.com/watch?v=tMnUVGOUXu8

RLEM identification

Redlegged earthmites (RLEM) are active from autumn to late spring and are found in southern Australia.

Adults and nymphs of RLEM have a ‘velvety' black body. Adult RLEM are 1 mm long with eight red-orange legs. Newly hatched mites are only 0.2 mm long and pinkish-orange with only six legs.[95 96]

Photo 21: *Redlegged earth mite (RLEM) close up.*

Photo: Grain Legume Handbook

94 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

95 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/Resources/Ute-Guides/Insects

96 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

Photo 22: *RLEM feeding causes leaves to first turn silvery, then brown and shrivelled, so that the plants look scorched.*

Photo: Grain Legume Handbook

RLEM damage

RLEM feed on the foliage for short periods and then move around. Other mites are attracted to compounds released from damaged leaves.

Typical RLEM damage appears as 'silvering' or 'whitening' of the attacked foliage. RLEM are most damaging to emerging crops, greatly reducing seedling survival and development.

In severe cases, entire crops may need re-sowing following RLEM attack. RLEM feed on a wide range of plant species.[97]

Photo 23: *RLEM damage on a faba bean seedling.*

Photo: Wayne Hawthorne, formerly Pulse Australia

97 P Umina (2007) Redlegged earthmite. Agnote AG0414, January 2007, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

Photo 24: *Damage to a faba bean crop from RLEM spreading from an adjacent pasture.*

Photo: Wayne Hawthorne, formerly Pulse Australia

RLEM life cycle

RLEM are usually active between April and November. During this period, RLEM may pass through 2–3 generations, with each generation surviving 6–8 weeks. Long, wet springs favour the production of over-summering eggs.

Autumn rains trigger hatching in 3–9 days. False autumn breaks can cause large losses in mite numbers. Mites take 20–25 days from hatching to mature and start laying eggs.

RLEM monitoring

Inspect faba bean crops from autumn to spring for mites and their damage, particularly in the first few weeks after sowing.

Mites feed on the leaves in the morning or on overcast days. In the warmer part of the day RLEM tend to gather at the base of plants, sheltering in leaf sheaths and under debris. They crawl into cracks in the soil to avoid heat and cold. When disturbed during feeding they will drop to the ground and seek shelter.

RLEM control and insecticide resistance management

Control strategies that only target RLEM may not entirely remove pest pressure. Other pests can fill the gap, and this is particularly evident after chemical applications, which are generally more effective against RLEM than other mite pests.

Non-chemical options are becoming increasingly important due to evidence of resistance in RLEM populations and concern about long-term sustainability. If using a chemical spray, choose one that has least environmental impact and aim to reduce the number of chemical applications. Pesticide groups exist with low to moderate impacts on many natural enemies, such as cyclodienes.

Insecticide resistance in RLEM is presently confined to Western Australia. High levels of resistance to pyrethroids exist within WA populations. Resistance to organophosphates has also evolved. A strategy to manage insecticide resistance in RLEM populations is available for use by grain growers and their advisers.

MORE INFORMATION

GRDC Fact Sheet: Resistance management strategy for the redlegged earth mite, https://grdc.com.au/FS-RLEM-Resistance-strategy-South

Chemical control of RLEM

While insecticides are registered for control of active RLEM, none currently registered are effective against RLEM eggs. Commonly used insecticides registered for use on RLEM are shown in Section 8.8 Registered insecticides, commonly used.

Four chemical sub-groups are registered to control RLEM in grain crops: organophosphates (Group 1B); synthetic pyrethroids (Group 3A); phenylpyrazoles

(Group 2B); and neonicotinoids (Group 4A). The latter two are registered only for use as seed treatments.

If spraying in autumn, control the first generation of mites before they lay eggs. Pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, before adults begin to lay eggs. Rotate products with different modes of action, to reduce the risk of insecticide resistance.

Autumn insecticide application includes:

- Pesticides with persistent residual activity used as bare earth treatments to protect seedlings.
- Foliage sprays applied after crop emergence, which and are generally an effective control.
- Systemic pesticides applied as seed dressings, which act by maintaining the pesticide at toxic levels within the seedling. Note, if mite numbers are high, plants may suffer significant damage before the pesticide has much effect.

A correctly timed spray in spring can reduce populations of RLEM the following autumn. Use climatic variables, and tools such as Timerite® to determine the optimum date for spraying. While Timerite® has less relevance in pulse cropping, it has an important role in pastures and RLEM population management. Research in southern Australia has shown the use of a Timerite® spring spray effective in reducing RLEM populations by 93%.

Users need to be mindful of its limitations and the issues around repeated insecticide applications according to this approach.

Spring RLEM sprays will generally not be effective against other pest mites.

MORE INFORMATION

Details on Timerite® can be found at https://www.wool.com/globalassets/start/woolgrower-tools/timerite/timeriteinformationpackage.pdf

Biological control of RLEM

At least 19 predators and one pathogen are known to attack earthmites in eastern Australia, particularly other mites, although small beetles, spiders and ants also play a role. Benefits of a predatory mite (*Anystis wallacei*) that has been released are yet to be demonstrated.

Natural enemies of RLEM residing in windbreaks and roadside vegetation need to be protected also, so avoid pesticides with residual activity applied as border sprays to prevent mites moving into a crop or pasture.

Cultural control of RLEM

Cultural control measures include:

- rotating crops or pastures with non-host crops, such as cereals;
- cultivating, which can also help reduce RLEM populations;
- clean fallowing and controlling weeds around crop and pasture perimeters; and
- controlling weeds, especially thistles and capeweed, to remove breeding sites for RLEM.[98 99 100 101 102]

98 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

99 P Umina (2007) Redlegged earthmite. Agnote AG0414, January 2007, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

100 GRDC (2016) Resistance management strategy for the redlegged earth mite in Australian grains and pastures in New South Wales, South Australia, Tasmania and Victoria, Fact Sheet.. Grains Research and Development Corporation, https://grdc.com.au/FS-RLEM-Resistance-strategy-South

101 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

102 TJ Ridsdill-Smith, C Pavri (2015) Controlling redlegged earth mite, Halotydeus destructor (Acari: Penthaleidae), with a spring spray in legume pastures. Crop and Pasture Sci., 66: 938–946.

8.4.2 Lucerne flea (*Sminthurus viridis*)

Lucerne flea is mostly found on loam or clay soils and can damage a wide range of crops.

Lucerne flea identification

Lucerne flea springs off plants when disturbed. It is yellow-green and may have dark markings. Adults are plump and wingless and approximately 2–3 mm long, often with mottled darker patches over the body. Newly hatched nymphs are pale yellow and 0.5–0.75 mm long, and resemble adults as they grow, but are smaller.

The lucerne flea is a springtail; this group has six or fewer abdominal segments and a forked tubular appendage under the abdomen. Springtails are one of the most abundant of all macroscopic insects and are frequently found in leaf litter and other decaying material.

Photo 25: *Lucerne flea with eggs. Adults are yellow-green and may have black or brown markings.*

Photo: Grain Legume Handbook

Lucerne flea damage

Faba bean is susceptible to lucerne flea, in contrast to chickpea. In addition to pulses, the insect can damage pastures, lucerne, oilseeds and cereals.

Lucerne flea is present in autumn to spring. Crops are most susceptible to damage immediately following seedling emergence. Numbers tend to peak in spring.

Although a serious pest of young crops, lucerne flea can also damage older crops. They move up plants from the soil level, leaving a distinctive transparent 'window' on leaves. A severe infestation may remove all green material.[103 104 105]

103 D Hopkins, M Miles (1998) Insects: the Ute Guide, Southern Region. Primary Industries and Resources SA.

104 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

105 www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/

Photo 26: *Leaf damage caused by lucerne flea feeding, resulting in a distinctive transparent 'window' appearance.*

Photo: Grain Legume Handbook

Lucerne flea life cycle

They are favoured by high humidity and moisture, a mild autumn and winter.

Long wet springs favour lucerne flea, often causing more serious outbreaks in the following autumn. It requires cool, moist conditions.

Lucerne flea will produce up to five generations in most years. Activity stops in late spring when dry conditions lead to the production of over-summering eggs by the final generation of females.

Over-summering eggs hatch the following autumn, usually soon after opening rains in southern Australia, when the right combination of temperature and moisture occurs.

Monitoring

Regularly monitor for damage from autumn to spring. Importantly, faba bean crops should be inspected frequently at emergence and during establishment, when they are most susceptible to damage.

Lucerne flea is often concentrated in localised patches or 'hot spots' so it is important to have a good spread of monitoring sites within each paddock.

Examine foliage for the characteristic damage and check the soil surface, where insects may be sheltering. Monitoring usually involves working on hands and knees.

Monitoring lucerne flea populations for growth stage as well as numbers can also be important for accurate timing of some sprays.

Chemical control of lucerne flea

In southern Australia, lucerne flea hatching starts after the first significant autumn rain. If damage warrants control, treat the infested area with an insecticide 3 weeks after lucerne flea first emerges. This will allow for the further hatching of over-summering eggs but will be before they reach maturity and begin to lay winter eggs

While insecticides provide the most effective means of control, lucerne flea has a high natural tolerance to synthetic pyrethroids and should not be treated with this class of insecticide. In paddocks where damage is likely, a border spray may be sufficient to prevent movement of lucerne flea into the crop from neighbouring paddocks. Lucerne flea is often patchily distributed within crops, so spot spraying may be sufficient. Do not blanket spray unless the infestation warrants it.

Control lucerne flea control in the paddock in the season before sowing susceptible crops like faba bean. Spring spraying can reduce the number of insects in the following autumn by preventing the laying over-summering eggs. A planned program of timely spring and autumn sprays with effective chemicals over 2–3 years can reduce populations to very low levels.

There are no formal spray thresholds for lucerne flea damage in crops. However, the key is early control because of the impact of seedling vigour on crop performance. Damage levels can be used to determine whether or not spraying is necessary.

It is important to assess the complex of pests present before deciding on the most appropriate control strategy.

When both lucerne flea and redlegged earth mite are present, control strategies should consider both pests.

Avoid 'insurance sprays' where insecticide is added to other sprays just in case an outbreak occurs. Spray decisions should be based on monitoring of the pest numbers across several weeks, and where an increase in numbers can be seen causing crop damage. If numbers are static or declining, it can mean that natural enemies are having an effect on the pest population. Overuse of chemicals when pest numbers are low or not causing economic damage will select for insecticide resistance in the long term. Timing sprays to have the most impact and rotating insecticide groups will help to avoid resistance developing.

Spray immature lucerne fleas before they have a chance to reproduce. Organophosphates (OPs) are recommended for lucerne flea and *Bryobia* mite control.

If spraying, use an organophosphate insecticide, e.g. omethoate. A border spray may be sufficient to stop invasion from neighbouring pastures or crops. Spot spraying, rather than blanket spraying, may be all that is required.

If warranted, treat the infested area approximately 3 weeks after lucerne flea has been observed on a newly emerged crop. This will allow for the further hatching of over-summering eggs but will be before lucerne flea reaches maturity and begins to lay winter eggs.

Biological and cultural control of lucerne flea

Several predatory mites, for example, snout mites, various ground beetles and spiders prey on lucerne flea.

Clean fallows and control of weeds within crops and around pasture perimeters, especially of capeweed, helps reduce lucerne flea numbers.

Cultivation using trap, border crops and mixed cropping can help reduce the overall infestation levels, particularly when used in conjunction with other measures. Grasses and cereals are less favourable to lucerne flea and as such can be useful for crop borders.[106 107 108 109]

106 www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/

107 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

108 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

109 G Jennings (2002) Knowledge, timing, key to lucerne flea control. Grains Research Advice, November 2002, Grains Research and Development Corporation,

MORE INFORMATION

More information on Blue oat mite, please see PestNotes Southern at http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

8.4.3 Blue oat mite (*Penthaleus* spp.)

Blue oat mite identification

Adult blue oat mites (BOM) are 1 mm long, with eight red-orange legs. They have a dark blue-black body with an oval red/orange spot on their back, which distinguished them from redlegged earthmite (RLEM). Mites generally feed singularly. They share similar life cycles with RLEM.

Three pest species of BOM exist in Australia, which complicates identification and control. These are *Penthaleus major*, *P. falcatus* and *P. tectus*.

Photo 27: *Blue oat mite has a blue-black or deep purple body with a distinct red to orange spot on its back, which distinguishes it from redlegged earth mite.*

Photo: Gordon Cumming, formerly Pulse Australia

Blue oat mite damage

The BOM species are predicted to be found on faba bean and cause feeding damage, although this has not been researched to date. Blue oat mite attack most crops and pastures, but cereals, canola and lucerne are most susceptible.

Blue oat mite life cycle

BOM are active from April to late October, and over-summer as eggs. Autumn rains trigger hatching within 3–9 days. False breaks in the season can cause large losses in mite numbers. Mites take 20–25 days from hatching to mature and start laying eggs.

Blue oat mite monitoring

It is important to monitor germinating pulse crops. Check paddocks before sowing in autumn and throughout winter.

Examine plants for damage and search for mites on leaves and the ground, especially in late-sown crops.

BOM spend most of their time on the soil surface, rather than on the foliage. They are most active during the cooler parts of the day, feeding in the mornings and in cloudy weather. They seek protection during the warmer part of the day on moist soil surfaces or under foliage, and may even dig into the soil under extreme conditions.

Chemical control

Each species differ in their distribution, pesticide tolerance and crop plant preferences. BOM is often misidentified as RLEM but some BOM species are more tolerant than RLEM to a range of synthetic pyrethroid and organophosphate insecticides.

All current pesticides are only effective against the active stages of mites, and do not kill mite eggs. Commonly used insecticides registered for use on BOM are shown in Table 7 with details in Table 8. See Section 8.8 Registered insecticides, commonly used.

P. falcatus has a high natural tolerance to a range of pesticides registered for use against earth mites. The other BOM species have a lower level of tolerance to pesticides and are generally easier to control with chemicals.

Control first generation mites before they can lay eggs to avoid a second spray. Pesticides used at or after sowing should be applied within 3 weeks of first appearance of mites, as adults will then begin laying eggs.

Spraying in spring is not a recommended strategy with BOM.

Pesticides with persistent residual effects can be used as bare-earth treatments. If applied by sowing, these treatments can protect the plants throughout their seedling stage.

Systemic pesticides applied as seed dressings can help minimise crop damage during establishment, however, if mite numbers are high, significant damage may still occur before the pesticide has much effect. (No systemic pesticides are registered for use in faba bean.)

Biological & cultural control

A number of predator species are known to attack earth mites in Australia. Leaving shelterbelts or refuges between paddocks will help maintain natural enemy populations.

Preserving natural enemies when using chemicals is often difficult for growers because the pesticides generally used are broad spectrum and kill beneficial species with the pests.

Cultural controls such as rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival, decreasing the need for chemical control. Non-preferred crops are:

- *P. major* – canola;
- *P. tectus* – chickpea; and
- *P. falcatus* – wheat, barley.

Faba bean should be considered as vulnerable, and should not be considered a useful rotational crop to help control BOM species.

Pre- and post-sowing weed management (particularly broadleaf weeds) is important.[110 111 112 113]

110 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

111 D Hopkins, M Miles (1998) Insects: the Ute Guide, Southern Region. Primary Industries and Resources SA.

112 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

113 P Umina, S Hangartner (2015) Blue oat mite, Pest Notes Southern. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

MORE INFORMATION

GRDC Fact Sheet: Plague locust control, https://grdc.com.au/Resources/Factsheets/2010/08/Plague-Locust-Control-Factsheet

8.4.4 Australian plague locust (*Chortoicetes terminifera*)

Australian plague locust identification

Adults of the Australian plague locust have a characteristic black spot on the tip of the hind wing. Nymphs or hoppers are more difficult to identify. If swarming in a large band, then it is likely to be the Australian plague locust.

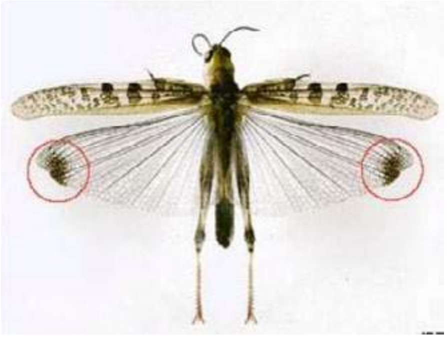

Photo 28: *Australian plague locust. Note the black spot at the tip of the hind wing.*

Photo: APLC via PIRSA

Australian plague locust damage

Locusts and grasshoppers will cause damage to faba bean in the same way that they will damage any green material when in plague numbers.

Faba bean seedlings may be less vulnerable in the stages compared with lupin and lentil but crops may still be significantly damaged.

Pulses are susceptible to attack while they remain green and susceptibility of drying pulse crops is unknown. Rejection at grain delivery can occur if adult locusts or parts of them are present in the sample, or objectionable stains and odours exist.

Australian plague locust life cycle

Most locust plagues originate in south-west Queensland and adjacent areas of South Australia, New South Wales and the Northern Territory. Populations develop following rainfall in this area.

With suitable conditions, autumn swarms may migrate 200–500 km into pastoral and adjacent agricultural areas. On arrival they lay millions of eggs in bare ground which can produce the spring outbreak.

Comprehensive details and government responses to plague locust threats can be found at the Australian Plague Locust Commission website (http://www.agriculture.gov.au/pests-diseases-weeds/locusts/about/australia).

Control

The Australian Plague Locust Commission (APLC) undertakes surveillance threat assessments, forecasting and control measures when locust populations in outbreak areas have the potential to cross into agricultural locations.

In the event of a plague, local government may undertake some spraying operations within their own area. Where significant problems are expected, government agencies may undertake large-scale control in pastoral and adjacent agricultural areas.

Effective locust suppression can only be achieved by landowners, local government and government agencies working cooperatively, together with ongoing APLC activities.

Cultivating egg beds will destroy the eggs. Use approved insecticides to target the bands of nymphs before they take flight. Advice on timings and chemicals can be obtained from state government departments or local chemical resellers. Often Australian Pesticides and Veterinary Medicines Authority (APVMA) Permits are required for chemical use.[114 115]

8.5 Occasional pests of faba bean

The pests listed below are seldom seen in faba bean crops, but have been known to occur over the years and under ideal conditions may occasionally represent an economic threat. See more specific publications for full details.[116,117]

MORE INFORMATION

For more details on identification, see Insects: the Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/West/Cutworms-Bogong-Moth-Black-Cutworm-Pink-Cutworm-And-Herringbone-Cutworm

8.5.1 Cutworms: Common cutworm or Bogong moth, black cutworm, brown or pink cutworm and herringbone cutworm (*Agrotis infusa*, *Agrotis ipsilon*, *Agrotis munda* and other *Agrotis* species)

Cutworm identification and life cycle

Cutworm larvae are hairless with dark heads and usually dark bodies. They live in the soil and grow to 50 mm long. They curl up and remain still if disturbed.

Female moths lay eggs in soil in lightly vegetated or bare areas. Larvae have six growth stages (instars).

Cutworm monitoring, damage and control

Cutworm is a sporadic emergence pest. It attacks all crops and pastures including faba bean and broad bean.

Large larvae (20–40 mm long) ringbark or cut off seedlings at ground level; the final sixth stage larvae eat 86% of food.

Check crops from emergence to establishment. Damage is often patchy. Larvae are usually just beneath the surface; check the base of healthy or recently damaged plants adjoining damaged, bare or thin areas.

Control by selective spraying. Treat affected patches with a standard insecticide (synthetic pyrethroid). Commonly used insecticides registered for use on cutworm are shown in Table 8 with details in Table 9. Section 8.8 Registered insecticides, commonly used.

Biological controls include a number of parasites, disease and spiders.

114 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

115 GRDC (2010) Plague locust control: a coordinated approach to control plague locusts. Fact Sheet. September 2010, Grains Research and Development Corporation and Australian Plague Locust Commission, https://grdc.com.au/Resources/Factsheets/2010/08/Plague-Locust-Control-Factsheet

116 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

117 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia

Photo 29: *Cutworm damage to faba bean plant at soil level.*

Photo: Wayne Hawthorne, formerly Pulse Australia

8.5.2 Balaustium mite (*Balaustium medicagoense*)

Balaustium mite identification and life cycle

Correct identification is critical for control. *Balaustium* mite adults grow to 2 mm long, may be variable in colour but are mainly dark red to brown. They are slow moving and have characteristic short hairs covering the body. They also have a 'pad'-like structure on the forelegs. Newly hatched nymphs have six bright orange legs, while adults have eight red legs.

Balaustium mite activity is from March to November in a Mediterranean climate. The mite requires autumn rainfall for over-summered eggs to hatch.

Balaustium mite monitoring, damage and control

Check crops throughout the growing season, particularly in paddocks with a history of chemical treatments for redlegged earth mite (RLEM).

Most synthetic pyrethroids are not effective on *Balaustium*, lucerne flea or *Bryobia* mites.

(Also, there are no insecticides registered for *Balaustium* in pulses.)

Balaustium mite is also more tolerant of organophosphate insecticides than RLEM.

MORE INFORMATION

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Mites/South/Balaustium-Mite

Crop Mites: The Back Pocket Guide https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/bpg-cropmites

8.5.3 Clover mite or Bryobia mite (*Bryobia* spp.)

Bryobia mite identification and life cycle

Adults are 0.75–1 mm long with pale orange legs with a dark grey-brown to fawn-orange body, which is oval and flattened. Their front legs are 1.5 times their body length. *Bryobia* mite leave distinct feeding trails.

Bryobia mite is highly active during warm conditions in autumn, spring and early summer. They are found in low numbers in winter when they are unlikely to cause problems. Summer rains followed by a warm autumn increases their survival.

Bryobia mite monitoring, damage and control

Control summer weeds early in paddocks to be cropped. Before sowing, look for damage and their presence on clover and *Brassica* weeds.

Monitor during crop establishment. Mites are difficult to find in wet conditions; check during the warmer part of the day.

MORE INFORMATION

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Mites/South/Clover-Mite

MORE INFORMATION

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Earwigs/South/European-Earwig-and-Native-Earwig

For information on management, see GRDC European earwigs Fact Sheet, https://grdc.com.au/Resources/Factsheets/2013/11/European-Earwigs-Fact-Sheet

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/Mandalotus-Weevil

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Thrips/South/Onion-Thrips-Plague-Thrips-and-Western-Flower-Thrips

Crop Weevils: The Back Pocket Guide https://grdc.com.au/resources-and-publications/all-publications/publications/2013/05/grdc-bpg-cropweevils

Spray only when necessary – avoid insurance sprays and rotate insecticide groups to reduce the risk of insecticide resistance. Faba bean is not a good break crop against *Bryobia* mite.

Most synthetic pyrethroids are not effective on *Bryobia* mites, lucerne flea or *Balaustium* (and there are no insecticides registered for *Balaustium* in pulses). Organophosphates are recommended for *Bryobia* mites and lucerne flea. Insecticide rate commonly used for redlegged earth mite are generally ineffective against *Bryobia* mite.

8.5.4 Other occasional pests of faba bean

Other occasional pests of faba bean are:

Earwigs

European earwig and native earwig (*Forficulina auricularia* and *Labidura truncata* plus other species)

Mandalotus weevil

(*Mandalotus* spp.)

Onion thrips, plague thrips, & western flower thrips

(*Thrips tabaci*, *Thrips imaginis* and *Frankliniella occidenttalis*)

Photo 30: *Thrip damage on the underside of faba bean leaves.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 31: *Thrip damage on the upper side of faba bean leaves.*

Photo: Wayne Hawthorne, formerly Pulse Australia

MORE INFORMATION

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/South/Brown-Pasture-Looper

For more details on identification, see: Insects the Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/South/Looper-Caterpillar

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/Bronzed-Field-Beetle

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/False-Wireworms

For more details on identification, see Insects: the Ute Guide, https://grdc.com.au/Resources/Ute-Guides/Insects/Flies/South/Onion-Maggot

Brown pasture looper

(*Ciampa arietaria*)

Looper caterpillar

(*Chrysodiexis* spp.)

Bronze field beetle

(*Adelium brevicorne*)

False wireworm

(*Gonocephalum misellum*)

Onion seedling maggot

(*Delia platura*)

MORE INFORMATION

Plant Heath Australia has a fact sheet on Exotic bruchids, please see http://www.planthealthaustralia.com.au/wp-content/uploads/2014/02/Exotic-Bruchids-FS.pdf

Plant Health Australia has produced a fact sheet on Exotic leafminers, see www.planthealthaustralia.com.au/wp-content/uploads/2014/02/Exotic-leaf-miners-FS-Grains.pdf

8.6 Exotic faba bean insects – biosecurity threats

8.6.1 Exotic seed beetles/bruchids (*Coleoptera*: Family: *Chrysomelidae*, sub-family: *Bruchinae*)

Seed beetles, also known as bruchids, are a group of relatively small beetles that attack ripe or ripening seeds, especially legumes. There are over 200 species of bruchids worldwide from several genera that are important primary pests with significant economic impact to pulses.

Several pest bruchid species occur in Australia, however, very few bruchid species in Australia attack faba bean. There is potential for other exotic bruchids that do attack faba bean being introduced and establishing in Australia. The host range for these may be quite specific, while other species can attack a wide range of pulse crops. Early detection of new bruchids in faba bean may have consequences across a range of crops.

The presence of damaged seed (round holes) in stored grain is an indication of bruchids. The general form of bruchids and their association with pulses make it unlikely to be confused with other beetle pests associated with stored product. It is suggested that any bruchids found in faba bean, in the field or in storage, should be sent in for further identification. **Call the Exotic Plant Pest Hotline, 1800 084 881**.

8.6.2 Exotic leafminers (*Diptera*: family *Agromyzidae*)

The Agromyzidae are a group of small flies whose larvae feed internally on living plant tissue, often as leaf and stem miners. Key exotic Agromyzid species for faba bean include the American serpentine leafminer (*Liriomyza trifolii*) and pea leafminers (*Chromatomyia horticola*, *Liriomyza huidobrensis*).

Leaf-mining (tunnelling) is the most obvious symptom that can be seen and surveyed for in the field. Leaf mining damage caused by exotic Agromyzidae species can be confused with native leaf miner species and moth larvae. Any suspect mining should be sent in for identification. **Call the Exotic Plant Pest Hotline, 1800 084 881**.

Control of *Liriomyza* is difficult. Economic impacts could be highly significant in most crops and across most cropping regions if eradication is not achieved.

MORE INFORMATION

See Beneficial Insects:The Back Pocket Guide for Southern and Western Regions https://grdc.com.au/resources-and-publications/all-publications/publications/2013/05/grdc-bpg-cropweevils

8.7 Beneficial species

All pest populations are regulated to some degree by the direct effects of other living organisms. Beneficial organisms include a range of wasps, flies, bugs, mites, lacewings, beetles and spiders that can reduce insect pest populations through predation and parasitisation. Virus and fungal diseases also provide control.

A wide range of beneficial organisms can be grouped into three categories:

- *Parasites* – organisms that feed on or in the body of another host. Most eventually kill their host and are free living as an adult (parasitoids) for example, aphid wasp parasites.
- *Predators* – mainly free-living insects that consume a large number of prey during their lifetime for example, shield bugs, lacewings, hoverflies, spiders, predatory mites and predatory beetles.
- *Insect diseases* – include bacterial, fungal and viral infections of insects.

Inappropriate use of an insecticide that reduces the number of beneficial species can result in a more rapid build-up of insect populations and reliance on further use of insecticide.

Integrated pest management (IPM) in its simplest form is a management strategy in which a variety of biological, chemical and cultural control practices are combined to provide stable, long-term pest control.[118]

Photo 32: *A pea aphid being consumed by the seven-spotted lady beetle (Coccinella septempunctata).*

Photo: Brad Stokes, University of Idaho

A list of some beneficial organisms is provided below.

Beetles

- Carabid beetle (*Notonomous gravis*), https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Carabid-Beetles
- Transverse ladybird and common ladybird, https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Predatory-Ladybird-Beetles-Transverse-Ladybird-Common-Spotted-Ladybird-Minute-TwoSpotted-Ladybird-And-Others

Bugs

- Damsel bug (Family: *Nabidae*), https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Damsel-Bug
- Assassin bug, https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Assassin-Bugs
- Glossy shield bug, https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Glossy-Shield-Bug
- Spined predatory shield bug (*Oechalia schellenbergii*), https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Spined-Predatory-Shield-Bug

Flies

- Hoverfly (Family: *Syrphidae*)
- Tachinid fly, https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Tachinid-Calliphorid-and-Sarcophagid-Flies

Lacewings

- Green lacewing (Family: *Chrysopidae*), https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Green-Lacewings
- Brown lacewing (Family: Hemerobiidae), https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Brown-Lacewings

Mites

- Pasture snout mite (*Bdellodes lapidaria*), https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Snout-Mites-Pasture-Snout-Mite-And-Spiny-Snout-Mite
- French anystis mite, https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/French-Anystis-Mite

MORE INFORMATION

For more details and photographs of beneficial organisms in insect management see: CESAR website, http://www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/

GRDC Insect ID: the Ute Guide, https://grdc.com.au/resources-and-publications/app

Faba beans: the Ute Guide, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

118 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

Caterpillar wasps

- Orange caterpillar parasite wasp, https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Orange-Caterpillar-Parasite
- Two-toned caterpillar wasp
- Banded caterpillar wasp, https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/North/Banded-Caterpillar-Parasite
- *Telenomus* wasp and *Trichogramma* wasp, https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Caterpillar-Egg-Parasites
- Orchid dupe, https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Orchid-Dupe
- Braconid wasp (*Microplitis demolitor*), https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/North/Microplitis-demolitor

Aphid wasps

- *Aphidius ervi* and *Trioxys complanatus* wasps, https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Aphid-Parasites

Spiders

Wolf spider (Family: *Lycosidae*)

Jumping spider (Family: *Salticidae*)

Insect diseases – viral & fungal

Bacillus thuringiensis (*Bt*)

Nuclear polyhedrosis virus (NPV)

8.8 Registered insecticides, commonly used

Table 7: Registered insecticides commonly used in pulse crops in Australia.[119] Adhere to registered rates and withholding periods.

Active ingredient Example trade name	**Redlegged earth mite**	**Blue oat mite**	**Lucerne flea**	**Bluegreen aphid**	**Native budworm**	**Brown pasture looper**	**Cutworm**	**Locust**	**Withholding period (days)**	
									Harvest	**Grazing**
alphacypermethrin DOMINEX®	NSW ACT Vic TAS SA WA	NSW ACT Vic TAS SA WA			NSW ACT Vic SA WA		NSW ACT Vic TAS SA WA	P	21	35
beta-cyfluthrin BULLDOCK®	All states				Qld NSW Vic SA WA				14	7
chlorpyrifos LORSBAN®	All states	NSW								2
cypermethrin SCUD®, SONIC®					NSW Vic TAS SA WA			P	21	35
deltamethrin DECIS® OPTIONS				All States			NSW WA		7	
dimethoate Various	Vic Tas SA		WA							14
endosulfan* Various	All states	NSW WA							Nil	49 days
esfenvalerate SUMI-ALPHA FLEX®	All states	All states			All states				14	2
gamma-cyhalothrin TROJAN®	NSW Vic Tas SA WA				Sth NSW, WA, Vic, SA			P	7	7
lambda-cyhalothrin KARATE® ZEON	NSW Vic Tas SA WA				NSW Vic SA WA			P	7	7
Maldison FYFANON®	All states									
omethoate LE-MAT®	NSW Vic Tas SA WA	Qld NSW								1
metarhizium anisopliae GREEN GUARD®								All states		

Source: Pulse Australia (2016) and updated by GRDC (2017)

(shaded cell) Registered for use in the indicated states.

* Endosulfan not permitted post-emergence in pulses.
P = Permit only so check if still applicable and which crops are listed on the permit.

119 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

8.8.1 Comments on insecticides

Registrations and use details may differ between states. Always read the label for specific details and information on registration status and insects controlled. Check the APVMA website for labels (http://apvma.gov.au/).

Table 8: Comments on insecticides.

Insecticide & trade name	Remarks
alphacypermethrin DOMINEX®	Best results if sprayed at egg hatching of native budworm. Apply when damaging numbers first appear in the crop. Use higher rate if native budworm larvae are >10 mm. Use higher rate if native budworm are >20 mm for Fastac®. Can be used post-emergence for redlegged earth mite control in field pea.
beta-cyfluthrin BULLDOCK®	Use higher rate if native budworm larvae are >10 mm. Bulldock® Duo can also be mixed with mineral oil and applied at ULV rates.
chlorpyrifos LORSBAN®	Active against a wide range of insect pests. Not systemic. Rainfast within 4 hours. Toxic to fish.
cypermethrin SCUD®, SONIC®	Use higher rate if native budworm larvae are >10 mm. Control of larvae >20 mm is unreliable at this rate.
deltamethrin DECIS® OPTIONS	Apply as soon as infestation occurs. Use lower rates only when infestation is low and most larvae are <5 mm long. Longer larvae not readily controlled. Use higher rate for pea weevil under high infestation and for chickpea, faba bean and lentil.
dimethoate Various	Apply to the emerged crop, not to bare ground. Has contact and systemic activity. Rain within 24 hours may reduce effectiveness. Can also be used as a seed treatment at 150 ml in 1 L water/ 100 kg seed, but not mixed with rhizobia.
endosulfan* Various	For redlegged earth mite use 0.5 L/ha for broad area spraying of bare earth after sowing. Use 1 .0 L/ha for perimeter spray to prevent reinvasion. Do not use post-emergence on any crop.
esfenvalerate SUMI-ALPHA FLEX®	Use 130 ml/ha for native budworm larvae <10 mm, 200 ml/ha if 10–20 mm long and 330 ml/ha for >20 mm long.
gamma-cyhalothrin TROJAN®	For native budworm use higher rate if larvae are >10 mm or the crop is dense. Rainfast within 30 minutes. S5 poison schedule.
lambda-cyhalothrin KARATE® ZEON	For control of native budworm apply at hatching or soon after when the larvae are small. Use the higher rate if larvae are >10 mm or if the crop is dense.
omethoate LE-MAT®	Spray crop 2–5 weeks after opening rains and before serious damage occurs. Rainfast in 1 hour. Application in spring (according to Timerite®) will reduce redlegged earth mite the following year.
metarhizium anisopliae GREEN GUARD®	Biological control agent. Apply in 75–225 L/ha of water for best results when locusts and grasshoppers are at the nymph stage. Do not apply in gusty conditions with winds >8 m/sec or rainfall imminent in next 6 hours. Surfactant and oil required.

* Endosulfan not permitted post-emergence in pulses.

Source: Pulse Australia (2016) and updated by GRDC (2017)

Diseases

Key points

- Faba bean need good disease management to protect yield and ensure a quality, blemish-free seed product.
- Key diseases in the southern region are chocolate spot, Ascochyta blight and Cercospora leaf spot. Rust can be a problem in prolonged wet seasons.
- Avoid growing susceptible varieties and practice sound agronomic management to minimise the risk of disease. Use a 4-year break between bean crops and sow at least 500 m from other bean crops or bean stubble.
- Crop monitoring for disease is essential. There are three critical periods for fungicide application. Accurately identify disease to choose the appropriate fungicide.
- Disease pathogens can mutate and overcome resistance. Monitor all varieties regardless of resistance rating.

Disease management is essential for successful faba bean production. Failure to manage diseases effectively can lead to substantial yield loss and damage to quality reducing the value of the grain.

Faba bean requires a high level of disease management to keep the product blemish-free, particularly during the podding stage.[1] The high market value of a quality product in the human food market means the effort will be rewarded.

Bad experience with disease epidemics in the past and the effort required to manage disease has led some growers to discontinue growing beans. However, crops are now more robust as newer varieties have better disease resistance and there have been improvements in disease management packages (i.e. fungicide and canopy management).

The major fungal diseases affecting faba bean in the southern region are chocolate spot, Ascochyta blight and Cercospora leaf spot.[2] Rust can become an issue in prolonged wet seasons.

These diseases can be effectively controlled to prevent them from causing yield loss. Management decisions and seasonal conditions play a significant role in disease outbreaks and grain yield. Bean growers need to take an integrated approach to disease management in most years to produce a profitable crop.

Growing resistant varieties in an integrated disease management program remains the most effective method of control. Breeding new varieties is a major focus of the Australian pulse breeding program.[3] The breeding program has identified good sources of resistance to Ascochyta blight, rust, Cercospora leaf spot and Bean leaf roll virus (BLRV). Many breeding lines have resistance to at least two and often three of these diseases.

Dramatically improving varietal resistance to chocolate spot remains problematic due to complicated genetics. Resistance sources exist mainly in varieties that are poorly adapted to Australia, and there is the difficulty of screening in the field.

9.1 Impact and cost of diseases

A 2012 GRDC study reported that disease costs the Australian pulse industry an average of $74 million per year or 14.8% of the gross value of pulse production.[4] Losses would be far higher without the current range of controls, which include the use of resistant varieties, rotation, paddock management and the use of fungicides.

In the Australian faba bean industry, disease causes an estimated current average annual loss of $4.4 million, or $31.43 per hectare. This is 10.6% of the average annual value of the crop. Most faba bean crops (97%) are treated with foliar fungicides at an average cost of $55/ha per year.

In the southern region the most important bean diseases with a yearly incidence of 25% or more were Ascochyta blight, Cercospora leaf spot, chocolate spot, Botrytis grey mould and Cucumber mosaic virus (CMV). These diseases (except for CMV) are also the ones that occur most widely in southern Australia.

In 2010 the value of disease resistance was emphasised when above-average rainfall resulted in widespread disease epidemics:

- Chocolate spot occurred throughout the southern and northern regions.
- There was potential for severe seed staining due to Ascochyta blight in the southern region.

1 K Lindbeck (2014) Faba bean and chickpea disease management. GRDC Update Papers, 31 July 2014, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2014/07/faba-bean-and-chickpea-disease-management

2 Pulse Australia (2016) Faba bean: Integrated disease management. Pulse Australia website, http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/idm-strategies

3 J Paull (2011) UA00097 Australian Faba Bean Breeding Program 2007-2011. Project Final Report, University of Adelaide, https://grdc.com.au/research/reports/report?id=1485

4 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

MORE INFORMATION

Pulse Australia has information on Faba bean IDM, please see http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/idm-strategies

- Cercospora leaf spot was also widespread in the southern region, although it was not as damaging as other diseases.
- Rust was widespread in the northern region, and also present in the southern region.

9.2 Integrated pest management (IPM) strategies

Disease management in pulses is critical, and relies on an integrated management approach to variety choice, crop hygiene and strategic use of fungicides.[5] The initial source of the disease can be the seed, the soil, the pulse stubble or self-sown seedlings, or in some cases other plant species. Once the disease is present, the source is then from within the crop itself.

A plant disease may be devastating at certain times and yet, under other conditions, it may have little impact. The interaction of host, pathogen and environment are all critical in disease development and can be represented by the two disease triangles (Figures 1 and 2).

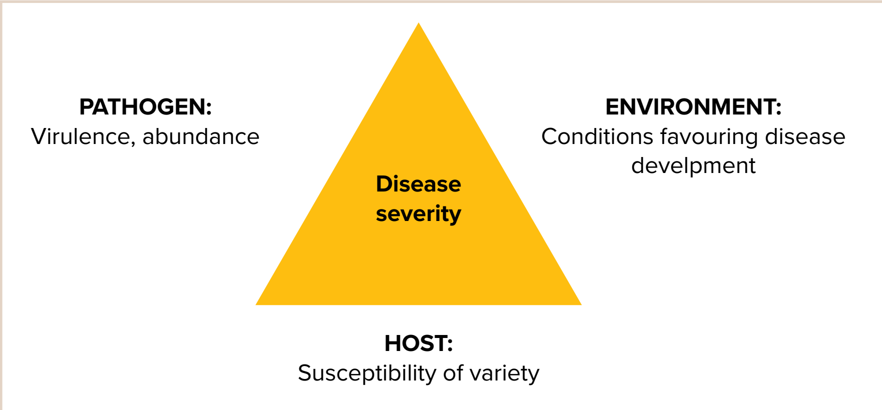

Figure 1: *Fungal disease triangle.*

Source: Agrios (1988)[6]

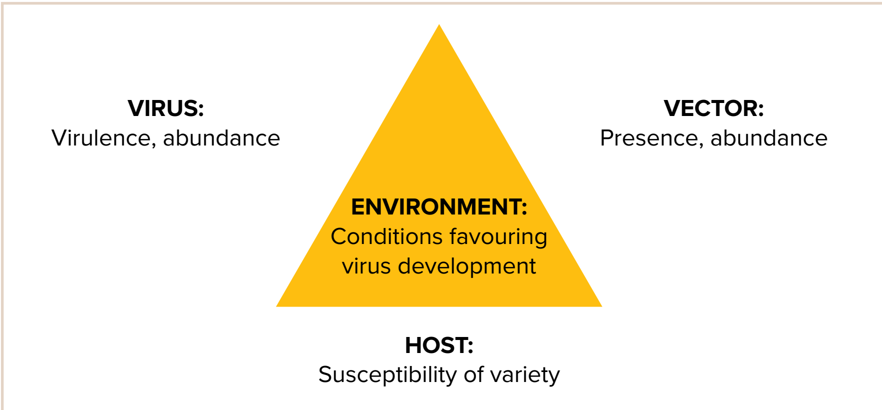

Figure 2: *Viral (and some bacterial) disease triangle.*

Source: Jones & Barbetti (2012)

Diseases such as Ascochyta blight and chocolate spot can cause total crop failures very quickly, whereas Botrytis grey mould and root-lesion nematodes can reduce vigour throughout the season, making it hard to judge their true impact on crop performance and yield.

5 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

6 GN Agrios (1988) Plant Pathology (3rd edition). Academic Press, New York.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Where possible choose a pulse variety that is resistant to the most important diseases in your area. Choose a paddock with low disease risk based on rotation and proximity to other pulse crops. Strategic fungicide application is necessary to minimise disease impact. In high-risk situations, fungicide disease control strategies alone may not be sufficient, particularly if susceptible varieties are grown.

The key aspects to managing diseases in pulses are detailed Sections 9.3 to 9.10. In summary:[7]

- **Varietal resistance** – select a resistant variety.
- **Distance** – separate, by at least 500 m, from stubble of the same pulse from the previous year. This reduces infection for some diseases.
- **Rotation** – aim for at least a 4-year rotation between planting the same pulse crop. A high frequency of crops like lentil, faba bean, vetch, field pea, chickpea, lathyrus or clover pasture puts pulses at greater risk of multi-host diseases such as Phoma, Sclerotinia and Botrytis grey mould, and canola can increase the risk of Sclerotinia.
- **Hygiene** – practice hygiene by reducing last year's pulse stubble if erosion is not a risk and removing self-sown pulses before the new crop emerges.
- **Clean seed** – sow seed from crops with no disease or a low level, especially at podding. Avoid using seed where there was a known disease infection, particularly for susceptible varieties. Have seed tested for disease.
- **Fungicide seed dressing** – in high-risk situations seed dressings provide partial early suppression of diseases like Botrytis grey mould, Phoma and Ascochyta blight. They are not effective against viruses and bacterial diseases.
- **Sowing date** – do not sow too early to avoid excessive vegetative growth and early canopy closure. Early crop emergence may coincide with greater inoculum pressure from old crop residues nearby. Aim for the optimum sowing window for the pulse variety and your district.
- **Sowing rate** – aim for the optimum plant population (depending on region, sowing time, crop type, variety), as denser canopies can lead to greater disease incidence. Adjust the seeding rate according to seed size and germination.
- **Sowing depth** – sowing deeper than normal any seed lot that is infected with disease will help reduce the emergence of infected seedlings. The seeding rate must be adjusted upwards to account for the potential of a lower emergence and establishment percentage.
- **Foliar fungicide applications** – susceptible varieties require a more intense fungicide program. Success depends on timing, weather conditions that follow and the susceptibility of the variety grown. Monitoring for early detection and correct disease identification is essential. Correct fungicide choice is also critical.
- **Mechanical damage** – physical damage from excessive traffic, wind erosion, frost, hail, post-emergent rolling or herbicide damage can increase the spread of foliar disease in pulses.
- **Control aphids** – integrated pest management to reduce the incidence of aphids can reduce the spread of viruses. Spraying insecticide may assist, but is not always effective or and rarely economic. Usually the virus spread has occurred by the time the aphids are detected.
- **Harvest** – harvest early to minimise disease infection on seed. Consider windrowing or desiccation as a tool to enable earlier harvesting.

7 Pulse Australia (2016) Faba bean: Integrated disease management, Pulse Australia website, http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/idm-strategies

MORE INFORMATION

GRDC Crop Variety Guides, https://grdc.com.au/resources-and-publications/all-publications/crop-variety-guides

The Crop Disease Au app is available at http://www.nvtonline.com.au/interactive-tools/apps/

9.3 Select a resistant variety

Selecting a resistant variety is the most effective method of disease control.[8] Other management practices are not always effective and can be expensive and highly dependent on seasonal conditions. Resistant varieties reduce the reliance on foliar fungicides.

The variety resistance ratings are defined as follows:

- Resistant (R) varieties – no economic yield loss is expected under average conditions. Control measures are unlikely to be profitable. Resistant varieties are not immune when conditions are conducive to disease.
- Moderately resistant (MR) varieties are expected to sustain low to moderate yield loss and control measures are likely to be cost effective.
- Moderately resistant to moderately susceptible (MR-MS) varieties are expected to sustain moderate to high losses and control measures are necessary to ensure a profitable crop.
- Moderately susceptible (MS) or worse varieties (susceptible (S), very susceptible (VS)) will sustain very high to total yield loss and control measures are essential to produce a harvestable crop.

No variety has resistance to all diseases of faba bean. Therefore, it is important to select the correct fungicide and application timing to best manage the target disease in the chosen variety. Control strategies vary according to the variety being grown.

In a wet season, such as 2010, when repeated cycles of infection occurred, even MR varieties can have yield reducing levels of disease.

Resistance can breakdown when there are disease incursions from overseas or there is high population pressure through frequent planting of varieties all relying on the same resistance gene.[9] For example, a new pathotype of Ascochyta blight with virulence against many previously resistant varieties was detected in the Mid North of South Australia in 2013 and has now spread to other areas.

The disease ratings in Table 1 are from early 2016. Always check the updated disease ratings each year in the current crop variety guides (see More Information) for each state or in the NVT Crop Disease Au app.

8 FL Stoddard, AH Nicholas, D Rubiales, J Thomas, AM Villegas-Fernandez (2010) Integrated pest management in faba bean. Field Crops Research, 115, 308–318 https://www.researchgate.net/publication/229612261_Integrated_pest_management_in_faba_bean

9 J Davidson, R Kimber, C Walela, L McMurray, K Hobson, J Brand and J Paull (2016) Pulse diseases in 2015. GRDC Updates Paper, 9 February 2016, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/pulse-diseases-in-2015

Table 1: Faba bean disease ratings.

Variety	Ascochyta blight Pathotype 1 (P1)	Ascochyta blight Pathotype 2 (P2)	Chocolate spot	Cercospora	Rust	PSbMV seed staining	*Pratylenchus thornei*
FABA BEAN							
Farah⁽ᵖ⁾	RMR	S	S	S	S	S	MS
Fiesta VF	MR-MS	S	S	S	S	S	MS
Nura⁽ᵖ⁾	RMR	RMR	MS	S	MS	VS	MS
PBA Rana⁽ᵖ⁾	R	MR-MS	MS	S	MS	MR	MS
PBA Samira⁽ᵖ⁾	R	RMR	MR-MS	S	MS	S	MR-MS
PBA Zahra⁽ᵖ⁾	R	MR-MS	MR-MS	S	MS	S	MS
BROADBEAN							
Aquadulce	MS	MS	MS	S	MS	S	-
PBA Kareema⁽ᵖ⁾	RMR	MR-MS	MS	S	MR-MS	S	-

Disease ratings from Pulse Breeding Australia.

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

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

Source: Victorian Winter Crop Summary (2017), Department of Economic Development, Jobs, Transport and Resources, Victoria, https://www.grdc.com.au/NVT-Victorian-Winter-Crop-Summary

9.4 Paddock selection

Sow beans into standing stubble of previous cereal stubble to protect against rain-splash of soil-borne spores, protect against erosion and reduce attractiveness of the crop to aphids that can spread viruses.

Rotational crops and weeds

Allow 4 years between growing bean crops in the same paddock and at least 500 m (preferably more) distance from previous year's bean crop to minimise the inoculum for chocolate spot, Ascochyta blight, rust and Cercospora leaf spot.

Some diseases have potential for cross infection across more than one pulse crop (Table 2).

Table 2: Diseases occurring on pulses with potential for cross-infection

	Chickpea	Faba bean	Lentil	Lupin	Peas	Vetch
Botrytis grey mould (BGM)						
*Botrytis cinerea**	★★	★★	★★	★	★★	★★
Chocolate spot						
Botrytis fabae	★	★★	★★			★★
Cercospora leaf spot						
Cercospora zonta		★★				
Sclerotinia						
Sclerotinia sclerotiorium	★★		★★	★★	★★	
Sclerotinia trifoliorium	★★	★★		★★		
Bacterial blight						
Pseudomonas andropogonis	★					
Pseudomonas syringae pvv *syringae*		★★	★		★★	

	Chickpea	Faba bean	Lentil	Lupin	Peas	Vetch
Pseudomonas syringae pvv pisi					★★	
Ascochyta blight						
Ascochyta fabae		★★				★
Ascochyta lentis			★★			
Ascochyta pisi	★				★	★
Ascochyta rabiei	★★					
Phoma blight						
Phoma medicaginis var *pinodella*	★		★	★	★★	★★
Black spot (see also Phoma & Ascochyta)						
Mycosphaerella pinodes	★★	★	★		★★	★
Anthracnose						
Colletotrichum gloeosporoides				★★		
Brown leaf spot						
Pleiochaeta setosa				★★		
Grey leaf spot						
Stemphylium botryosum	★		★★	★★		
Downy mildew						
Peronospora viciae					★★	★
Powdery Mildew						
Erysiphe pisi					★★	
Septoria						
Septoria pisi					★★	
Phomopsis						
Phomopsis leptostromiformis				★★		
Rust						
*Uromyces viciae-fabae***		★★			★	★★
Root-lesion nematode						
Pratylenchus neglectus	★					
Pratylenchus thornei	★★					★★
Stem nematode						
Ditylenchus dipsaci	★	★★			★★	★
Viruses						
Bean yellow mosaic virus		★		★★		
Cucumber mosaic virus	★★	★	★★	★★		
Luteo viruses complex (e.g. BLRV & BWYV)***	★★	★★	★★	★	★★	★★
Pea seed-borne mosaic virus (PSbMV)‡		★★			★★	
Alfalfa mosaic virus	★★	★	★★			★
Wilt						
*Fusarium oxysporum***				★★	★★	

	Chickpea	Faba bean	Lentil	Lupin	Peas	Vetch
Root rots						
Aphanomyces root rot (*Aphanomyces euteiches*)§		★★			★	
Fusarium	★	★	★	★	★	★
Macrophomina	★				★★	
Phytophthora medicaginis	★★					
Pleiochaeta setosa			★★			
*Pythium**	★		★	★	★	
Rhizoctonia	★	★★	★★	★★	★★	★★
Sclerotinia¥	★		★	★	★	

★ This disease occurs in this crop, but does not caused major damage.

★★ This disease has caused major damage to this crop.

* Pythium and Botrytis grey mould are worse (★★★) in white peas than dun peas (★★)

** Strain differences between crops.

*** Luteovirus complex on pulse crops consists of Bean leaf roll virus (BLRV), Beet western yellows virus (BWYV, syn. Turnip yellows virus, TuYV), Soybean dwarf virus (SbDV) and Phasey bean virus. Each of these viruses can be found on each of the pulse crops, but their impact varies between host species and regions.

± PSbMV causes seed markings on faba bean that can have a serious impact on price. However, as Australian PSbMV strains are only seed-borne in field pea, faba bean infections only occur if the crop is grown in the vicinity of PSbMV infected field pea crops.

§ Aphanomyces root rot has been identified as a cause of severe root rot on faba bean in commercial fields in NSW. So far it is not reported as a problem in Australian field pea, but it is considered a very serious field pea disease overseas.

¥ Sclerotinia (root rot) is worse (★★) in kabuli than desi (★).

Source: Pulse Australia (2016)[10]

Do not sow adjacent to lentil and vetch crops or stubble as these may harbour *Botrytis fabae*, the primary cause of chocolate spot in faba bean. If this is not possible manage as for high disease risk situations.

It is recommended to avoid a high frequency of other pulse crops, lathyrus or clover pasture as these can increase the risk of multi-host diseases such as Phoma, Sclerotinia and Botrytis grey mould.

The Botrytis grey mould pathogen (*Botrytis cinerea*) has a wide host range including lentil and weeds such as *Euphorbia* spp., groundsel and emu-foot. *Phoma medicaginis* var. *pinodella* can be hosted by lucerne, clover, field pea, lupin and chickpea, as well as *Phaseolus* spp.

Sclerotinia can be hosted by canola and most weed species.

Growers who plan to sow more than one variety of faba bean should ensure there is at least 500 m between different varieties. Faba bean cross-pollinate, increasing the risk of disease resistance breaking down and producing mixed seed types that are difficult to market.

Some of the viruses affecting faba and broad bean also have wide host ranges. Weeds, particularly perennial legumes, host viruses and their aphid and leafhopper vectors (e.g. Cucumber mosaic virus).

It is not recommended to grow a pulse again after a failed pulse crop because disease pressure is increased, herbicide residues can be limiting, and there is the potential for cross-contamination of seed reducing its market value.[11]

Herbicide interaction

Herbicide residues in soil and crop damage from herbicides are known to increase the risk of disease. This may be by directly damaging the plant making it easier for the disease to enter, or by reducing the overall health of the plant making it more vulnerable to disease.

10 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

11 Pulse Australia (2016) Residual herbicides and weed control. Pulse Australia website, http://pulseaus.com.au/growing-pulses/publications/residual-herbicides

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Ensure the maximum plant-back period and rainfall conditions for herbicides are adhered to. Triazine, clopyralid, imidazolinone and sulfonylurea herbicides are known to predispose plants to disease.

When diagnosing damage in the field it can be difficult to determine whether the cause of damage is disease or herbicide or a combination of both.

9.5 Good hygiene

Diseases can carry over on stubble, seed or soil (Table 3).

Table 3: Carryover of major faba bean diseases. The relative importance as sources of infection is indicated by the number of stars with three starts being the most important.

Disease	Stubble	Seed	Soil
Ascochyta blight	★★★	★★	★
Chocolate spot (Botrytis)	★★★	★	★
Cercospora	★★	—	★★★
Rust	★	—	—

Source: Pulse Australia (2016)[12]

Chocolate spot and Ascochyta blight can carry over from one season to the next on infected faba bean seed. Purchase disease-free seed or retain seed from the healthiest crop to avoid carryover on infected seed.

Control volunteer beans, vetch and lentil during the summer–autumn season and in fallows to avoid carryover of inoculum of chocolate spot, Ascochyta blight and rust pathogens. Some broadleaf weeds are alternative hosts of one or more of the viruses that affect beans, and of *Sclerotinia* species, and should be controlled prior to planting and during crop growth.

Burn or bury last year's pulse stubble if erosion is not a risk. Grazing over summer may reduce stubble, but be aware that stock can carry infected stubble between paddocks. Adhere to grazing restrictions on stubble from crops treated with fungicides.

Infected stubble may also be carried by wind, water (particularly flooding) or machinery at harvest.

Where practical, clean all machinery, transport equipment and storage bins thoroughly with compressed air before moving to the next paddock. Spray rigs, should also be cleaned to reduce the risk of disease transmission particularly if contractors are used.

Paddock inspections should be carried out using clothing suitable to the task and footwear should ideally be disinfected prior to entering a crop. This is an important point for agronomists who may move through several crops in one day.

Floodwaters may transport disease agents. Floods during January 2011 would have moved faba bean stubble infested with Ascochyta blight, as well as soil and weeds harbouring the pathogen.

12 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

9.6 Use clean seed

Use only high-quality seed with good purity, germination and vigour.

Seed-borne inoculum is usually less important than stubble-borne inoculum, except for Ascochyta blight, which is carried under the seed coat. It is not the major source of infection for chocolate spot, Cercospora leaf spot and rust, but can be a factor. Infected seed is important in the establishment of diseases in new faba-bean growing regions.

Avoid using seed with greater than 5% Ascochyta blight infection or 10% chocolate spot, and where possible use seed with nil infection. It is more important to avoid seed with disease infection in susceptible varieties. Source seed from a paddock where diseases, particularly those which affect pods, were not detected. Where possible, have seed tested for disease status.

9.6.1 Seed dressings

Fungicide seed dressings are registered for faba and broad bean but not often used (Table 4).

Table 4: Seed dressings registered for use with faba and broad bean.

Active ingredient	Thiram + thiabendazole
Example trade name	**P-Pickel® T**
Ascochyta blight	NR
Botrytis grey mould	NR
Damping-off	Registered
Fusarium	Registered
Phoma root rot	NR
Phytopthora root rot	NR
Pythium	Registered
Jurisdiction	All states

Registered = registered product label claim, NR = not registered for use in this crop
Refer to the current product label for complete 'Direction for Use' prior to application.

Prior to the use of any crop protection product, ensure that it is currently registered or that a current permit exists for its use in faba and broad bean.

Source: Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia

Thiabendazole plus thiram (e.g. P-Pickel T®) is registered in faba bean for seedling root rots (*Fusarium* spp. and *Pythium* spp.). It has some efficacy against Ascochyta blight and Botrytis grey mould (BGM). Seed dressings are not effective against viruses and bacterial diseases.

Seed dressings only protect the emerging seedling from seed-borne Ascochyta and Botrytis. They will not protect the emerged seedling from raindrop-splashed Ascochyta or wind-borne Botrytis.

The presence of rhizobium for effective nodulation and healthy plant growth is usually more important than a fungicidal seed treatment. Do not mix rhizobia inoculant with fungicide seed dressings. Apply the fungicide seed dressing first and then apply the inoculants as a second operation sometime later after the fungicide has dried and immediately prior to seeding. Granular inoculant or fluid injection of rhizobia avoids contact between rhizobia and any seed treatment.

13 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

9.7 Sowing

9.7.1 Sowing date

Aim for the optimum sowing window for the pulse variety and your district. The recommended sowing times are in Section 4 Planting.

Avoid sowing too early as early crop emergence may coincide with greater inoculum pressure from old crop residues nearby. Early sowing may also lead to excessive vegetative growth and early canopy closure, providing a more humid environment ideal for infection.

Later sowing reduces disease risk, but can result in lower yields due to the risk of dry conditions and high temperatures at flowering to pod-fill. Yield can be reduced by 150–250 kg/ha for every week past the optimum sowing time.

9.7.2 Sowing rate and row spacing

Higher plant populations can exacerbate foliar disease development by encouraging a dense canopy and a more humid environment.

Reduced humidity can be achieved by reducing the sowing rate, increasing the row spacing and by achieving good weed control. Avoid sowing headlands.

Optimum plant populations for most faba beans (e.g. 50–70 g/100 seeds) can range from 20–35 plants/m^2.

For the medium to larger sized faba beans and for small broad bean seed (e.g. 85–110 g/100 seeds), optimum plant populations can vary from 15–25 plants/m^2.

For larger broad bean seed (e.g. 110–160 g/100 seeds), optimum plant populations can vary from 8–12 plants/m^2.

Seeding rates resulting in lower than recommended plant populations can reduce disease but can also reduce potential crop yield.

If seed with possible disease infection needs to be used sow deeper than normal to help reduce the emergence of infected seedlings. The seeding rate must be adjusted upwards to account for the potential of a lower emergence and establishment percentage.

Generally, faba bean row spacing varies from 15 to 30 cm, but up to 55 cm with broad bean. Wide row spacings (25–60 cm) can assist with the control of chocolate spot by delaying canopy closure and reducing the humidity between rows.

Some growers are now using row spacing of 75–100 cm, or using paired rows, to improve pod-set, delay canopy closure and hopefully minimise disease. Wide rows allow herbicides to be sprayed between rows with hooded shields or targeted row spraying with fungicides to reduce the amount of product applied. However, wide rows can also lead to crop lodging, which can exacerbate disease in the later stages.

To avoid potential ‘hot spots’ for disease, consider ‘tram-lining’ and controlled traffic. Physical damage to the crop from machinery travelling over the paddock can be a major cause of disease outbreaks.

Some growers believe that sowing in wide rows in a north–south direction improves pod-set and disease control.

9.8 Risk assessment

Risk assessment is about assessing the known risks (e.g. paddock history), deciding what can be changed and weighing these up against the unknowns (e.g. seasonal conditions).[14] While the overall aim is to reduce the level of risk each grower will have a different level of tolerance to risk.

There are three steps in risk assessment.

1. Identify factors that determine risk

Pathogen: Exotic *v.* endemic; biotypes, pathogenicity, survival and transmission, amenable to chemical management.

Host: Host range; varietal reactions, vulnerability, does susceptibility change with growth stage?

Environment: Weather dependency, interactions with nutrition, herbicides, other diseases, agronomic factors, e.g. planting depth, row spacing, no-tillage, soil conditions.

Risk management: Access to components of management plan; ease of implementing plan; how many options; cost of implementation.

2. Assess level of factors

Pathogen: Level of inoculum, dirty seed, aggressiveness of isolate, weed hosts prevalent in paddock or nearby, paddock history.

Host: How susceptible, nutritional status, frost susceptibility, herbicide susceptibility.

Environment: Length of season; likelihood of rain, drought, waterlogging, irrigation; availability of spray gear; paddock characteristics, herbicide history.

Risk management: Has it not yet been considered; a plan is being developed; or is a plan in place?

3. What risk level is acceptable?

High: Grower is prepared to accept substantial yield loss as potential returns are high and financial situation sound; crop failure will not impact on rotation or other components of the farming system.

Low: Grower needs cash flow and cannot afford to spend much or lose the crop; failure impacts seriously on farming system.

9.9 Symptom sorter

This symptom sorter (Table 5) can be used to help diagnose diseases from other crop damage causes starting from the symptom description.

14 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

Table 5: Faba bean symptom sorter.

Description	Crop effect	Plant symptoms	Disorder
Scattered plants	Wilting	Premature death	Sclerotinia rot
	Yellow/pale green	Leaves distorted	Mosaic viruses
	Stunted	Premature death	Yellowing viruses
Patches	Poor emergence	Plants chewed	Mouse damage
			Snails
	Brown/grey	Stem & leaf spotting	Redlegged earth mite
			Chocolate spot
	Yellow/red	Stunted	Root rots
			Dodder
		Premature death	Root & crown rot
	Pale green	Leaf & pod spotting	Thrips
	Stunted	Leaves/stem distorted	Stem nematode
			Mites (seedlings)
	Wilting	Leaves distorted	Cow pea aphids
	Physically damaged	Stems, leaves & pods	Mouse damage
			Bird/ hare damage
Highly alkaline soil	Yellowing	Young leaves yellow	Iron deficiency
		Tip death	Manganese deficiency
	Patches	Plants chewed	Snails
	Stunted	Black leaf edges	Group B herbicide damage
Acidic soil	Yellow/red	Stunted	Nodulation failure
Low-lying areas	Grey	Black leaf edges	Frost
	Yellow/red	Premature death	Waterlogging
General	Poor emergence	Stunted	Seed sown too deep
		Tip death	Triazine herbicide
	Stunted	Young leaves yellow	Group F herbicide damage
		Leaf spotting	Zinc deficiency
		Leaves distorted	Clopyralid herbicide damage
	Pale green	Leaves distorted	Group M damage
			Group I herbicide damage
		Leaf spotting	Downy mildew
	Yellow/red	Tip death	Boron toxicity
	Grey/brown	Leaf spotting	Ascochyta blight
			Chocolate spot
			Rust
			Cercospera
			Alternaria
			Hail
	Physically damaged	Leaf, stem & pods damaged	Triazine herbicide
	None obvious	Pods chewed	Native budworm
		Pod spotting	Oedemas

Source: Faba beans: The Ute Guide (2009) Yeatman *et al*[15]

15 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

9.10 Crop monitoring

The four main diseases where monitoring is necessary are chocolate spot, Ascochyta blight, Cercospora leaf spot and rust.[16] Monitoring for these diseases also provides the opportunity to look for other diseases, weeds or plant disorders. To be effective, crop monitoring needs to include a range of locations in the paddock, preferably following a 'V' or 'W' pattern.

9.10.1 Ascochyta blight

The initial symptoms will be lesions on the leaves and stems of young plants. A distinguishing feature is fungal fruiting structures (small black dots) visible within the centre of lesions.

Monitoring should commence 2–3 weeks after emergence, or 10–14 days after a rain event. This allows time for disease expression after an infection event, such as transmission from infected seed or rain-splashed inoculum. Note that infected seedlings may deteriorate quickly and plant-parts above the lesion may also break-off making symptoms difficult to detect.

Timing is critical. After the initial inspection, subsequent inspections should occur every 10–14 days after a rain or heavy dew event. During dry periods, inspections can be less frequent. When monitoring, look for signs of lesions on leaves, or if severe, wilting in upper foliage or small areas of dead or dying plants, and if present examine individual affected plants for symptoms of infection. This method will allow more of the crop to be inspected than a plant-by-plant check.

9.10.2 Chocolate spot

Chocolate spot may be found at low levels in the middle of the season. It can gradually spread up the canopy and will be ready to progress rapidly when temperatures rise and leaf moisture conditions are favourable. Look for lesions low in the canopy when inspecting for Aschochyta or Cercospora.

Chocolate spot is more likely to occur in bulky crops where there is canopy closure. The critical stage for management will be just before the commencement of flowering, as temperatures begin to increase, and then regularly through the flowering and seed filling period. Lesions occur on leaves and flowers first, but can occur on stems and pods. Flower abortion and drop can occur. Protection of flowers is an important component of a fungicide strategy.

Symptoms first appear as small brown spots on leaves and flowers that rapidly develop into large, irregular-shaped lesions on leaves and decay of flowers when conditions remain favourable.

Chocolate spot requires high leaf moisture or humidity (>70%) within the crop canopy and optimal temperatures of 15°C–28°C. When humidity levels decrease or maximum daily temperatures exceed approximately 28°C, the infection levels decline sharply.

More regular crop monitoring and protection may also be required if high-risk situations exist such as:

- immediately adjacent to last year's crop;
- non-optimal paddock selection (e.g. waterlogging);
- high disease pressure experienced last year;
- a susceptible variety is planted; and
- shortened rotation.

16 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

9.10.3 Cercospora leaf spot

Cercospora leaf spot monitoring must start 2–3 weeks after emergence, or within 4–6 weeks from sowing, when seedlings are small. This is particularly so where faba beans have been grown in the paddock in recent years or there have been many bean crops grown in that paddock over time.

Protective fungicide needs to be applied before or at first signs of Cercospora leaf spot lesions, or within the monitoring timeline irrespective of symptoms when disease risk is high.

Subsequent monitoring should occur when checking for chocolate spot prior to and during flowering and podding.

9.10.4 Rust

In the southern region rust is more commonly observed later in the season when temperatures are 20°C–30°C and conditions are humid. However, it can occur earlier. The time to start monitoring for rust in southern Australia depends on sowing time and presence of infection on bean stubbles from the previous year.

With early-sown beans, infection may occur at early emergence when temperature and rainfall conditions are suitable for its spread. Later-sown beans may not get infected until spring time when temperatures, moisture conditions and humidity are high.

Monitor for rust 2–3 weeks after emergence, or 4 or 5 weeks after sowing, usually when monitoring for Cercospora leaf spot or Ascochyta blight. Protect early-sown beans against early infection when Cercospora leaf spot is also being controlled with foliar fungicide.

Also monitor for rust when monitoring for chocolate spot and late Ascochyta blight.

MORE INFORMATION

More information about free information services is available on eXtensionAUS, http://extensionaus.com.au/field-crop-diseases/pathology-electronic-newsletters/.

IN FOCUS

9.11 Free alert services for diseases

Growers can subscribe to newsletters that provide local pest updates. The services listed below are all free.

South Australian Research and Development Institute (SARDI)

- Crop Watch disease newsletter by email. Subscribe by emailing DK Communications (dvkam@iprimus.com.au)
- Follow the Crop Watch Twitter account @CropWatchSA

Agriculture Victoria

- Crop Alert disease update by email. Subscribe by emailing crop.safe@ecodev.vic.gov.au
- General grains information is available on the Twitter @VicGovGrains

Southern NSW and northern Victoria

- NSW DPI and GRDC provide the Crop Disease Bulletin for advisers in southern NSW and northern Victoria. To subscribe contact Kurt Lindbeck (kurt.lindbeck@dpi.nsw.gov.au) or Andrew Milgate (andrew.milgate@dpi.nsw.gov.au).

Australia-wide

- GrowNotes™ Alert on the latest weed, pest and disease issues in your area delivered via App, SMS, voice, email, social media or web portal (or a combination of preferred methods). Subscribe to this GRDC and Agriculture Victoria service on the GRDC website.
- For disease issues across Australia follow eXtensionAus on Twitter @AusCropDiseases or Facebook (https://www.facebook.com/AusCropDiseases/)

MORE INFORMATION

For details on permits and registrations visit:

https://portal.apvma.gov.au/permits

https://portal.apvma.gov.au/pubcris

9.12 Using fungicides

The legal considerations for using fungicides are the same as for herbicides (see Section 7.7 Using herbicides).

9.12.1 Registered products

Managing foliar disease in faba bean is all about reducing the risk of infection. Fungicides are preventative and need to be sprayed before disease is evident.[17] Fungicides protect against new infection, but do not cure existing infection. Getting the timing right is critical.

Unprotected crops can lose over 50% in yield and in severe cases the crop may drop all of its leaves. Monitoring for early detection and correct disease identification is essential.

Controlling disease with fungicides depends on:

- the timeliness of spraying;
- the weather conditions that follow; and
- the susceptibility of the variety grown.

Disease-resistant varieties require a much less intensive foliar fungicide program than susceptible varieties.

Fungicides last around 2–3 weeks. Any new growth after fungicide is applied is not protected. In periods of rapid growth and intense rain (50 mm over several days) the protection period will reduce to 7–14 days.

The need and timing of repeat fungicide sprays depends on:

- the amount of unprotected growth;
- rainfall since spraying; and
- the likelihood of a further extended rainy period.

Plan ahead to ensure that fungicides can be applied as soon as a decision is made.[18] Do not compromise a fungicide spray to wait until it can be combined with herbicide application. Ideally, spray 1–2 days before significant rain is forecast. Don't delay if rain has already started. A light rain of less than 12 mm can increase the efficacy of mancozeb.

Good leaf coverage with lots of fine droplets will maximise the benefit. Use high water rates. For ground application use 100 L water/ha, unless a different minimum rate is specified on the label. For air application use 30 L/ha. Spray early in the morning when dew is present to assist fungicide spread.

The registered fungicides are mancozeb, carbendazim, chlorothalonil, copper, metiram, procymidone.[19] Tebuconazole is available under permit (PER13752). Check pesticide permits and registrations for any changes in use patterns before using fungicides. Selecting the right fungicide for the specific disease being targeted is important.

Check the efficacy of each fungicide against each disease (Table 6). Some products are broad-spectrum and are effective against more than one disease (such as products containing carbendazim, mancozeb and chlorothalonil), while others are specific against single diseases (such as products containing procymidone).

Mancozeb, chlorothalonil, metiram and copper are protectants and have no curative action on existing infections. Newly grown, untreated foliage will not be protected.

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17 NSW DPI 2002 Foliar diseases of faba beans: management in southern NSW. Pulse point 16, NSW Department of Primary Industries, http://archive.dpi.nsw.gov.au/__data/assets/pdf_file/0017/157400/pulse-point-16.pdf

18 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016, NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

19 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016, NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

Carbendazim and procymidone have protectant and limited curative action and work best when applied before an infection event. These fungicides are not translocated from sprayed leaves so foliage that grows after spraying is not protected.

Label regulations limit carbendazim to a maximum of 2 consecutive sprays at 14 day intervals. Carbendazim is a systemic fungicide with single-site specificity so the probability of resistance developing increases with regular use. It is best to alternate carbendazim with either chlorothalonil or mancozeb. Observe the withholding period for grain prior to harvest for carbendazim (4 weeks).

Table 6: Foliar fungicides for the control of foliar diseases in faba and broad bean.

Active ingredient	Carbendazim	Procymidone	Chlorothalonil	Mancozeb	Tebuconazole	Copper
Example trade name	**Spin Flo®**	**Sumisclex®**	**Barrack®/ Unite® #**	**Dithane® Rainshield**	**Folicur®**	**Blue Shield®**
Ascochyta blight	-	-	E	R	-	-
Chocolate spot	R	R*	R	R	-	R
Cercospora leaf spot	E			R	P*	
Rust	-		R	R	P*	R
Jurisdiction	All states	Most states	All states	All states	Most states	All states

R = Registered product label claim P = permit E = has efficacy on this disease but is not registered for its control in this crop
* = not registered all states

These are the only registered chlorothalonil products that allow grazing of bean stubble and are registered in other pulses.

Refer to the current product label for complete 'Directions for Use' prior to application.

Prior to the use of any crop protection product, ensure that it is currently registered or that a current permit exists for its use in faba bean or broad bean.

Source: Southern faba & broad bean best management practices training course, (2016), Pulse Australia

The first fungicide spray must be applied as early as necessary to minimise the spread of the disease (Table 7). Additional sprays are required if the weather conditions favour the disease.

Table 7: When to spray for fungal disease control in faba bean.

Disease	Occurrence	When to spray
Ascochyta blight	First appears in cool and wet conditions before flowering	At 6–8 weeks after sowing, during seedling stage. Again during flowering if Ascochyta blight is detected and rain is likely. Again at end of flowering when pods are filling, if Ascochyta blight is detected and rain is likely. Disease is spread by rainfall.
Chocolate spot	Develops late winter (15°C–20°C) in humid (>70%) conditions, usually at flowering	During early to mid-flowering as a protective spray. An earlier spray may be required if lesions are observed prior to flowering. Additional sprays may be necessary through flowering and pod-filling if disease progresses. Disease is favoured by warm weather (15°C–20°C) and high humidity (>70% RH).
Cercospora leaf spot	On lowest leaves soon after emergence	Shortly after emergence prior to establishment of disease. Approximately 5–7 weeks after sowing
Rust	Later in the season, during warm (20°C–30°C) humid conditions.	At first sign of disease during flowering or pod-filling. Disease is favoured by warm (20°C–30°C) and humid conditions.

Source: Southern faba & broad bean best management practices training course (2016). Pulse Australia

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

MORE INFORMATION

Pulse Australia has information on crop protection products and minor use permits, please see http://www.pulseaus.com.au/growing-pulses/crop-protection-products

9.12.2 Current minor use permits (MUP)

Some products may be available under permit, with conditions attached, until enough data is generated for full registration. In other cases, a temporary permit may be granted when there is a particular seasonal issue.

Pulse Australia holds several minor use permits (MUPs) on behalf of the pulse industry and is actively involved in the pursuit of new permits and label registrations to meet industry needs.[20]

The current minor use permit for fungicides is:

- **PER13752**
  Tebuconazole for use in faba and broad bean to control Cercospora leaf spot and rust.
  Current to 30 June 2019.

Tebuconazole can be applied early in the crop cycle for Cercospora leaf spot or later in the season to control both Cercospora leaf spot and rust.[21] Apply at the first sign of disease or when conditions favour disease development. Apply a maximum of 3 times per season, 14–21 days apart.

9.12.3 The critical periods for fungicide use

Monitor crops at least once a week during all critical periods. Be prepared to spray when rain is forecast. Visible lesions will only appear several days after wet conditions.

Fungicide application during critical periods is a standard practice in high rainfall regions, irrigation districts, in a wet year or in high disease risk situations. A crop is at high risk if susceptible varieties are grown, crop rotation is short, sown adjacent to faba bean stubble, infected seed is sown or where all preventative management strategies cannot be followed.

The timing based on the resistance status of varieties is detailed in Figure 3.

20 Pulse Australia (2016) Crop protection products. Pulse Australia website, http://pulseaus.com.au/growing-pulses/crop-protection-products

21 C Benjamin (2013) New faba bean rust option. GRDC GroundCover™, Issue 106, September–October 2013, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-106-sept-oct-2013/new-faba-bean-rust-option

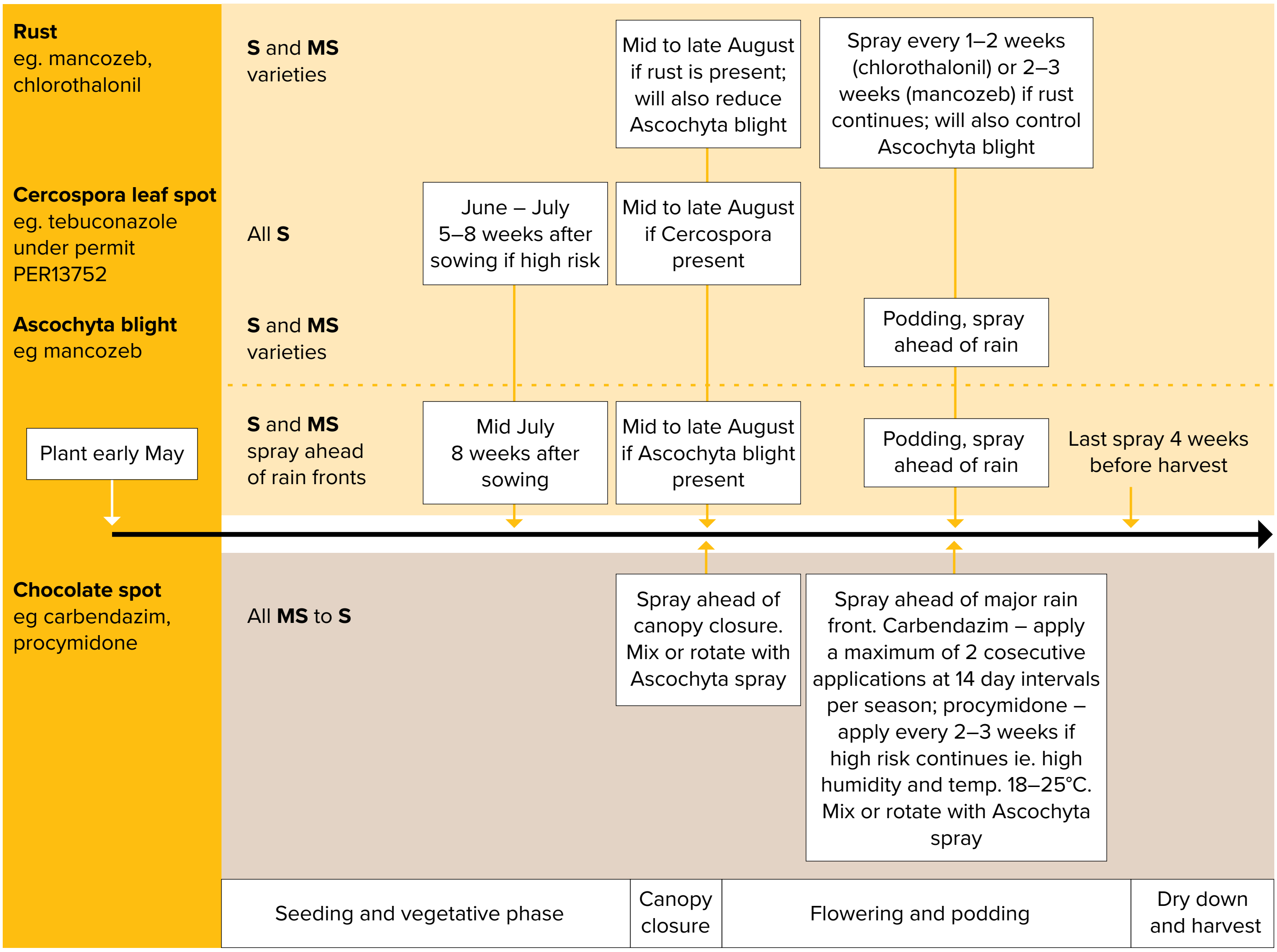

Figure 3: *Fungicide timing for faba bean disease control. The specific times are based on variety Resistance (R) or Susceptibility (S) to that specific disease.*

Source: Jenny Davidson, SARDI

First critical period

This is 5–8 weeks following emergence.

The main target is Ascochyta blight in susceptible varieties to limit the early establishment of the disease. For Ascochyta blight, mancozeb is recommended to be applied regardless of whether symptoms are visible. Cercospora leaf spot should also be targeted at this stage and is most effectively controlled in this period with tebuconazole.

Second critical period

This is during early flowering just prior to canopy closure, 13–16 weeks after emergence.

This is the last opportunity to protect against disease prior to canopy closure. It is the critical period when the fungicide can penetrate deep into the canopy to protect lower leaves at a time when disease can impact on yield by causing leaf lesions, flower drop and pod abortion.

Chocolate spot is most devastating at flowering and pod-set. A protective foliar fungicide application at early to mid-flowering, before symptoms appear is vital to prevent it becoming established under the crop canopy. If symptoms were observed and managed earlier this pre-canopy closure spray is still important. Varieties susceptible to Ascochyta blight will require a fungicide application at this time to prevent further spread of the disease. A fungicide to target Cercospora leaf spot may be required if early control was inadequate.

If the crop has good yield potential apply fungicide when:

- rain events are likely;
- canopy closure is about to occur;
- chocolate spot is present; or
- Ascochyta blight is present and the variety is susceptible.

Fungicide mixtures may be required to target multiple diseases. More than one spray may be required when disease pressure is high.

Third critical period

This is at the end of flowering and early pod-fill, 15–20 weeks after emergence.

Apply fungicide to protect developing pods, preventing any further disease spread. Target Ascochyta blight, chocolate spot and rust.

Chocolate spot must be controlled when conditions are favourable for this disease. It may be necessary to control rust if it has become established as epidemics can form rapidly.

Control Ascochyta blight in susceptible varieties to limit seed staining when wet weather persists up to harvest. Fungicide can be applied until just prior to drying down provided withholding periods are adhered to.

Apply fungicide if the crop has sufficient yield potential and when:

- rain is forecast; or
- significant growth has occurred since previous fungicide application.

Fungicide mixtures may be required to target multiple diseases. More than one spray may be required when disease pressure is high.

MORE INFORMATION

NVT Crop Disease AU app for android and iOS, http://www.nvtonline.com.au/interactive-tools/apps/

SARDI has information on:
Seed and crop testing
http://pir.sa.gov.au/research/services/crop_diagnostics/seed_and_crop_testing

and PreDicta B® testing
http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

AgVic has information on CropSafe
http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/grain-and-crop-health/cropsafe-program

and seed health testing in pulse crops http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops

DPIPWE has information on plant pathology http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/plant-pathology-laboratory

NSW DPI has information on plant health diagnostic services
http://www.dpi.nsw.gov.au/about-us/services/laboratory-services/plant-health The eXtensionAUS webpage has details on disease testing services around Australia http://extensionaus.com.au/field-crop-diseases/disease-testing-services-around-australia/

9.13 Correctly identifying diseases

Correct disease identification is important as this will determine the choice of product.

Symptoms of Ascochyta and chocolate spot, the most damaging diseases, can be confused with symptoms of Cercospora leaf spot. In addition, symptoms may be similar to damage on leaves from herbicides or physical events, which then allow minor diseases such as Alternaria (*Alternaria alternata*) to infect the plant tissue. Correct disease identification is necessary to avoid unnecessary spraying or incorrect fungicide use.

9.13.1 Diagnostic skills

Accurate diagnosis is essential to effectively manage disease. An incorrect diagnosis can be more costly than inaction.[22]

Not all plant disorders are cause by plant pathogens; consider genetic, insect, animal, environmental and agronomic causes.

Some problems involve more than one cause, although usually there will be only one major cause.

Looking at the problem in the paddock is more likely to lead to a correct diagnosis than examining specimens in the office.

Take notes and photographs. As well as recording historical information (e.g. sowing date, variety, previous crop etc), describing the distribution and symptoms in writing forces us to see what we're looking at. Include this information when sending a sample away for diagnosis.

Follow these steps for an accurate diagnosis:

What is the distribution of the disorder across the district?

- Regional distribution of a problem can eliminate many causes and may identify likely ones.
- If only one crop or one grower in the district has the problem, the cause is unlikely to be environmental (but it could be lightning), or an air-borne disease e.g. faba bean rust.
- Isolated problems often reflect some agronomic problem e.g. wrong type or rate of herbicide, poor quality seed, inadequate nutrition, nodulation failure, deep seeding or a soil-borne pest or disease.

What is the distribution of the disorder across the paddock? Is the pattern linked with a farming operation (past and present)?

- For example, cultivation, old fence line, sheep camp, sowing, varieties, spraying, harvesting?
- Does it follow drainage lines or is it confined to low or high parts of the paddock?
- Does it affect individual plants throughout the paddock; individual plants at the edge of the crop or in thin areas.
- Does it occur in patches?

Walk through the crop with your eyes shut sensing changes in soil compaction to establish links between hard zones and symptoms.

- Run your hands across the plants – do they feel stiff and leathery; cool or hot?

What's the weather been like?

- Could it be frost, heat stress, drought, waterlogging?

What's the insect activity been like?

- Aphids on the windscreen, moths in the crop.

22 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

Determine the progression of symptoms. Look at plants showing the range of symptoms from apparently healthy to just starting to show the problem to just about the die.

- Are plants easy to pull up?
- Do they break off at ground level?
- Look for evidence of feeding by insects, birds or rodents.

Dig up plants:

- Is soil clinging loosely to their roots (evidence of fungal hyphae)?
- Wash soil from roots in bucket and examine against a light-coloured background.
- Make progressive tangential slices into the root, collar and stem looking for vascular discolouration.

Finally, if you suspect a plant disease, remember the Disease Triangle (Figure 1). A crop can only have a serious disease problem if three conditions are met:

- susceptible host;
- prevalent causal agent; and
- favourable environment.

9.13.2 Sending samples for disease diagnosis

For accurate diagnosis it is imperative that specimens are carefully selected, well presented and submitted with adequate information.[23]

Selection of specimens

Select plants that show the range of symptoms from slightly to severely affected. Include several healthy plants for comparison. Collect whole plants if practicable, including the roots. For root diseases, include roots and some soil from the root zone (i.e. roots contained in a soil plug).

Preservation

Fresh plant specimens are preferred. If delays in transit are likely and plant material is likely to break down and/or become mouldy, dry specimens are recommended.

DO NOT FREEZE samples.

Fresh specimens are best stored in aerated conditions at high humidity and cool temperatures, preferably not on the back seat of a ute in the sun. Use an esky with fridge bricks to keep samples cool. Diagnosis of viruses requires very fresh specimens. Plants should be wrapped in dry paper and placed in a plastic bag. The paper should not be wet. If dead tissue is present on the sample, damp paper should be avoided as moulds may develop.

Dried specimens are best when dried rapidly, but again not in the back of the ute. Place plant parts between sheets of newspaper (with some pressure), and change paper daily for 1 week.

Packaging

Fresh specimens: specimens likely to decompose e.g. pods should be wrapped in paper and placed in a suitable container. Other plant parts can be placed in partially inflated plastic bags and tied-off (fairly loosely to allow aeration but not desiccation). Soil samples should be packed in a sealed plastic bag or airtight container.

Dry specimens: should be supported between 2 firm surfaces e.g. cardboard, before dispatch.

Note that diagnoses for suspect virus diseases can only be made with fresh specimens.

23 QDAF (2016) How to collect, prepare and package samples for analysis. Queensland Department of Agriculture and Fisheries, https://www.daf.qld.gov.au/plants/health-pests-diseases/plant-pest-diagnostic-services/grow-help/collecting-samples

Labelling

Use waterproof ink. All containers should be clearly marked. If labels are placed inside bags use plastic as paper can become mush.

Dispatch

Specimens should be sent ASAP after collection. Send early in the week to avoid delays over the weekend. Label the item 'Plant Specimens – Perishable' or 'Soil Samples'.

Before sending check whether the relevant authority has a submission form.

The information usually required includes:

- Name and address of grower and location of crop
- Host and variety (if not obvious)
- Area of injury e.g. leaves, roots, pods
- Nature of injury e.g. leaf scorch, root rot, leaf spot
- Prevalence/distribution e.g. localised, entire field, scattered
- Severity
- Soil type, moisture and drainage
- Previous cropping history
- Other useful details such as chemical usage, fertiliser applications, irrigations, growing conditions, frost, weather conditions.

Relevant contacts

South Australia

SARDI Plant Diagnostic Centre
Ph: (08) 8303 9400

Seed and crop testing:
http://pir.sa.gov.au/research/services/crop_diagnostics/seed_and_crop_testing

Post to:
Locked Bag 100,
Glen Osmond, SA, 5064

Courier to:
Plant Research Centre, Waite Institute
Gate 2B, Hartley Grove,
Urrbrae, SA 5064

South Australia

SARDI Molecular Diagnostics Group
Ph: (08) 8303 9400

PreDicta® B nematode testing:
http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

Post to:
C/- SARDI RDTS
Locked Bag 100,
Glen Osmond, SA, 5064

Courier to:
SARDI Molecular Diagnostics Group
Plant Research Centre
Gate 2B
Hartley Grove
Urrbrae SA 5064

Victoria

DEDJTR Pulse Pathology,
Ph: (03) 5362 2111

Post to:
Private Bag, Natimuk Rd,
Horsham, VIC 3401

Courier to:
110 Natimuk Rd
Horsham, VIC 3401

Victorian samples may also be submitted via agronomists through the Cropsafe program. The program aims to provide the early detection of exotic diseases.
http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/grain-and-crop-health/cropsafe-program

Tasmania

Ph: 1300 368 550
Email: Biosecurity.planthealth@dpipwe.tas.gov.au

Prices:
http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/plant-pathology-laboratory

New South Wales

Prices and submission forms:
http://www.dpi.nsw.gov.au/about-us/services/laboratory-services/plant-health

Plant Health Diagnostic Service
– Wagga Wagga
Ph: (02) 6938 1608

Post to:
Wagga Wagga Agricultural Institute,
Private Bag, Pine Gully Road,
Wagga Wagga, NSW 2650

Plant Health Diagnostic Service
– Tamworth
Ph: (02) 6763 1133

Post to:
Tamworth Agricultural Institute,
RMB 944, 4 Marsden Park Rd,
Calala, NSW 2340

MORE INFORMATION

The CropPro webpage has information on Ascochyta blight of faba bean, please see http://www.croppro.com.au/crop_disease_manual/ch06s03.php

9.14 Ascochyta blight (AB) (*Ascochyta fabae*)

9.14.1 Symptoms

Lesions can form on leaves, stems and pods of infected plants. Small, circular, dark brown spots first appear on both sides of the leaves unlike chocolate spot, which is initially only on one side.[24] These enlarge and turn light to dark grey in colour becoming irregular in shape, often zonate and may coalesce to cover most of the leaf surface. Leaf tissue next to the lesions may become black and necrotic.

If conditions are moist numerous pycnidia (pinhead-sized black fruiting bodies) develop within the lesions and are often concentrically arranged.

On the stem, lesions are more elongated, sunken and darker than leaf lesions and are usually covered with scattered pycnidia. Stems may split and break at the point of infection causing plants to lodge.

On pods, lesions are sunken, with pale centres and dark margins and may be covered by numerous pycnidia. Well-developed lesions may penetrate the pod and infect developing seeds causing them to be shrunken and discoloured. Badly infected seeds have yellowish-brown stains on the outer seed coat.

Symptoms of Ascochyta blight may be confused with symptoms of Cercospora leaf spot or damage on leaves from herbicides or physical events, which then allow minor diseases such as Alternaria to infect. Correct disease identification is necessary to avoid unnecessary spraying or incorrect fungicide use.

Photo 1: *Typical Ascochyta blight lesion. Infections start as small grey spots and may spread to the leaf edge following moisture run.*

Photo: SARDI via Pulse Australia (2016) Southern faba & broad bean best management practices training course

24 G Hollaway, F Henry, M McLean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Diseases in pulses: faba bean. In Identification and Management of Field Crop Diseases in Victoria, Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch06.php

Photo 2: *Older infections turn pale with black specks.*

Photo: Grain Legume Handbook, (2008), https://grdc.com.au/grainlegumehandbook

Photo 3: *Herbicide damage. Spotting from herbicide application can look like Ascochyta blight or Cercospora leaf spot, but note absence of pycnidia.*

Photo: SARDI via Pulse Australia (2016) Southern faba & broad bean best management practices training course

Photo 4: *Stem infections are sunken with pale centres.*

Photo: Grain Legume Handbook, (2008), https://grdc.com.au/grainlegumehandbook

Photo 5: *Ascochyta blight pod lesions affect seed quality. They range from small isolated spots to the large multiple infections shown here.*

Photo: Agriculture Victoria via Pulse Australia (2016) Southern faba & broad bean best management practices training course

Photo 6: *Damage to stem and grain. (Left) Ascochyta blight on bean stems causes stem breakage and lodging and (right) staining resulting from Ascochyta blight infection. The disease is transferred by seed to new crop.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

9.14.2 Economic importance

Ascochyta blight is a widespread and important disease in southern Australia. A 2012 GRDC survey estimated the incidence of Ascochyta blight is 77% of years and 76% of bean crops in the southern region.[25]

Severity varies considerably from crop to crop and between seasons. When seasons are favourable for the disease yield losses range from 10–30% in protected crops. Susceptible varieties can suffer significant yield losses and poor seed quality with losses of up to 80% are possible in unprotected crops (see Section 3.10 Seed quality). Discoloured grains may be rejected or discounted in markets.

A change in Ascochyta blight virulence was observed in 2013 with the new pathotype 2 particularly virulent on PBA Rana$^{\phi}$ and Farah$^{\phi}$.[26] Isolates collected from the field

25 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

26 J Davidson, R Kimber, C Walela, L McMurray, K Hobson, J Brand and JPaull (2016) Pulse diseases in 2015. GRDC Updates Paper, 9 February 2016, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/pulse-diseases-in-2015

have found that pathotype 2 is currently mainly found in the Mid North region of SA, but has also spread to Victoria and the South East of SA. Testing of older isolates show that it was present in the Mid North in 2012, a year before changes were observed in the field. Pathotype 1 is widely distributed in the southern region.

Breeding material has been screened against pathotype 2 and while 73 accessions are resistant to pathotype 1, only 24 were also resistant to pathotype 2. This material will be used in future breeding programs.

9.14.3 Disease cycle

The Ascochyta fungus can survive on crop debris, self-sown plants and on infected seed. The disease spreads short distances from infected to healthy plants by rain-splash spores during the growing season, or over longer distances via wind early in the season.

Infection can occur at any stage of plant growth following rain or heavy dew. Ascochyta infection is likely to occur in environments with prolonged wet, cool (5°C–15°C) conditions and usually develops early in the growing season. Early infection results in the development of leaf lesions. In susceptible varieties these can spread and develop into stem lesions causing crop lodging.

After the commencement of flowering the disease can spread onto developing pods and cause seed staining.

The disease cycle is shown in Figure 4.

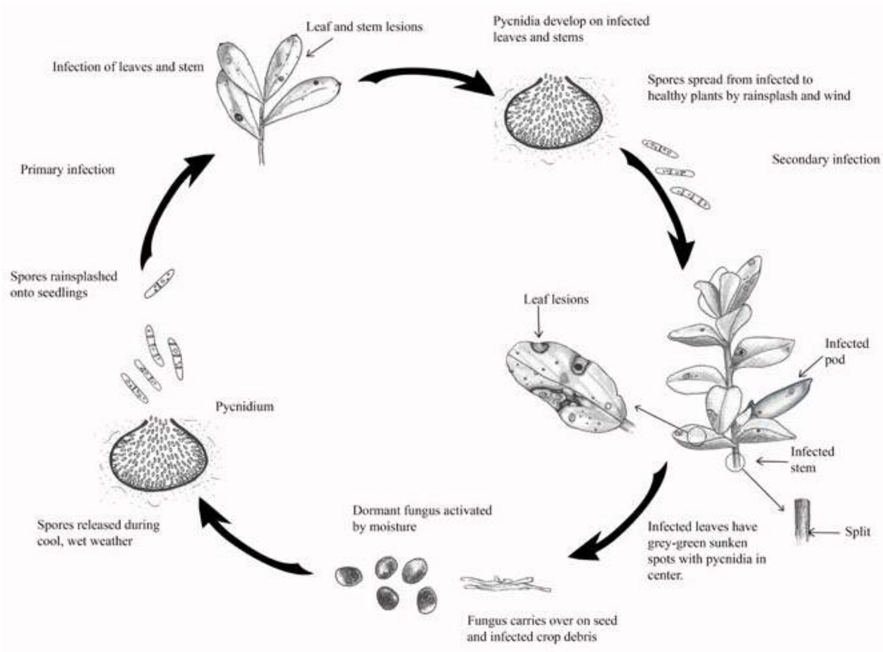

Figure 4: *Disease cycle of Ascochyta blight on faba bean.*

Illustration by Kylie Fowler. Source: Hollaway *et al* (2015), Diseases in pulses: faba bean. In Identification and Management of Field Crop Diseases in Victoria. Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch06.php

9.14.4 Management options

Integrated disease management (IDM) can minimise the presence of inoculum and protect against potential infection as the crop develops:

- Use crop rotation and careful paddock selection – allow 4 years between bean crops and control self-sown beans.
- Select resistant varieties (see Table 1).
- Sow disease-free seed (with no more than 5% infection).
- Use fungicide seed dressings (Table 4).
- Monitor crops regularly.
- Use fungicides strategically.

Seed dressings are not usually required, and only protect the emerging seedling from seed-borne Botrytis and common root rots. They will not protect the emerged seedling from raindrop-splashed Ascochyta or wind-borne Botrytis.

Fungicides used in faba and broad bean are protectants only. Unlike wheat stripe rust fungicides, they have no systemic action and will not eradicate an existing infection. To be effective they must be applied before infection i.e. before rain. The key to a successful Ascochyta spray program is regular monitoring combined with timely application of registered fungicides.

Specific spray programs have been developed based on varietal Ascochyta resistance ratings.

Currently Nura⁽ᵈ⁾ and PBA Samira⁽ᵈ⁾ are the only varieties with resistance to both pathotypes (Table 1). PBA Rana⁽ᵈ⁾ and PBR Zahra⁽ᵈ⁾ have partial resistance to pathotype 2 and will need to be carefully monitored with the use of protective fungicides during podding. Farah⁽ᵈ⁾ needs to be managed as a susceptible variety where pathotype 2 is likely to be found.

The Ascochyta pathogen can mutate to overcome plant resistance and all varieties should be monitored regardless of nominated resistance ratings.

For resistant varieties:

- Resistant varieties require fewer and later fungicide applications for Ascochyta control, if at all.
- Only consider applying an early foliar fungicide for Ascochyta blight if the disease is present and the risk is high. If not controlling Ascochyta blight be aware that control of chocolate spot may still be required to prevent early development.
- Resistant varieties have pod resistance. In most situations foliar fungicide during podding is not likely to be required to protect grain quality.

For susceptible varieties:

- Foliar sprays are likely to be economic in susceptible varieties.
- Fungicides will be required in most areas, commencing early.
- Apply in the first critical period (5–8 weeks after emergence) and before the disease is detected to reduce lodging losses from stem infections. Control is ineffective once the disease has taken hold.
- When conditions favour Ascochyta blight, fungicides will be required in all critical periods.
- Apply through to 4 weeks before maturity. Late sprays can reduce seed infection.

Strategic spraying with mancozeb is effective for disease management.

Mancozeb is a broad-spectrum fungicide and might need to be used through the season on varieties that are susceptible to Ascochyta blight. The withholding period for grain prior to harvest for mancozeb is 4 weeks.

Harvest at maturity to minimise Ascochyta blight and chocolate spot infection on seed. Infection, harvest losses and downgrading in quality can be substantial when bean harvest is delayed until moisture content is below 12%. Ascochyta blight can grow on dead plant tissue once wet, so infection on pods can spread to the seed if harvest is delayed and conditions are wet.

MORE INFORMATION

The CropPro webpage has information on chocolate spot of faba bean, see http://www.croppro.com.au/crop_disease_manual/ch06s02.php

9.15 Chocolate spot (*Botrytis fabae*)

9.15.1 Symptoms

Symptoms are varied and range from small spots on the leaves to complete blackening of the entire plant. Leaves are the main part of the plant affected, but under favourable conditions for the disease it also spreads to stems, flowers and pods.[27]

Two stages of the disease are usually recognised. First, a non-aggressive phase, when discrete reddish-brown spots are peppered over the leaves and stems (Photo 7).

The second stage is an aggressive phase where tissue around the spots is rapidly killed leaving large, black or grey blighted sections on plant parts (Photo 8).

Small black sclerotia may sometimes be found inside the stems of badly diseased plants.

In moist conditions, the fruiting structures of this fungus may be visible, protruding as grey, hair-like formations from the surface of infected plant parts e.g. on the underside of diseased leaves (Photo 9).

Chocolate spot infecting the flowers can prevent pod-set (Photo 13 and Photo 14) and on the pods can cause seed staining (Photo 15).

Symptoms of chocolate spot can be confused with symptoms of Cercospora leaf spot or damage on leaves from herbicides or physical events, which then allow minor diseases such as Alternaria to infect.

Redlegged earth mite damage can also be mistaken for chocolate spot. This starts as silvery patches, which become red-brown, similar in colour to chocolate spot, but form large, irregularly shaped areas. Redlegged earth mite damage usually occurs during the seedling stage and on the lower leaves.

Correct identification of damage is necessary to avoid unnecessary spraying or incorrect fungicide use.

Photo 7: *Infections of chocolate spot on beans start as small brown spots.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

27 G Hollaway, F Henry, M McLean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Diseases in pulses: faba bean. In Identification and Management of Field Crop Diseases in Victoria. Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch06.php

Photo 8: *Chocolate spot lesion showing some expansion across the leaf.*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 9: *Chocolate spot showing lesion expansion and sporulation after a few days in humid chamber.*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 10: *Poor pod-set and leaf loss from failing to protect against chocolate spot early.*

Photo: Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 11: *Chocolate spot can cause thick parts of crop (e.g. headlands) to lodge.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

Photo 12: *Chocolate spot on stems.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

Photo 13: *Chocolate spot on flowers will prevent pod-set.*

Photo: SARDI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 14: *Grey, dead areas of chocolate spot spread, and flowers are also blighted, stopping any pod-set.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

Photo 15: *Chocolate spot lesion on pod leading to infection and staining on seed.*

Photo: SARDI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

9.15.2 Economic importance

Chocolate spot is the major disease of faba bean in southern Australia and occurs in all areas where faba bean is grown. Losses can be substantial depending on the seriousness of infection, the time at which infection occurs and the amount of spring rainfall. When chocolate spot develops it is very aggressive.

A 2012 GRDC survey estimated the incidence of chocolate spot is 54% of years and 62% of bean crops in the southern region.[28]

In unprotected crops pod-set can fail and the disease commonly reduces yields by 30–50% in a bad year. Seed from badly affected plants may have a reddish-brown stain that will lower its market value.

9.15.3 Disease cycle

The fungus may either survive as sclerotia in the soil or on crop debris, on self-sown volunteer plants, or occasionally on infected seed. It may be hosted by other crops, including vetch and lentil, and, to some extent, chickpea. In new bean-growing areas the disease often becomes established by sowing infected seeds. In subsequent years the initial infection usually occurs when spores formed on old bean trash are carried by wind into new crops. These spores may move long distances.

Once the disease becomes established it rapidly spreads within the crop. It spreads most aggressively in warm (15°C–25°C), humid conditions (>70%) that extend for 4–5 days.

28 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

It typically develops later in the season during flowering and after canopy closure when the environment becomes more humid. Yield loss due to chocolate spot results from pod abortion and plant damage (leaf infection and loss of leaf tissue).

Botrytis grey mould (BGM, *Botrytis cinerea*) can sometimes contribute to chocolate spot.

The disease cycle is shown in Figure 5.

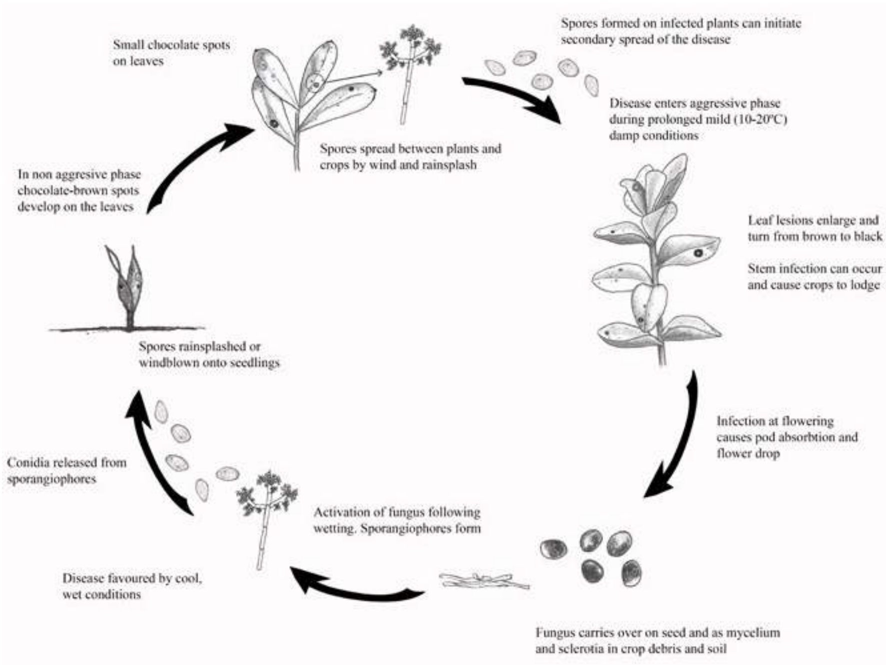

Figure 5: *Disease cycle of chocolate spot on faba bean.*

Illustration by Kylie Fowler from Hollaway *et al* (2015), Diseases in pulses: faba bean. In Identification and Management of Field Crop Diseases in Victoria. Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch06.php

9.15.4 Management options

The most effective method of control is to use a less susceptible variety, particularly in areas where the likelihood of chocolate spot is high. There are no resistant varieties.

Crops are at high risk of chocolate spot if one or more of the following conditions is met:

- sown early, producing bulky canopy;
- sown in a high-rainfall area;
- spring rains are forecast; or
- disease has established in the lower canopy.

Follow the principles of integrated disease management (IDM), those with particular benefit for managing chocolate spot include:

- Use crop rotation – allow 4 years between bean crops.
- Select paddocks carefully, ensuring 500 m from the previous year's bean stubble and not adjacent to vetch, lentil or chickpea stubble. Destroy bean trash and self-sown plants if this is not possible.
- Grow less suceptible varieties (see Table 1).
- Delay sowing.
- Sow disease-free seed (with no more than 10% infection).
- Use fungicide seed dressings.

- Practice canopy management through time of sowing, seeding rate and row spacing.
- Monitor crops regularly.
- Practice strict hygiene on and off farm.
- Use foliar fungicides strategically.

Seed dressings are not usually required, and only protect the emerging seedling from seed-borne Botrytis and common root rots. They will not protect the emerged seedling from raindrop-splashed Ascochyta blight or wind-borne Botrytis.

Sowing later can be reduce disease pressure as the crop will have a lower biomass, a more open canopy and be growing in warmer and drier weather. The trade-off in yield may be offset by reduced disease pressure and control costs. However, this increases the risk of a dry and sharp finish to the season.

Fungicides for chocolate spot include mancozeb, chlorothalonil, carbendazim or procymidone. Copper products may have some efficacy.

When chocolate spot pressure is high or the disease is spreading in the crop, then carbendazim or procymidone are more effective than chlorothalonil, mancozeb or copper. Label regulations limit carbendazim to a maximum of two consecutive sprays at 14-day intervals.

It is essential to control chocolate spot before it has a significant impact on crop yield. Check for disease every seven days while the temperature remains below 15°C. If the weather is mild with day temperatures between 15°C and 20°C and humidity over 70% in-crop inspections should be made every 3 days, typically from early spring.

Infections can start earlier and crops should be monitored from late winter.

Chocolate spot is targeted by fungicide sprays in critical period 2 and critical period 3. Spraying could begin at early flowering as a protective spray that is able to penetrate the canopy.

Follow-up sprays will be necessary where:

- chocolate spot lesions are visible within the upper canopy; or
- relative humidity in the crop is likely to remain high for at least a week; or
- disease is increasing.

Fungicides are generally only protectants with little or no systemic activity. Most will not eradicate an existing infection. Procymidone has some systemic activity, and carbendazim has some limited systemic activity that should not be relied upon.

To be effective, all these fungicides must be applied before infection and spread, i.e. before rain.

All varieties will require fungicide spray before canopy closure when conditions or location are ideal for infection. Further applications are required under wet conditions particularly if symptoms are evident, soil moisture is high and the crop canopy is dense.

The recommended spray program depends on each variety's chocolate spot resistance rating.

For moderately susceptible (MS) varieties:

- Apply an early foliar fungicide for chocolate spot just before canopy closure or before flowering if the disease is present or the risk is deemed high.
- Repeat foliar fungicide will likely need to be applied during flowering and podding to ensure leaves are retained clean of lesions.
- Application at late podding may be required to protect grain quality in high-risk situations or if the disease is present. Note that these varieties will have minimal Botrytis in the pods and seeds if the leaf canopy is kept clean of the disease.
- Varieties with moderate susceptibility to chocolate spot may require the same number of fungicide applications as a susceptible variety. The disease does

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

move slower, but will be devastating if left unprotected in medium to high disease pressure situations.

For susceptible (S) varieties:

- Apply an early foliar fungicide for chocolate spot just before canopy closure or before flowering if the disease is present or the risk is deemed high.
- Repeat foliar fungicide applications likely will be required during flowering and podding until flowering is completed and no more new growth occurs.
- Ensure leaves are retained clean of lesions so that grain can be filled and to protect grain quality in high risk or disease pressure situations.
- Note that these varieties will have minimal Botrytis in the pods if the leaf canopy is kept clean of the disease.

For very susceptible (VS) varieties:

- Regular foliar fungicide applications for chocolate spot control will be necessary in most areas, commencing early and applying before a prolonged rainfall event. This is critical, as control is often ineffective if fungicides are applied after the disease has taken hold.
- Apply a fungicide before the disease is detected, from the commencement of flowering until 4 weeks before maturity.

Harvest at maturity to minimise chocolate spot infection on seed. Seed infection is usually more severe when crops are harvested late and is more likely when harvest is delayed until moisture content is below 12%.

MORE INFORMATION

The CropPro webpage has information on rust of faba bean, see http://www.croppro.com.au/crop_disease_manual/ch06s06.php

9.16 Rust (*Uromyces viciae-fabae*)

9.16.1 Symptoms

Leaves have numerous small, orange-brown pustules, surrounded by a light yellow halo (Photo 16).[29] As the disease develops, severely infected leaves wither and drop off.

Rust pustules on the stems are similar, but often larger, than those on the leaves (Photo 17). Late in the season, stem lesions darken as resting spores of the fungus are produced in pustules.

Isolated rust pustules may also appear on the pods. A severe rust infection may cause premature defoliation, resulting in smaller seeds.

Photo 16: *Bean rust shows as orange 'bumps' on leaves.*

Photo: SARDI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 17: *Rust on faba bean stem.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

29 G Hollaway, F Henry, M McLean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Diseases in pulses: faba bean. In Identification and Management of Field Crop Diseases in Victoria. Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch06.php

9.16.2 Economic importance

Rust occurs sporadically in the southern region. Rust epidemics can significantly reduce faba bean yields. Rust often occurs in years with good spring rainfall and mild temperatures. A 2012 GRDC survey estimated the incidence of rust is 20% of years and 30% of bean crops in the southern region.[30]

Rust has the potential to reduce seed size. On its own the disease has caused losses of up to 30%. In combination with chocolate spot yield reductions may be up to 50%.

9.16.3 Disease cycle

The fungus survives on stubble trash and infects self-sown bean plants directly without the need for alternate hosts. Infection of volunteer faba bean plants is thought to be an important factor in the early development of rust epidemics. Rust spores are blown long distances onto new crops by the wind.

Rust pustules form on the first few plants to be infected and the disease spreads from these to other plants.

Rust can occur from early to mid-spring onwards and is favoured by humidity and warm temperatures (>20°C). Infection can follow just 6 hours of leaf wetness and does not require extended wet periods.

Rust commonly occurs late in the growing season during podding, resulting in premature leaf drop that can reduce seed weight and size.

The same species also causes rust on vetch and lentil.

9.16.4 Management options

Prevention of rust is difficult because the fungus spores can be carried long distances by wind to infect crops far away from the initial source of infection.

Control options for rust include:

- Crop rotation – allow 4 years between bean crops.
- Select paddocks carefully, ensuring 250 m from the previous year's bean stubble. Burn or bury old bean stubbles.
- Growing resistant varieties is ideal because rust spores can travel long distances, however the current southern varieties have limited resistance (see Table 1).
- Delay sowing – late planting is recommended in high-risk areas.
- Monitor crops regularly.
- Use foliar fungicides aimed at control of other diseases.

Foliar sprays of mancozeb provide the added benefit of suppressing chocolate spot and Ascochyta blight later in the season. Copper sprays will control rust and chocolate spot.

Where there is a high risk of rust infection fungicides may be required before flowering. Fungicide to control rust may be applied at the same time as chocolate spot is being targeted. In areas where the disease is most prevalent (northern NSW) several sprays are necessary for control.

30 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

MORE INFORMATION

The CropPro webpage has details on Cercospora leaf spot of faba bean, see http://www.croppro.com.au/crop_disease_manual/ch06s05.php

9.17 Cercospora leaf spot (*Cercospora zonata*)

9.17.1 Symptoms

Symptoms can be difficult to distinguish from those of chocolate spot or Ascochyta blight.

Cercospora leaf spot first appears as dark, round lesions soon after emergence and may merge rapidly to form irregular blighting on leaves (Photos 18 and 19). Cercospora leaf spot lesions tend to be confined to lower leaves of plants and do not affect flowers.

Cercospora leaf spot lesions are generally darker than those of chocolate spot, with irregular shaped edges.[31] Within the spots a concentric ring pattern can often be seen. Cercospora leaf spot lesions do not have pycnidia, which distinguish them from Ascochyta blight, but light-grey fruiting structures with a short furry covering may be visible within lesions.

Severe infection leads to defoliation of leaves. Occasionally stem lesions will also occur but these tend to be superficial.

Damage on leaves from herbicides or physical events may look similar and can allow minor diseases such as Alternaria (*Alternaria alternata*) to infect plants. Correct disease identification is important to avoid unnecessary spraying or incorrect fungicide use.

Photo 18: *Cercospora leaf spot lesions on faba bean.*

Photo: SARDI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

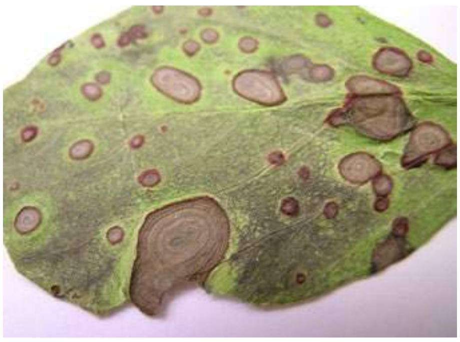

Photo 19: *Cercospora leaf spot lesions on faba bean.*

Photo: SARDI via Pulse Australia (2016), Southern faba & broadb ean best magenemt practices training course

31 G Hollaway, F Henry, M McLean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Diseases in pulses: faba bean. In Identification and Management of Field Crop Diseases in Victoria. Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch06.php

9.17.2 Economic importance

Cercospora zonata is ubiquitous in southern Australia and sporadic outbreaks result from the right seasonal conditions. Lesions will reach the top of the plant in wet springs and yield loss of 5–10% has been reported. It will become a regular occurrence and need early control in faba bean crops that are growing in a paddock that has had a recent or prolonged history of growing faba beans.

A 2012 GRDC survey estimated the incidence of cercospora leaf spot is 63% of years and 49% of bean crops in the southern region.[32] The incidence and severity is believed to be on the increase.

9.17.3 Disease cycle

Cercospora leaf spot disease has not been well studied. It can also affect vetch, narbon bean and possibly lentil.

Cercospora is soil-borne and prevalent in paddocks with a history of faba bean, particularly where they are grown more frequently than 4–6 years or within close proximity of other bean crops.

Cercospora it is not known to be seed-borne, but survives on old bean trash and spores are spread passively by wind or rain-splash. Disease spread is limited to short distances within a paddock from carryover of the fungus on the trash. Spores do not spread long distances to other paddocks but may be carried in soil or on debris distributed by strong wind events.

Cercospora, like Ascochyta blight, develops early in the season during wet and cold conditions but is less damaging. The disease can develop later in the season and if uncontrolled can cause extensive defoliation.

The disease often occurs when plants are grown in wet patches, particularly where free water remains on the soil surface.

9.17.4 Management options

All current faba bean varieties are susceptible to Cercospora leaf spot. Breeding resistant varieties is an aim of the current Australian faba bean breeding program.

The severity of Cercospora leaf spot appears to be strongly linked to close faba bean rotation. Wide rotations of susceptible crops (allow 4–6 years) and good crop hygiene are the best means of cultural control.

Fungicide application for protection from Cercospora leaf spot must start early (5–8 weeks post-emergence) before lesions develop. Use tebuconazole (under permit) to prevent Cercospora leaf spot establishing in a crop.

32 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

MORE INFORMATION

The CropPro webpage has information on Alternaria leaf spot of faba bean, see http://www.croppro.com.au/crop_disease_manual/ch06s04.php

9.18 Alternaria (*Alternaria alternata*)

9.18.1 Symptoms

Alternaria appears as dark brown leaf spots, often with a zoned pattern of concentric brown rings with dark margins (Photo 20).[33] Symptoms can be confused with chocolate spot or Cercospora leaf spot. It can also be confused with Ascochyta blight, but does not produce black pycnidial fruiting structures within leaf lesions.

Photo 20: *Alternaria lesions have concentric rings with lesions.*

Photo: Hollaway *et al.* (2015), Cereal root disease management in Victoria. GRDC Update Papers, 24 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Cereal-root-disease-management-in-Victoria

9.18.2 Economic importance

Alternaria is a minor disease occurring late in the season. A 2012 GRDC survey estimated that Alternaria has minimal incidence in minimal years in the southern region.[34]

9.18.3 Disease cycle

Alternaria is a weak pathogen of many hosts and infection often follows insect damage or other leaf spots caused by rust or chocolate spot. It develops late in the season as the plants start to mature. The fungus is thought to survive on crop residues and on other hosts.

9.18.4 Management options

Control of Alternaria alone is not warranted. There is no fungicide-efficacy data for Alternaria on faba bean and no registered products. However, sprays aimed at other major pathogens may give control.

33 Pulse Australia (2016) Southern faba & broadbean best management practices training course – 2016. Pulse Australia.

34 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

MORE INFORMATION

GRDC Updates: The 'watch outs' for pulse diseases in 2017
https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/the-watch-outs-for-pulse-diseases-in-2017

9.19 Sclerotinia stem rot (*Sclerotinia trifoliorum var. fabae, S. sclerotiorum, S. minor*)

9.19.1 Symptoms

Plants can be attacked at any stage of growth. Usually, isolated plants are infected rather than multiple plants in patches.[35]

In young plants the infection usually begins close to ground level and a slimy, wet rot extends into the stem and down into the roots. Affected plants are easily pulled from the soil. They usually have a blackened base that is covered with cottony, white fungal growth.

Older plants can get the infection on any part of their stems, leaves or pods. Infected plants suddenly wilt and collapse.

Sclerotes (2–5 mm in diameter) form on the surface of infected plants and in the central cavity of the stem. These sclerotes are usually white at first then turn black.

9.19.2 Economic importance

Crop losses in Australia have been small so far. A 2012 GRDC survey estimated the incidence of Sclerotinia stem rot is 11% of years and 7% of bean crops in the southern region.[36] However, the disease poses a potential threat.

9.19.3 Disease cycle

The fungus can survive in the soil for several years. It has a wide host range, including oilseed crops, and may survive on other plants even if beans are not grown.

Sclerotinia may act as either a leaf or root disease. The foliar form of the disease may be spread by air-borne spores. Infection begins when these spores settle on the crop. If conditions are cool and wet, the disease develops rapidly and affected plants soon wilt and die.

The fungus infects damaged tissue more easily but can also infect uninjured tissue.

Root disease occurs when soil-borne spores directly invade the root tissue. A slimy, wet root rot develops and the infected plants suddenly wilt and die.

9.19.4 Control

Crop rotation prevents rapid disease build-up, but once established in a crop it is difficult to control. Rotations with other legumes and oilseed crops will not break the disease cycle. Cereal crops are not hosts and are a suitable break crop.

Lower seeding rates, wider row spacing and good weed control give a more open crop, which remains drier and is less prone to disease.

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35 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

36 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

VIDEO

GRDC Video: Botrytis in Chickpeas
https://youtu.be/P7C9g2eRw80

9.20 Botrytis grey mould (BGM) (*Botrytis cinerea*)

9.20.1 Symptoms

The life cycle and symptoms of Botrytis grey mould (BGM) are similar to those of chocolate spot.[37]

As with chocolate spot, flowers are especially vulnerable to BGM infection.

9.20.2 Economic importance

BGM is a minor disease in faba bean compared with chocolate spot (*Botrytis fabae*) in southern Australia, but the two are sometimes found together in association. A 2012 GRDC survey estimated the incidence of BGM is 54% of years and 62% of bean crops in the southern region.[38]

Discoloured seed may be rejected or heavily discounted when offered for sale. If seed infection levels are higher than 5% then it may be worth grading the seed.

9.20.3 Disease cycle

BGM is a significant pathogen of other pulse crops particularly lentil and chickpea, and it has been recorded on over 138 genera of plants in 70 families. BGM does not infect cereals or grasses.

As well as being a serious pathogen, *B. cinerea* can infect and invade dying and dead plant tissue. This wide host range and saprophytic capacity means inoculum of *B. cinerea* is almost always present. If conditions favour infection and disease development, BGM will occur.

This makes management of BGM different from Ascochyta blight, which is more dependent on inoculum, at least in the early phases of an epidemic.

Occurrence is worst in wet seasons, particularly when crops develop very dense canopies.

9.20.4 Management options

The only fungicide specifically registered for control of BGM in faba bean is carbendazim.

37 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

38 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

9.21 Aphanomyces root rot (*Aphanomyces euteiches* f.sp. *phaseoli*)

9.21.1 Symptoms

Chlorosis and wilting of the plant, associated with necrosis in the roots. Roots show discolouration and the absence of nodulation.[39] Diseased plants are likely to appear in clusters within waterlogged areas. It can be confused with other types of root rot (see Section 9.22 Other root rots).

Photo 21: *Faba bean affected by Aphanomyces euteiches.*

Photo: J van Leur, NSW DPI via Yeatman *et al*. (2009), Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/allpublications/publications/2009/11/faba-beans-the-ute-guide/

9.21.2 Economic importance

This root rot is common in parts of northern NSW and has also been detected in Tasmania in bean-growing soils. A 2012 GRDC survey estimated the incidence of Aphanomyces is 3% of years and 3% of bean crops in the southern region.[40]

It is unlikely to be a major pathogen of faba bean at the present. However, the expansion of this crop in regions with heavy soils and high rainfall or irrigation will increase the risk of losses. Infection by Aphanomyces can also predispose plants to infection by secondary fungi including *Pythium*, *Rhizoctonia* and *Fusarium* species.[41]

9.21.3 Disease cycle

The fungus survives in soil and is exacerbated by waterlogging. It can spread from crop to crop in the soil, either via infected plant debris or as resting spores.

MORE INFORMATION

A Horticulture Australia report on Aphanomyces in bean is at http://ausveg.com.au/insights-database/development-of-methods-to-monitor-and-control-aphanomyces-root-rot-and-black-root-rot-of-beans

39 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

40 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

41 A Watson, H Pung, A McKay (2013) Development of methods to monitor and control Aphanomyces root rot and black root rot of beans, VG08043 Final report. Horticulture Australia Ltd, http://ausveg.com.au/insights-database/development-of-methods-to-monitor-and-control-aphanomyces-root-rot-and-black-root-rot-of-beans

In wet soils these fungi invade plant roots and cause root rot. Wet conditions also encourage the spread of disease within a field. The reduced root development causes the plants to die when they are stressed.

9.21.4 Management options

The disease can be reduced by crop rotation. Cross-infection with other hosts is not fully understood, but initial studies show that bean isolates do not infect peas. No cost-effective options are available for identification prior to planting.

MORE INFORMATION

GRDC Fact Sheet: Pythium root rot, www.grdc.com.au/GRDC-FS-PythiumRootRot

9.22 Other root rots, including Phoma blight and damping-off (*Fusarium*, *Rhizoctonia*, *Pythium* spp. and *Phoma medicaginis* var *pinodella*)

9.22.1 Symptoms

Root rot is the most common symptom of Phoma blight, as plants can be infected on the stem below ground level. Lesions on the stems below soil level are black. Infected plants are stressed.

Seedlings affected by root rot gradually turn black and leaves droop. The plants usually don't collapse completely. The taproot may become quite brittle, except in Pythium root rot when it becomes soft. When plants are pulled from the ground the lower portion of the root snaps off and remains in the soil. The upper portion of the taproot is dark, shows signs of rotting and may lack lateral roots. Distinct, dark-brown to black lesions may be visible on the taproot.

The leaves and stems of affected plants usually start turning black. Older plants dry-off prematurely and are often seen scattered across a field. In some cases, seeds may rot before they emerge.

9.22.2 Economic importance

Root rot can occasionally be a serious disease especially when soils are wet for prolonged periods. Severe pod infection can result in reduced seedset and infected seed. A 2012 GRDC survey estimated the incidence of root rots ranges from 0–18% of years and 0–16% of bean crops in the southern region, depending on the causal agent.[42]

9.22.3 Disease cycle

All the fungi responsible for root rot are soil-dwellers. They can survive from crop to crop in the soil, either on infected plant debris or as resting spores.

Soil-borne fungi invade the roots and stem base of young plants, particularly under wet conditions. Wet conditions also encourage the spread of disease within a field. However, recent research has shown that Pythium does not require high rainfall or cold, waterlogged soils.[43] The reduced root development causes the plants to die when they are stressed.

During wet weather the disease may spread further, when fungal spores are carried onto neighbouring plants by wind and rain-splash.

42 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

43 GRDC (2010) Pythium root rot. Root disease Fact Sheet. GRDC, May 2010, https://grdc.com.au/GRDC-FS-PythiumRootRot

9.22.4 Management options

The disease can be reduced by crop rotation. As this disease may also affect other pulses it is recommended to rotate with non-legume crops.

Disease risk can be reduced by using fresh, undamaged and robust seed to prevent disease build-up. Avoid areas subject to waterlogging. Damping-off can be controlled using fungicide seed treatment, but this is not common practice in faba and broad bean.

Pythium root rot can be detected with a SARDI PreDicta B® soil test prior to sowing.

9.23 Stemphylium blight (*Stemphylium botryosum*)

MORE INFORMATION

A GRDC media release on leaf blight can be found at https://grdc.com.au/Media-Centre/Media-News/North/2016/08/Mild-wet-winter-leads-to-emergence-of-leaf-blight

9.23.1 Symptoms

Stemphylium blight is characterised by large, grey-black, necrotic lesions, restricted to the leaves, often starting from the leaf edge.[44]

It differs from chocolate spot, the symptoms of which are small, discrete, reddish-brown lesions on leaves, that form after extended periods of leaf wetness and increase rapidly, causing severe leaf necrosis, as well as symptoms on stems, flowers and pods.

9.23.2 Economic importance

Stemphylium is considered a minor disease of faba bean in Australia, although it is common in lucerne and can cause severe defoliation. In 2016 the mild, wet winter led to an unusually high number of reports of stemphylium on faba bean in northern NSW. A 2012 GRDC survey did not estimate the incidence of stemphylium.

9.23.3 Disease cycle

Stemphylium botryosum occurs on lucerne, clovers, lupin, bean and tomato. In lucerne Stemphylium can be carried over on infected plant debris, seed and in soil. The disease is favoured by warm, moist conditions and spores are spread by wind or rain-splash.

9.23.4 Management options

As a minor disease no control is generally required.

44 S Jeffrey (2016) Mild, wet winter leads to emergence of leaf blight. GRDC media release, 18 August 2016, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/pests-diseases/winter-crops-lupins-chickpeas-other-pulses/stemphylium-blight-in-faba-bean

MORE INFORMATION

Plant Health Australia fact sheet: Stem nematode, http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf

APPS fact sheet: Ditylenchus dipsaci, http://www.appsnet.org/publications/potm/pdf/Mar11.pdf

9.24 Stem nematode (*Ditylenchus dipsaci*)

9.24.1 Symptoms

Symptoms in faba bean are only seen in seedlings.[45] Heavy infections will show up as poor germination and emergence with patches of malformed and stunted plants (Photo 22).

The malformation, curling of leaves and water-soak spots are often confused with herbicide damage. Sometimes the stem will die back, turning reddish-brown from the base and stopping at a leaf.

Photo 22: *Stem nematode causes stunting and twisting of leaves. Black streaks down stems are also a symptom.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

9.24.2 Economic importance

Stem nematode is a soil-borne pest of oat, pulse and some pasture crops.[46] In South Australia and Victoria there are three different races of the nematode: the oat, lucerne and clover races. The oat race infects the cultivated and wild oat, faba bean and field pea and has been recorded on lentil, chickpea and canola seedlings.

Access to some international and domestic markets requires seed to be tested and found free of stem nematode.

A 2012 GRDC survey estimated the incidence of stem nematode is 6% of years and 5% of bean crops in the southern region.[47]

A heavy infestation of this nematode can cause large yield losses, but this has occurred only rarely.

45 Plant Health Australia (2013) Stem nematode fact sheet. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf

46 Plant Health Australia (2013) Stem nematode fact sheet. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf

47 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

MORE INFORMATION

GRDC Fact Sheet: Plant parasitic nematodes, http://www.grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW

A Soil Quality fact sheet on root-lesion nematode is at http://soilquality.org.au/factsheets/root-lesion-nematode

The SARDI webpage has information on PreDicta B® testing http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

VIDEO

GRDC Video: Root-lesion nematodes https://youtu.be/Ntf08QGXPI0

VIDEO

GRDC Video: Root-lesion Nematodes. Resistant cereal varieties have surprising impact on RLN numbers https://youtu.be/1dt64MfUmOc

9.24.3 Life cycle

Stem nematode infects bean crops from infested seed, straw or soil. The nematode can survive for many years in seed, straw or soil without having to infect plants.

It infects above-ground parts of plants and can multiply many times during the growing season. Disease build-up is worse in wetter soils and at temperatures below 15°C.

It is more common in high-rainfall areas on clay soil.

9.24.4 Management options

There are no chemical options for managing nematodes. Hygiene is very important. Do not introduce the nematode onto the farm or into clean paddocks. Test seed for the presence of stem nematode with a SARDI seed test. Do not bring oaten hay or straw from infested areas onto the property.

Rotate with non-host crops such as wheat and barley to reduce nematode numbers.

Soil-borne disease risk can be assessed through the SARDI PreDicta B® soil test.

9.25 Root-lesion nematodes (RLN) (*Pratylenchus neglectus*, *P. thornei* and other *Pratylenchus* spp)

Faba bean is grown as a rotational crop to reduce the population of root-lesion nematodes (RLN) in the soil.

9.25.1 Symptoms

There are few symptoms above ground in faba bean, but diseased plants usually have shorter lateral roots and fewer root hairs.

Diagnosis can be difficult and the presence of RLN in the soil can only be confirmed with a SARDI PreDicta B® soil test to identify the particular RLN species.

9.25.2 Economic importance

There is minimal yield loss in the bean crop.

Root-lesion nematodes can cause large grain yield losses in susceptible crops such as wheat and chickpea.[48] At least 20% of cropping paddocks in south-eastern Australia have populations of RLNs high enough to reduce yield. The extent of yield loss is directly related to the population density at sowing.

Worldwide, the genus *Pratylenchus* is the second most important group of plant-parasitic nematodes, with more than 90 species of RLN known worldwide. The two main species of RLN in Australia's southern region are *Pratylenchus neglectus* and *P. thornei*.

P. teres and *P. penetrans* are found in the western region.

More than one RLN species can be found in the roots of an individual crop, although one species usually dominates.[49] Identification is important as different crops have different resistance or susceptibility depending on the *Pratylenchus* type. All species of *Pratylenchus* have a wide host range.

The estimated incidence of RLN in faba bean was not quantified in the 2012 GRDC study on the cost of diseases in Australia. However, SARDI have published results of recent PreDicta B® soil tests for root-lesion nematode.

48 G Hollaway (2013) Cereal Root Diseases. Agnote AG0562, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases

49 GRDC (2010) Root-lesion nematodes Fact Sheet. GRDC, Southern Region, February 2015, https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

9.25.3 Life cycle

Nematodes are small worm-like organisms less than 1 mm in length that are able to move freely through moist soils and young root tissues. As the females move through plants they feed on the plant roots, causing lesions, and depositing eggs.

There may be 3–5 generations of nematodes within a growing season. Nematodes are likely to multiply under a range of host crops such as wheat and chickpea. Barley is only moderately susceptible. Many grass weeds and legumes can also host the nematode.

The nematode survives over the summer months in dry soil and root residues to become active again when the winter rains start.

Nematodes will not move great distances unless they are spread by surface water, soil on farm machinery or wind-blown soil in summer.

VIDEO

DPIRD video: How to diagnose root-lesion nematode
https://youtu.be/ttFltE-B4qA

9.25.4 Management options

There are no chemical options for managing nematodes. Rotation of susceptible crops (e.g. cereals, chickpea) with resistant crops such as lentil, faba bean, field pea or lupin is the most important management tool for RLN.

Resistant crops reduce the population of nematodes in the soil. Tolerant crops do not reduce the population, but are less vulnerable to damage from nematodes.

Resistant crop species can reduce nematode populations by up to 50% per year. A 2 or more year break from susceptible crops may be necessary to minimise yield loss if nematode numbers are high. Resistant varieties of susceptible crop species should be grown in the following years.

With the exception of chickpea, pulses tend to have good resistance to *P. neglectus* and *P. thornei*, so can reduce nematode populations in cropping rotations (Table 8).

Resistant crops may differ in their capacity to host *P. neglectus* or *P. thornei,* so tailor rotations to manage the predominant species. Crops such as field pea and lentil provide some control for *P. thornei*, while faba bean, field pea and lentil provide control for *P. neglectus*.

Controlling volunteer crops and host weeds is also important. Weeds that can host nematodes include wild oat, barley grass, brome grass and wild radish and *Brassica tournefortii*.

Nematode numbers increase where susceptible crops like chickpea and wheat are grown in rotation.

Reducing the nematode population can lead to higher yield in subsequent cereal crops. Yield loss in south-eastern Australia from RLN is lower than in northern Australia.

The simplest way to identify a nematode problem is with a SARDI PreDicta B® soil test prior to sowing.

MORE INFORMATION

GRDC Fact Sheet: Aphids and viruses in pulses, http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

The Pulse Australia webpage has information on managing viruses in pulses, see http://pulseaus.com.au/growing-pulses/publications/manage-viruses

The Agriculture Victoria webpage has information on managing viruses in pulse crops http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/managing-viruses-in-pulse-crops

Table 8: Resistance and tolerance of pulses to the major **Pratylenchus** species.

Crop	*Pratylenchus neglectus*		*Pratylenchus thornei*	
	Resistance	Tolerance	Resistance	Tolerance
Faba bean	R	-	MR	MI
Chickpea	S - MR*	MI - T*	VS - R*	MI - T*
Field pea	R	-	R	T
Lentil	R	T	R	MT
Vetch				
Blanchefleur	MR	T	S	I - MI
Languedoc	MR	T	MS	I - MI
Morava⁽ᵈ⁾	MR	T	MS	I - MI

* Chickpea varieties have a range of resistances and tolerances to *Pratylenchus* species.

Source: Pulse Australia (2016)[50]

9.26 Viruses

9.26.1 Viruses in pulses

Faba and broad bean are naturally infected by around 50 viruses worldwide, and the number continues to increase. Fortunately, only a few are of major economic importance in Australia (Table 9). Viruses can become a problem in bean crops in some seasons.

Major viruses that are known to infect faba and broad bean in Australia include:

- Bean leaf roll virus (BLRV)
- Beet western yellows virus (BWYV), also known as Turnip yellows virus (TuYV)
- Soybean dwarf virus (SbDV), also known as Subterranean clover red leaf virus (SCRLV)
- Sub clover stunt virus (SCSV)
- Bean yellow mosaic virus (BYMV)
- Pea seed-borne mosaic virus (PSbMV).

Less common viruses that occur in Australia are:

- Clover yellow vein virus (ClYVV)
- Alfalfa mosaic virus (AMV)
- Tomato spotted wilt virus (TSWV)
- Broad bean wilt virus (BBWV)
- Cucumber mosaic virus (CMV).

50 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

Table 9: Virus categories and general symptoms.

Virus	Aphid transmission	Seed transmission*	Visual symptom type	Visual symptoms	Virus type (genus)
AMV	Non-persistent	Yes	Shoot tip	Necrotic or chlorotic local lesions, sometimes mosaics that do not necessarily persist.	alfamovirus
BBWV	Non-persistent	No	Mosaic, shoot tip	Vein clearing, mottling and necrosis of shoot apex, plant wilts, mottled, malformed and stunted.	fabavirus
BLRV	Persistent	No	Top yellowing	Upward leaf-rolling accompanied by interveinal yellowing of older leaves and flowers abscissed.	luteovirus
BWYV	Persistent	No	Top yellowing	Interveinal yellowing of the older or intermediate leaves. Mild chlorotic spotting, yellowing, thickening and brittleness of older leaves.	luteovirus
BYMV	Non-persistent	Yes	Mosaic	Transient vein chlorosis followed by obvious green or yellow mosaic. Usually no leaf distortion.	potyvirus
CMV	Non-persistent	Yes	Shoot tip	Mosaics, stunting and possibly some chlorosis.	cucumovirus
ClYVV	Non-persistent	No	Shoot tip, mosaic	Mosaics, mottles or streaks, vein yellowing or netting.	potyvirus
PSbMV	Non-persistent	Yes	Mosaic	Systemic dark and light-green zonal leaf mottle, slight to moderate downward rolling of leaf margins. Distortions of leaf shape associated with mottle patterns. Seed markings.	potyvirus
SCRLV	Persistent	No	Top yellowing	Mild yellowing, stunting and reddening.	luteovirus
SCSV	Persistent	No	Top yellowing	Top yellows, tip yellows or leaf roll. Leaf size reduced, petioles and internodes shortened.	nanavirus
TSWV	Persistent	No	Shoot tip, mosaic	Necrotic and chlorotic local lesions, mosaic, mottling, leaf shape malformation, vein yellowing, ringspots, line patterns, yellow netting and flower colour-breaking.	tospovirus

*Seed transmission in faba bean is minimal for all viruses, but of no epidemiological significance. However, it is important for quarantine to keep foreign virus strains out of Australia.

Source: Pulse Australia (2016)[51]

The South Australian Research and Development Institute (SARDI) found relatively low virus infection rates in faba bean in SA in 2014 (Table 10). BWYV infected canola crops across Victoria, SA and NSW in 2014, but was only detected at a high infection rate in one crop in SA late in the season.

Table 10: Results of virus testing in South Australia in 2014.

Crop type	Number of crops or trials tested	Test period	Number of crops with positive virus tests (average % infection rate in brackets)					
			BWYV	PSbMV	CMV	AMV	BLRV	BYMV
Faba bean	24	Jul–Aug	6 (2%)	4 (4.5%)	0	1 (100%)	0	0
	19	Sep–Oct	11 (2%, 1 at 62%)	1 (6%)	0	0	0	0

Source: Kimber *et al* (2015)[52]

51 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

52 R Kimber, J Davidson, M Rodda, M Aftab, J Paull (2015) Diseases of pulse crops in 2014. GRDC Update Papers, 10 February 2015, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/diseases-of-pulse-crops-in-2014

9.26.2 How viruses spread

Viruses need aphid vectors to spread from infected to healthy plants. The exception is TSWV, which is transmitted by specific thrip species. Some viruses can be introduced by sowing infected seed. Viruses such as Bean leaf roll virus (BLRV), Beet western yellows virus (BWYV) and, to some extent, Pea seed-borne mosaic (PSbMV) are not seed-transmitted, but can become established after aphid-vector activity.

The most important factors that predispose pulse crops to severe virus infection are:

- Infected seed or close proximity to a substantial virus reservoir (e.g. lucerne, summer weeds).
- A wetter-than-average summer-autumn with green material to allow uncontrolled multiplication of aphids during the time when numbers are usually low. When aphids are present early in the season, epidemics are more likely to occur and the level of damage will be higher.

While field pea seed infected with PSbMV may infect seedlings at a rate of 100%, the rate of transmission for faba bean is thought to be much lower (<1%).

Viruses can be classified by the manner in which they are transmitted by insect vectors: persistent or non-persistent.

Persistent transmission

These viruses are ingested by the insect and are passed to healthy plants through the saliva. It can take more than a day for these insects to become infectious, but the insect will remain infectious for the rest of its life.

Not all aphid species are vectors of this kind of virus in pulses so the identification of aphid species is very important. The main vectors of these viruses are pea, cowpea and green peach aphids. Viruses include BWYV, BLRV and SCSV. Infection will start with random plants and increase as the vectors colonise the crop. Aphids generally only become visible in the crop once they have colonised.

Insecticides that kill aphids can work in suppressing the spread of these types of viruses as transmission rates increase dramatically when the aphids fly.

Non-persistent transmission

Insects transfer these viruses on their mouth parts directly by carrying it from an infected plant to a healthy one. It can only infect one or two more plants at a time.

Many aphid species are vectors of this type of virus, including ones that do not colonise legumes but just land and probe while searching for their preferred hosts (e.g. oat and turnip aphids). Viruses include PSbMV, AMV, CMV and BYMV.

Insecticides are less effective at suppressing these types of viruses as they do not act fast enough. They may make the situation worse as the insecticide can agitate aphids and increase virus spread.

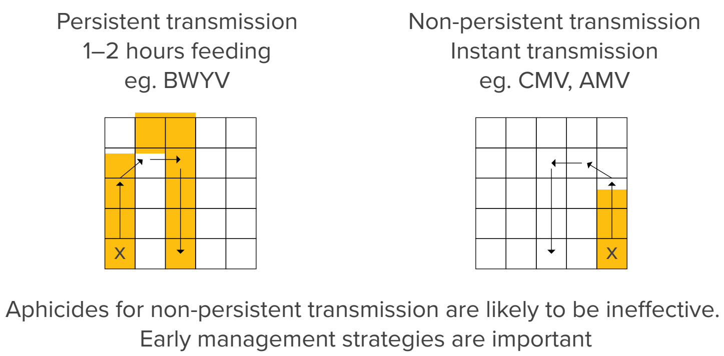

Figure 6: *Differences in the progression of infection within a field of persistent and non-persistent viruses vectored by aphids.*

Source: I SPY manual https://grdc.com.au/i-spy-manual

9.26.3 Symptoms

Initially diseased plants are scattered, but by the time the crop matures, luteoviruses may have infected nearly the entire crop.

Luteoviruses (e.g. BLRV, BWYV and SCRLV) cause yellowing and stiffening of the leaves and sometimes an upwards rolling of the leaf margins. The whole plant will yellow when infected at the seedling stage. When infection occurs later, only the tops of shoots show symptoms – described as 'top yellows'. Infected plants become stunted and die prematurely, unless infection occurs after podding.

BYMV causes leaves to turn pale green. Usually there is a mosaic of dark green patches over the pale green leaves. The leaves develop an uneven surface texture and outline compared with healthy leaves. There is little or no stunting.

CMV infection on faba bean is often symptomless or mild and difficult to observe.

TSWV causes tip necrosis and plant death. Economically significant incidences have been found in the northern region since the introduction of the western flower thrip, a highly efficient TSWV vector in that region. To date it does not appear to be a major problem in the southern region.

Photo 23: *Bean leaf roll virus.*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016)

Photo 24: *Bean leaf roll virus.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

Photo 25: *Clover yellow vein virus (ClYVV) leaf symptoms and tip necrosis prior to eventual plant death. Symptoms in beans can resemble those of Tomato spotted wilt virus (TSWV), with death of the growing point.*

Photo: SARDI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 26: *Close up of Tomato spotted wilt virus (TSWV) ring spot lesions.*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 27: *Tomato spotted wilt virus (TSWV) stem and tip necrosis.*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 28: *Tomato spotted wilt virus (TSWV) pod necrosis.*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 29: *Necrosis of the growing tip can be caused by thrip feeding only, not by TSWV.*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 30: *Stem necrosis can result from causes other than TSWV, in this case frost.*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 31: *Leaf symptoms of Bean yellow mosaic virus.*

Photo: Grain Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

Photo 32: *Pea seed-borne mosaic virus (PSbMV) symptoms in faba bean.*

Photo: Roger Jones, DPIRD via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 33: *Subclover stunt virus (SCSV) in very early sown bean.*

Photo: Wayne Hawthorne, Pulse Australia via Pulse Australia (2016), Southern faba & broad bean best management practices training course

Photo 34: *Soybean dwarf virus (SbDV), also known as subterranean clover red leaf virus (SCRLV).*

Photo: Joop Van Leur, NSW DPI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

9.26.4 Economic importance

Viruses are not considered a major problem of faba and broad bean in the southern region, but should not be ignored (Table 11). Infection can reduce yield and seed quality.[53] (See also Section 3.10 Seed quality.)

Table 11: Incidence and faba bean crop area affected by viruses in the southern region.

Virus**	Incidence* (%)	Area of crop (%)
Beet western yellows virus	6.8	0.3
Broad bean wilt virus	17.0	3.4
Clover yellow vein virus	17.0	0.3
Cucumber mosaic virus	34.1	17.0
Pea seed-borne mosaic virus	6.8	0.3
Soybean dwarf virus	0.0	0.0
Subterranean clover red leaf virus	19.9	2.0
Subterranean clover stunt virus	4.0	0.2
Tomato spotted wilt virus	6.8	0.3

*Incidence as a proportion of years when the disease occurs and area as a percentage of crop area affected when the disease develops.
** No incidence was listed for Alfalfa mosaic virus, Bean leaf roll virus or Bean yellow mosaic virus.

Source: Murray and Brennan (2012), Current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

53 K Perry, P Mangano, P Umina, A Freeman, R Jones, W Hawthorne, J Davidson (2010) Aphids and viruses in pulse crops Fact Sheet. GRDC, Western and Southern regions, July 2010, http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Previous cases of virus damage in southern Australia include:

- The BWYV outbreak in 2014, which damaged canola crops in SA, Victoria and NSW. While there was concern that it could spread to pulse crops including beans, the cold conditions over winter substantially reduced the spread of aphids.[54]
- Seed staining from PSbMV was widely detected in southern Australia in 2013, with severe cases downgraded of quality (Photo 35).[55] It is likely that the source of the virus was nearby infected field pea crops. Nura⁽ᵈ⁾ appeared more prone to expression of symptoms than other faba bean and PBA Rana⁽ᵈ⁾ less prone.
- In 2007 early-sown beans in southern Victoria were substantially damaged by SCSV after the crop emerged into high aphid activity after a wet summer–autumn.
- BLRV had a major impact in parts of South Australia in the drought of 2007. It was first detected in 1993 in northern NSW in faba bean, narbon bean and the forage legume *Lathyrus ochrus*, and by 1995 BLRV had caused major yield losses in faba bean in northern NSW.
- ClYVV caused plant death in spring-sown beans grown adjacent to irrigated white clover in South Australia in the late 1990s. Similar symptoms are seen in faba bean crops on occasion, but can be confused with other causes.

While viruses occur in all states, they are a more of a problem in northern NSW and southern Queensland, occasionally causing total crop failures in chickpea.

Damage caused by the viruses varies greatly from season to season and depends on the prevalence of aphids. Infection is more likely to cause yield loss when infected seed stock is sown, and aphids arrive early in the season. When aphids arrive late other plants can compensate for individual plant losses.

Another luteovirus, SbDV (also known as SCRLV), has been infecting faba bean crops in Australia since the 1970s and does not appear to be a serious problem.

BYMV occurs commonly at a low frequency in faba bean crops and has not caused any serious losses.

Photo 35: *Bean seed showing Pea seed-borne mosaic virus (PSbMV) marking that can affect marketability.*

Source: R. Kimber, SARDI via Pulse Australia (2016), Southern faba & broad bean best management practices training course

54 B Coutts, R Jones, P Umina, J Davidson, G Baker and M Aftab (2015) Beet western yellows virus (synonym: Turnip yellows virus) and green peach aphid in canola. GRDC Updates Paper, 10 February 2015, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/beet-western-yellows-virus-synonym-turnip-yellows-virus-and-green-peach-aphid-in-canola

55 J Brand, M Rodda, P Kennedy, M Lines, L McMurray, J Paull and K Hobson (2014) Pulse varieties and agronomy update (Ballarat). GRDC Update Papers, 5 February 2014, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2014/02/pulse-varieties-and-agronomy-update-ballarat

9.26.5 Disease cycle

Aphids bring the viruses into faba bean crops from surrounding plants, mostly legumes (like lucerne or clovers). Some viruses, like BWYV, AMV, CMV, BYMV and TSWV, have a host range that includes non-legume species. Hence other plant species (e.g. sow thistle, turnip weed) can act as a virus source at the start of the season.

CMV and AMV are non-persistently transmitted by a range of aphid species. *Acyrthosiphum gossypii* is one of many possible vectors of both. The luteoviruses are persistently aphid-transmitted, but are more vector-specific. Correct identification of the aphid is important for effective management.

TSWV is spread by thrips.

Probing and feeding needs to be prolonged for persistently transmitted viruses (0.1–4.0 hours for luteoviruses), but needs be only brief for non-persistently transmitted viruses. Eventually, aphids colonise the bean plant and only then do they become very visible in the crop.

Aphids move between adjacent plants to feed before colonising faba bean plants. Faba bean show a characteristic scattered distribution of patches of virus-infected plants in contrast with a crop like chickpea, where aphids do not colonise and individual plants are infected.

Crop loss depends on the growth stage at infection and the number of plants infected. Early and widespread infections lead to the greatest losses.

Aphid activity is influenced by seasonal conditions and will require early monitoring in nearby crops and pastures. See Section 8 Pest management for more information on monitoring and managing aphids.

9.26.6 Management options

There are no proven methods for controlling viruses. Breeding resistant varieties is the most economical and sustainable way to control viruses.[56] Prevent viruses using integrated management of both the virus and the aphid.

While a large population of aphids is required to inflict feeding damage, virus transmission can occur before aphids are seen to be present. Pre-emptive management is required.

Management options at the planning stage:

- Suppress the virus source within the crop by purchasing virus-tested seed. Only retain seed from crops with no visible symptoms. Grade out smaller grain, which is more likely to be infected. PSbMV, CMV, BYMV and AMV survive through seed transmission. A threshold of 0.1% seed infection is recommended for sowing in high-risk areas, and less than 0.5% for low-risk areas.
- Distance crops from lucerne, weeds or other species that act as a reservoir for viruses, diseases and aphids.
- Control volunteer weeds and self-sown pulses that are a 'green bridge' host for viruses and a refuge for aphids and their multiplication during summer and autumn.
- Rotate pulse crops with cereals to reduce virus and vector sources (aphids or other insects) and, where possible, avoid close proximity to perennial pastures (e.g. lucerne) or other crops that host viruses and aphid vectors.

Management options at sowing and in-crop:

- Use a seed treatment of Gaucho® 600 Red Flowable seed treatment insecticide (imidacloprid), which is registered for early aphid protection to control persistently transmitted viruses.

56 J Paull (2011) UA00097 Australian Faba Bean Breeding Program 2007-2011. Project Final Report, University of Adelaide, https://grdc.com.au/research/reports/report?id=1485

- Retain cereal stubble as aphids are less likely to land in stubble.
- Sow at recommended times to avoid autumn aphid flights.
- Sow at recommended plant densities to achieve early closure of the crop canopy. Closed canopies deter aphids.
- Note that high seeding rates and narrow row spacing to provide early canopy closure assists in aphid control, but conflicts with management of fungal diseases.
- Manage crops to minimise seedling stress through disease, herbicide damage and poor nutrition. Stressed crops are more attractive to aphids.
- Insecticides after emergence may be effective for persistently transmitted viruses. However, they may not be effective for non-persistently transmitted viruses as the insecticide can agitate aphids and increase virus spread.
- Monitor faba bean and nearby crops and pastures for aphids. Be prepared to use insecticide when there may be localised flights.

Insecticide resistance is becoming more common in aphids. Growers should only consider applying insecticide for virus control if they consider their crops to be at high risk. Insecticides aimed at controlling damage from aphid feeding are normally too late to control virus spread and damage.

MORE INFORMATION

The Agriculture Victoria webpage has information on seed health testing in pulse crops http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops

The DPIRD webpage has details on seed testing at: https://www.agric.wa.gov.au/plant-biosecurity/ddls-seed-testing-and-certification-services

The TASAG webpage has testing details at: http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/tasag-elisa-testing

The Agrifood Technology webpage has information on food safety at: http://www.agrifood.com.au/index.php/services/food-safety

9.26.7 Virus testing

Diagnostic testing is available for plant viruses. Only some tests can be performed with relative ease in the field. Current testing options may not detect the less common viruses.

Detection of virus in 1 or 2 plants is not proof that the virus is causing a problem. It is important to check for a range of viruses, as the one detected by a test may not be the virus actually causing symptoms.

Detection of a seed-borne virus does not mean there will be virus present in progeny seed. Seed samples from the crop require testing to determine if seed infection has occurred.

Serological testing for viruses is available through DDLS Seed Testing and Certification (formerly AGWEST Plant Laboratories), TASAG ELISA and pathogen testing service or Agrifood Technology.

TASAG also sell Agdia Immunostrips test kits. A result can be obtained in minutes. (Also see Section 3.11 Seed testing).

DPIRD Diagnostic Laboratory Services (DDLS) Seed Testing and Certification

DDLS conduct seed tests for CMV.

Department of Primary Industries and Regional Development
Reply Paid 83377
3 Baron Hay Court
South Perth, WA 6151
Ph: 08 9368 3721

Email: DDLS-STAC@agric.wa.gov.au

https://www.agric.wa.gov.au/plant-biosecurity/ddls-seed-testing-and-certification-services

TASAG

TASAG offer in-house virus testing of plants or seed and test kits that can be used in the field (Agdia Immunostrips test kits, US website www.agdia.com).

Contact: Peter Cross
New Town Laboratories
13 St John's Ave
New Town, Tasmania, 7008
Ph: 03 6165 3252
Email: peter.cross@dpipwe.tas.gov.au
http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/tasag-elisa-testing

Agrifood Technology

Agrifood conduct testing for CMV and AMV.

Contact: Robert Rantino or Doreen Fernandez
260 Princes Highway, Werribee, VIC 3030, Australia
Postal: PO Box 728, Werribee, VIC 3030, Australia
Phone: 1800 801 312
http://www.agrifood.com.au/index.php/services/food-safety

9.27 Exotic diseases with potential to impact on Australian crops

If you suspect an exotic disease immediately contact Plant Health Australia's **Exotic Plant Pest Hotline** on **1800 084 881**.

9.27.1 Downy mildew (*Peronospora viciae*-fabae)

Downy mildew is considered the major exotic disease risk for faba bean. It is host-specific, but symptoms are similar to the closely related downy mildew of peas (*Peronospora viciae*).[57]

Systemic, localised and pod infections can all occur in faba and broad bean. Young plants can develop symptoms, but generally symptoms become obvious at a later stage, with the leaves developing the characteristic pale patches on the surface, and grey-mauve fluffy mycelium on the undersides. Red-brown flecks can develop on the lesions and occasionally the edges of the lesions become discoloured (Photo 36).

Plants that are infected systemically show stunting and distortion, and are pale green in colour (Photo 37). In cool, wet or humid weather, infected leaves develop characteristic greyish-fawn mycelium with spores visible. Often sporulation is confined to those leaves at the apex of the plant. Localised infections produce light green to pale brown or yellow irregular patches or more regular circles on the upper leaf surface. Sporulation occurs on the corresponding underside of the leaf, showing greyish fluffy growth. Infected material quickly becomes reddish-brown and necrotic.

Plants that are systemically infected from soil-borne inoculum are pale and stunted and may be scattered among the crop. Secondary infection symptoms are distinctive, with the fluffy fungal growth on the undersides of leaves being a specific symptom of downy mildew.

As symptoms are perhaps characteristic of a number of seedling and leaf diseases or disorders of faba and broad bean, plant samples showing suspected 'mildew-like' symptoms, reddening, wilting and/or yellowing should be sent for diagnosis.

Entry would be through debris or soil contamination. Severe infections can have a dramatic effect on yield.

Photo 36: *Typical 'mildew-like' symptoms on a faba bean plant affected by downy mildew.*

Photo: SARDI via Pulse Australia (2016) Southern faba & broad bean best management practices training course

57 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

Photo 37: *Bean plant systemically infected by downy mildew.*

Photo: NIAB via Pulse Australia (2016) Southern faba & broad bean best management training practices training course

9.27.2 Fusarium wilt (*Fusarium avenaceum* f. sp. *fabae* and *F. oxysporum* f. sp. *fabae*)

The primary host is faba bean. Fusarium wilt affects stems, roots, growing points, inflorescence and seeds. Seedling wilt is characterised by sudden drooping and drying of leaves and whole seedling. Adult symptoms appear at flowering to late pod-fill, with sudden drooping of top leaflets, leaflet closure without premature shedding, and dull green foliage followed by wilting of whole plant or individual branches. Root systems will appear normal, with a slight reduction in lateral roots.[58]

The pathogen has a low entry potential but high establishment and spread potential. It is viable in soil and debris for up to 3 years and in spores spread by mechanical means and on seed.

This is the most destructive disease of faba bean in China.

9.27.3 Red clover vein mosaic virus (carlavirus)

Red clover vein virus (RCVV) is polyphagous with numerous legume hosts. It affects the whole plant in the vegetative phase and is seed-borne. Generally, it causes vein mosaic, mosaic, streaking and stunting in various legumes. Faba bean may have chlorotic lesions, or general chlorosis, tip mottle and abscission.[59]

There is high entry potential via seed. It has high establishment and spread potential with four of seven known vectors present in Australia.

58 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

59 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia.

Plant growth regulators and canopy management

Key points

- Canopy management of faba bean crops aims at managing biomass.
- Management is based on variety choice and crop agronomy at sowing.
- No plant growth regulators (PGRs) are registered for faba bean. Research is continuing but results do not support the use of PGRs in faba bean crops.

Canopy management is about producing the most appropriate amount of crop biomass for the growing season, to optimise grain yield and input use. It is also about canopy duration in a particular environment.[1]

10.1 Canopy management in faba bean and broad bean

Attempting to grow high-yielding irrigated (and high-rainfall) crops with high inputs can promote tall and bulky vegetative crops at increased risk of lodging.[2 3] Lodging can reduce yields and cause harvest difficulties. Irrigated faba bean crops can grow to 2 metres and collapse close to harvest.

Large faba bean and broad bean crop canopies often lead to poor penetration of fungicides. This is particularly so in high-rainfall and irrigation areas, where crop canopies are large and disease incidence can be high because of high humidity within the canopy.[4]

Canopy management of faba bean involves reducing crop height to allow improved fungicide application and efficacy, and may reduce disease intensity and plant lodging, potentially increasing grain yield.[5]

IN FOCUS

Canopy management in faba bean is largely related to:

- variety selection (see Section 3.7 Southern faba bean varieties);
- time of sowing (see Section 4.1 Time of sowing);
- sowing rate (see Section 4.2 Sowing rates and plant density);
- row spacing (see Section 4.2 Sowing rates and plant density); and
- fertiliser use (see Section 6 Nutrition and Fertiliser).

While grazing is used for canopy management of other crops, it is not an agronomic practice commonly used in faba bean. Grazing is an alternative to chemical plant growth regulators (PGRs). Grazed plants are often shorter than non-grazed plants and are less prone to lodging.[6]

Growers can use PGRs to control crop height, although none are registered for faba bean.

1 GRDC (2009) Canopy management: Cereal canopy management more than delayed nitrogen, Fact Sheet. Grains Research and Development Corporation, https://grdc.com.au/uploads/documents/GRDC_CanopyManagement_4pp.pdf

2 D Jones (2016) Molybdenum, row spacing, plant population and PGRs in faba beans, https://thestubbleproject.wordpress.com/2016/04/26/molybdenum-row-spacing-plant-population-and-pgrs-in-faba-beans/

3 E Armstrong, L Gaynor, G O'Connor, S Ellis and N Coombes (2015) Faba beans for acidic soils in southern NSW – yields and time of sowing effects. GRDC Update paper, 17 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Faba-beans-for-acidic-soils-in-southern-NSW

4 D Jones (2014) Plant growth regulators. GRDC Update paper, 31 July 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators

5 M Lines, L McMurray (2014) Broad bean canopy management. Mackillop Farm Management Group Trials Results 89-91, http://www.mackillopgroup.com.au/media/2013%20Trial%20Book/bean_management.pdf

6 D Jones (2014) Plant growth regulators. GRDC Update paper, 31 July 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators

10.2 Plant growth regulators

While there are no plant growth regulators registered for use on faba bean, new research is underway in this area,[7 8] see Section 10.2.2 Plant growth regulator trials in faba bean and broad bean.

'Plant growth regulator' (PGR) is a term that describes many agricultural and horticultural chemicals that influence plant growth and development. This influence can be positive, such as larger fruit or more pasture growth, or negative, for example, shorter stems or smaller plant canopies.[9]

PGRs tested or faba bean and broad bean are applied with the intention of:

- producing a smaller plant, resistant to lodging; or
- reducing excessive growth in irrigated or high-rainfall crops.

Crop responses to the use of PGRs can be inconsistent. In general, yield responses, if any, are produced by the reduction in lodging rather than as a direct effect of the PGRs.

PGRs must be applied at the correct crop growth stage according to product directions, which can be well before any lodging issues are apparent.[10]

10.2.1 Survey of the use of PGRs in Australia

A survey funded by the GRDC on the use of PGRs in Australian grain-growing regions found that growers who use PGRs aim to produce a compact crop that is easy to harvest.

The survey found no consistent yield improvement in response to PGRs.[11 12]

10.2.2 Plant growth regulator trials in faba bean and broad bean

Plant growth regulators used in trials in faba bean in Victoria and South Australia shown no effect on grain yield.

A recent trial in Hart, South Australia, found that PGRs were effective in reducing the height of early-sown faba bean, while one PGR reduced the level of crop lodging. Grain yield was unaffected. Further field testing is needed to better understand the best application timing and quantify the benefits of PGRs.[13]

A 2013 trial at Glenroy, south-east South Australia, compared 17 canopy management treatments, including PGRs, herbicides, fungicides, grazing and delayed sowing for the broad bean variety PBA Kareema⁽ᶦᵇ⁾. All products are unregistered for broad bean but were used for experimental purposes in the trial. An earlier trial in the same project evaluated the use of several PGR hormones and two herbicides for their effect on plant growth, and found a number of these treatments regulated plant growth at Tarlee in South Australia's Mid North.

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7 M Lines, L McMurray (2014) Broad bean canopy management. Mackillop Farm Management Group Trials Results 89-91, http://www.mackillopgroup.com.au/media/2013%20Trial%20Book/bean_management.pdf

8 D Jones (2016) Molybdenum, row spacing, plant population and PGRs in faba beans, https://thestubbleproject.wordpress.com/2016/04/26/molybdenum-row-spacing-plant-population-and-pgrs-in-faba-beans/

9 T Botwright Acuna, A Merry, G Dean, A Carew, P Leith, R Nelson (2014) Plant growth regulators in broadacre crops. GRDC Update paper, 25 February 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Plant-growth-regulators-in-broad-acre-crops

10 D Jones (2014) Plant growth regulators. GRDC Update paper, 31 July 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators

11 D Jones (2014) Plant growth regulators. GRDC Update paper, 31 July 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators

12 T Botwright Acuna, A Merry, G Dean, A Carew, P Leith, R Nelson (2014) Plant growth regulators in broadacre crops. GRDC Update paper, 25 February 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Plant-growth-regulators-in-broad-acre-crops

13 C Walela, J Paul, A Pearce, A Ware, J Brand, L McMurray (2016) Faba bean agronomy and canopy management. Hart Trial Results 2016, 25-30, http://www.hartfieldsite.org.au/media/2016%20Trial%20Results/Hart_Trial_Results_2016_Faba_bean_agronomy_and_canopy_management.pdf

Two canopy management treatments (simulated grazing and a low rate of glyphosate) suppressed plant height with no significant effect on grain yield. All other treatments either caused a yield penalty or did not suppress plant height. Several herbicides showed promise as growth regulators, but require revision of application rates.[14]

In an irrigated trial at Kerang in north-west Victoria, a chemical PGR and fungicide (used as a PGR) were applied before flowering. PGRs had no effect on the yield, height or lodging of faba bean (Table 1).

Table 1: Yield, height and lodging of faba bean with applied plant growth regulator in an irrigated trial at Kerang, Victoria.[15]

PGR	Yield (t/ha)	Height (cm)	Lodge score
Control	6.24	137	4.3
Reward®	6.24	133	4.3
Prosaro®	6.34	127	3.7
P	0.795	0.373	0.694
L.S.D.	Not significantly different (NS)	NS	NS
CV%	3.3	6.2	20

14 M Lines, L McMurray (2014) Broad bean canopy management. Mackillop Farm Management Group Trials Results 89-91, http://www.mackillopgroup.com.au/media/2013%20Trial%20Book/bean_management.pdf

15 D Jones (2016) Molybdenum, row spacing, plant population and PGRs in faba beans, https://thestubbleproject.wordpress.com/2016/04/26/molybdenum-row-spacing-plant-population-and-pgrs-in-faba-beans/

Pre-harvest treatments

Key points

- **Desiccation and windrowing can be used to enable earlier harvest and to dry out green weeds. They assist with uniform ripening of the crop.**
- **Crop-topping is primarily used to minimise weed seedset and is based on the maturity of the target weed. In most cases beans will not be fully mature when crop-topping for weed management and there will be some yield penalty, but this may be necessary to achieve control of particular problem weeds such as herbicide-resistant weeds.**
- **Weed wiping is not suitable for beans as even the shorter varieties are too tall relative to weeds such as ryegrass.**
- **Do not use glyphosate on crops intended for use as seed or for sprouting markets, even when applied after physiological maturity, as it reduces seed viability.**

MORE INFORMATION

GRDC Fact Sheet, Pre-harvest herbicide, www.grdc.com.au/GRDC-FS-PreHarvestHerbicide

Pulse Australia has information on desiccation and crop-topping in pulses, see http://pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping

11.1 Purpose

Pre-harvest treatments to assist with harvest and weed management include:[1]

- Desiccation — herbicide is applied to a mature crop to remove moisture from the crop and any green weeds to enable an earlier harvest. Faba bean is well suited to desiccation and this is becoming common practice.
- Windrowing – cutting the crop to assist with direct heading, uneven crop maturity, drying green weeds or for weed seed management. Windrowing should be used if direct heading is likely to be a problem and should not be necessary every year.
- Crop-topping – herbicide is applied specifically to reduce weed seedset with minimal damage to the crop. In longer growing season environments faba bean mature too late to crop-top successfully without damaging seed yield and quality.
- Weed wiping – herbicide is applied to weeds that project above the crop canopy. While this technique is widely used in other pulse crops it is not suitable for beans as even the shorter varieties are too tall relative to weeds such as ryegrass.

Desiccation and windrowing are primarily used to enable earlier harvest and to dry out green weeds. Timing is based on the maturity of the crop.

Crop-topping is primarily used to minimise weed seedset and its timing is based on the maturity of the target weed. It is essential to ensure that the crop is mature enough so that the seed is not damaged. Crop-topping uses different chemical products or rates to desiccating.

Desiccation and crop-topping can reduce seed viability depending on the timing and product used. They are not recommended for crops intended to be saved for seed.[2]

1 Pulse Australia (2016) Southern faba & broad bean best management practices training course – 2016. Pulse Australia

2 Pulse Australia (2016) Pulses: Desiccation and crop-topping. Pulse Australia, http://pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping

11.2 Correct timing based on seed and pod development

Seed is at its maximum size and weight once a seed is physiologically mature. Faba bean maturity can vary substantially both within the plant and between different parts of the paddock. Both soil type and disease severity can influence seed maturity.

Lower pods will mature before the upper pods. In commercial crops it is common for the lower 30% of pods to have dried below 15% seed moisture content (seeds detached from the pod) while the upper 25% of pods on each branch are still at 30–40% moisture and at varying stages of maturity.

Take samples from a number of sites within a paddock to accurately assess seed maturity in both upper and lower pods.

Select a representative stem or branch from each of the plants sampled.[3] Start at the bottom of the plant and check one pod at each node moving up the stem (Figure 1). Remove the seeds from each pod and check the hilum to determine maturity. The hilum is the scar-like part of the seed where it is attached to the pod (Figure 2). A mature seed will have a black line on the hilum. Plants will still be green when the hilum has started to turn black.

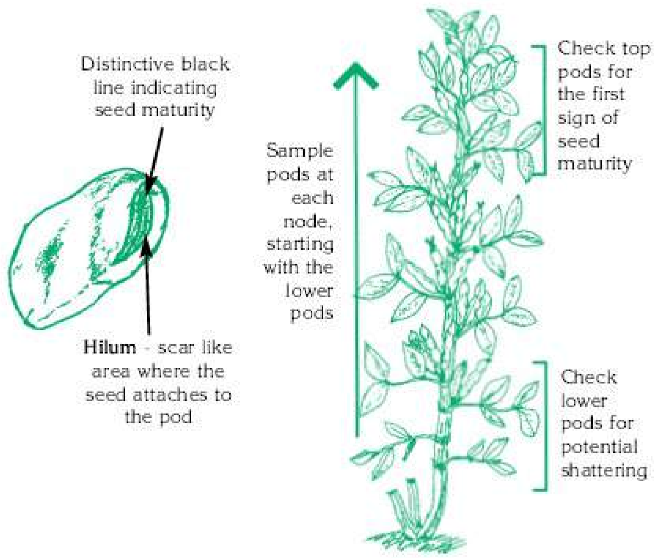

Figure 1: *Check maturity of pods from the bottom of the plant to the top.*

Source: Matthews and Carpenter (1999) NSW DPI

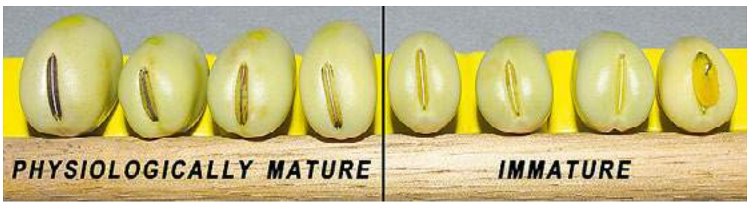

Photo 1: *Faba bean seed is mature when the hilum has started to turn black.*

Photo: Gordon Cumming, Pulse Australia

Seed maturity is the only way to fully determine crop maturity. Using alternative measures such as leaf senescence or the colour of lower pods is misleading as they may be influenced by disease.

3 P Matthews, D Carpenter (1999) Windrowing faba beans. Pulse Point 9, NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/windrowing-faba

Correct timing is essential to ensure that both yield and grain quality are not compromised. Desiccation, crop-topping and windrowing will stop seed from maturing further.

Timing is similar for desiccation and windrowing. The ideal timing for crop-topping is more dependent on balancing the correct stage of weed development with suitable timing for crop maturity. Understanding and measuring seed maturity is essential.

Crop maturity will vary within a plant and across a paddock so timing will always be a compromise between too early or too late depending on the purpose of the activity.

11.3 Desiccation

The purpose of desiccation is to ensure an even ripening of the crop and to 'brown-off' late weed growth for earlier and easier harvesting.[4] It is particularly useful when there is uneven ripening across the paddock. Desiccation can advance maturity by up to 10 days.

The optimal stage to desiccate the crop is when the vast majority of seeds have reached physiological maturity, i.e. 90–95% of the crop. This is when the hilum is turning black on the seeds in the uppermost (25%) pods (Figure 2). At this stage the upper pods are still bright green, there is still green leaf present, but the lowest pods are starting to turn black and have seeds with completely black hilums.

Applying desiccants to seed that is still green and actively filling will result in:

- a reduction in grain size (and yield);
- an increase in a greenish discolouration of the seed coat; and
- a reduction in seed viability (dead or abnormal seed).

Do not use glyphosate in faba bean crops intended for use as seed or for sprouting markets, even when applied after physiological maturity. It can substantially reduce seed viability (Table 1).

Table 1: The effect of desiccation and windrowing timing on seed viability.

Treatment	Crop stage	Normal seed (%)	Abnormal seed (%)	Total germinated (%)
Nil pre-harvest treatment		92	2	94
Desiccated – glyphosate	Seed physiological maturity	27	63	90
	Seed physiological maturity + 6 days	64	29	93
Windrowed	Seed physiological maturity	89	2	91
	Seed physiological maturity + 6 days	85	7	92

Source: Matthews & Holding (2004) via Southern faba & broad bean best management practices training course 2016

Herbicide rates for desiccation are higher than required for crop-topping.

Harvest 5–10 days after desiccation. Observe all withholding periods to avoid chemical residues in grain.

4 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

MORE INFORMATION

A fact sheet on 'Windrowing faba beans' is at http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/windrowing-faba

A GRDC Update paper on 'Direct heading v. windrowing' is at https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/Faba-beans-Direct-Heading-vs-Windrowing

VIDEO

Swathing faba bean, https://youtu.be/5JonEwOa6HM

VIDEO

Windrowing and harvesting faba bean, https://youtu.be/ijmlTLt5jNI

11.4 Windrowing

The purpose of windrowing is to reduce problems associated with direct heading, uneven crop maturity or weed seed management. The technique can bring the harvest date forward (Figure 3), uniformly ripen the crop and protect from shattering where harvest is to be delayed. It can also reduce weed seedset.

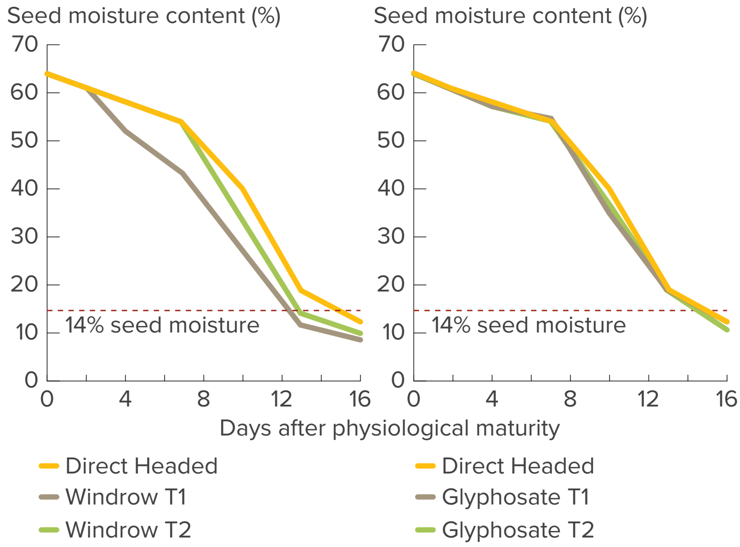

Figure 2: *Moisture content of faba bean at harvest: comparison of windrowing (left) or desiccation (right) with direct heading with no pre-harvest treatment.*

Source: Matthews & Holding (2004)

The timing for windrowing is similar to desiccation and should be based on seed maturity (see Section 11.2 Correct timing based on seed and pod development).

Windowing too early can cause yield loss as seeds are not filled, and small or shrivelled seeds classed as defective. This can reduce quality, causing downgrading from human consumption markets to stockfeed grade.

The earliest a bean crop should be windrowed is when the top pods are mature, as indicated by the blackening of the seed hilum.

IN FOCUS

The advantages of windrowing beans are:[5]

- Uniform maturity of the crop for harvest.
- Earlier harvest is possible at higher grain moisture content, avoiding clashes with cereal harvest.
- Early harvest with fewer losses where lodged.
- Reduced pod splitting and shattering after rain.
- Lower cutter-bar height, enabling lowest pods to be harvested.
- Reduced damage to headers working in rougher country. Sticks and stones can damage knife fingers and sections, retractable fingers and other components. Using pick-up fronts to harvest windrows will leave most of these on the ground.
- Better handling of excessively tall crops. In tall crops the harvester reel can push plants forward, causing problems feeding material into the harvester, and leading to grain loss as the cutter bar causes vibration and pod shattering in front of the harvester. Direct heading of tall crops can also be very slow, so windrowing can increase harvest efficiency.
- Late-maturing weeds are dried to enable earlier harvest. This reduces the risk of seed staining, quality downgrading and storage problems from green weed contamination. Staining of seed by green weed trash can be avoided. Heat build-up during storage by green weed trash is avoided.
- Weed seed is moved into a windrow that can be burnt after harvest.
- Better crop survival when harvest is delayed through reduced shattering and lodging.
- Reduced snail contamination in the sample, if windrowed late directly in front of the harvester.
- Harvest efficiency where two windrow widths are harvested in one pass of the harvester.

Windrowing is often used if directing heading is likely to be a problem and should not be necessary every year.

Disadvantages of windrowing:

- An extra paddock operation and cost is involved.
- Windrowing too early (prior to crop maturity) can cause significant yield and quality losses. Small and shrivelled seed will result from drying-down of immature seed.
- Windrowing too late can cause shatter losses as the cutter bar hits the crop.
- Heavy rain on windrowed beans may downgrade quality.

If windrowing is too early some cotyledons may stay green and affect marketability.

5 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

Windrowing too late can result in shattering losses. Lower pods may be more advanced than the top pods and may become brittle and shatter when windrowed. Disease, a spell of hot windy weather or moisture stress can cause the lower pods to ripen prematurely. Windrowing can only be delayed in cold and moist conditions.

The crop will not mature evenly, so it is important to select a timing that balances potential for lower pod shattering and possible yield losses from immature top pods.

When windrowing faba bean set, the cutting height just below the bottom pods, with the reel following the top of the crop. Use a slow reel speed.

Ensure the delivery opening in the windrower is large enough to prevent blockages that will result in lumpy windrows.[6] Use a maximum windrower width in bulky crops to avoid problems with windrowing, extended drying time or harvesting of excessively large windrows. A dense and tightly knit windrow will produce the best results (Photo 1).

Curing usually takes 10–12 hot days but could take longer if there are green weeds (Photo 2). Adverse weather conditions between windrowing and harvest may result in losses, as with any other windrowed crop.

Windrowed crops can contain more dirt, particularly if rain has fallen on the windrow.[7] Avoid placing the windrow onto wheel tracks, particularly in controlled-traffic area paddocks. Avoid particularly bulky windrows as these will take longer to dry. Likewise, avoid windrowing smaller crops where the smaller windrows may be difficult to pick up and the cost cannot be recouped.

Pick-up fronts are the most common type used for harvesting windrows. However, crop lifters used close together on open fronts have been used with some success.

Birchip Cropping Group (BCG) trials from 2001 in the Wimmera showed that direct heading could be a better option than windrowing.[8] Windrowing reduced yield and quality, even at the preferred windrow timing, when seed at the top had a distinct black hilum. Seed discolouration in the windrow resulted from rainfall and contact with moist soil.

A 2008-09 survey of faba bean growers in northern NSW found that windrowing generally produced fewer harvest losses than direct heading, but that direct heading could achieve similar success rates if done carefully.[9] When prices are low direct heading can be more profitable. Factors to consider for successful windrowing included:

- correct timing;
- size of the windrow – having enough material to feed into the pick-up front;
- skill and speed of the swather operator – use a reliable contractor and adjust the speed;
- placement – it is difficult to pick up windrows in wheel tracks; and
- level ground – hollows and ridges make it difficult to place and pick up the windrow.

South Australian Research and Development Institute (SARDI) trials from 2013 to 2015 at three locations in South Australia showed that windrowing and crop-topping did not reduce seed quality (size, staining, mould, etc).[10] However, a delayed late harvest after windrowing or crop-topping (e.g. leaving the windrow a longer period before pick-up) did reduce seed quality. In general, the older varieties (Fiesta VF, Nura⁽ᵇ⁾)

6 T Weaver (2015) Profitable pulses – it's all about the harvest window. GRDC GroundCover™, Issue 118, September—October 2015, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-118-Sep-Oct-2015/Profitable-pulses-its-all-about-the-harvest-window

7 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

8 Birchip Cropping Group (2002) Faba beans – windrowing vs direct heading 2001. Online farm trials website http://www.farmtrials.com.au/trial/13605

9 M Parker (2010) Faba beans: direct heading v. windrowing. GRDC Update Papers, 21 September 2010, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/Faba-beans-Direct-Heading-vs-Windrowing

10 J Davidson, R Kimber, C Walela, L McMurray, K Hobson, J Brand and J Paull (2016) Pulse diseases in 2015. GRDC Updates Paper, 9 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Pulse-diseases-in-2015

were more vulnerable to deterioration in seed quality than the newer varieties (PBA Rana(b), PBA Samira(b) and PBA Zahra(b)). Note that the trial was set up to evaluate the impact of windrowing and crop-topping on the development of field mould, but conditions were too dry.

Photo 2: *Faba bean windrows.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 3: *Inside an opened faba bean windrow.*

Photo: Wayne Hawthorne, formerly Pulse Australia

11.5 Crop-topping

Crop-topping is primarily used to minimise weed seedset and is based on the maturity of the target weed. However, it is essential to ensure that the crop is mature enough to prevent damage to the seed. Correct timing is critical.

Crop-topping will also bring forward the harvest date (Photo 4).

Photo 4: *Crop-topping. Missed strip during crop-topping shows later maturity than the crop that has been crop-topped.*

Photo: Wayne Hawthorne, formerly Pulse Australia

MORE INFORMATION

The DPIRD website has information on crop-topping pulse crops, including ryegrass stages for crop-topping, at https://www.agric.wa.gov.au/lupins/crop-topping-pulse-crops

Pulse Australian web alert: Desiccation and crop-topping in pulses, http://pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping

Most faba bean varieties mature too late to crop-top successfully without damaging seed yield and quality. It is only suitable for earlier-maturing varieties of faba bean. Broad bean generally matures too late for crop-topping.

The risks of crop-topping are:

- Topping too early can reduce crop yield by increasing the number of small, immature seeds.
- Topping too early can damage seed quality through discoloured cotyledons (kernel) and seed coats.
- Rain soon after topping can make seed more vulnerable to seed staining.

The benefits of crop-topping are:

- To control seedset in late-germinating or herbicide-resistant weeds such as ryegrass.
- To dry-off late-maturing weeds to reduce high moisture or contamination of harvested grain.
- To stop crop growth and help to mature beans earlier.

Crop-topping is not recommended for crops that are to be kept for seed or sprouting. The risk of reduced seed viability is dependent on the timing and product used. Desiccation, but not with glyphosate, is a better option for seed crops.

To minimise the further development of glyphosate resistance in grass weeds, growers are encouraged to use alternatives wherever possible, e.g. to use paraquat for crop-topping in pulses rather than glyphosate, due to the high number of glyphosate crop-topping uses in other crops.[11]

Crop-topping with glyphosate or paraquat can reduce viable seedset in ryegrass by 90%.[12] However, in practice, crop-topping controls 70–80% of seedset as it is generally applied later to reduce the risk of reducing crop yield.

For ryegrass control, glyphosate can be applied at the lower recommended rate when the ryegrass is flowering or at the higher label rate when the ryegrass is at the milky dough stage (label).

For ryegrass control, paraquat should be applied at the milky dough stage. This is ideally when the last of the seeds have emerged at the bottom of the plant and the majority are at or just past flowering. It should be before haying-off is observed. Higher rates will provide better reduction of seedset, but is also more likely to result in crop damage and yield reduction.

At the milk stage paraquat is more effective on ryegrass seedset (64–97% control) than glyphosate (14–74% control).[13]

The preferred timing for ryegrass seedset is often before the crop has fully matured and topping early can lead to yield losses of more than 25%.

Radish needs to be sprayed at the pre-embryo stage and for most bean crops this will pose a significant threat to crop maturity. The effectiveness of crop-topping for radish control is lower because of the indeterminate flowering of radish that means it flowers over an extended period of time.

SARDI trials in 2009 found that there was no general yield loss when crop-topping at the recommended time. However, there was an average loss of 9% in grain weight (Table 2). A hot and dry November led to early senescence of bean varieties and reduced grain yields in later maturing varieties. This may have masked responses to the crop-topping treatments. Results showed that:

- Manafest was the only variety to show a yield loss at the recommended timing based on ryegrass seed stage. Breeding line 2 (early maturing) was the only

11 J Davidson, R Kimber, C Walela, L McMurray, K Hobson, J Brand and J Paull (2016) Pulse diseases in 2015. GRDC Updates Paper, 9 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Pulse-diseases-in-2015

12 MJ Walsh and SB Powles (2007) Management strategies for herbicide-resistant weed populations in Australian dryland crop production systems. Weed Technology, 21, 332-338.

13 GRDC (2014) Pre-harvest herbicide use Fact Sheet. GRDC, October 2014, www.grdc.com.au/GRDC-FS-PreHarvestHerbicide

variety to show no loss of grain weight. Breeding line 2 also showed the least grain yield loss (73% of untreated, but not significantly different) with early crop-topping.

- When crop-topped 3 weeks earlier than the recommended ryegrass stage, faba bean yields ranged from 49–73% to that of untreated (27–51% yield loss).
- When crop-topped at the recommended stage, yields were 73–98% that of untreated (2–27% yield loss).
- When crop-topped 2 weeks after the optimum ryegrass stage, yield was 71–107% of untreated.
- Grain size was affected by crop-topping, being reduced to 73% of untreated when crop topped 3 weeks early, 91% at the recommended stage and unaffected when crop topped 2 weeks late. Visual grain quality may have been affected to prevent delivery under national receival standards.

Table 2: Impact of crop-topping timing on faba bean varieties of differing maturity, Cockaleechie SA, 2009.

	Yield (t/ha)	Yield (% of nil) for each timing			Grain weight (g/100 seeds)	Grain weight (% of nil) for each timing		
	Nil	Minus 3 weeks (8/10/09)	Recommended* (19/10/09)	Plus 2 weeks (2/11/09)	Nil	Minus 3 weeks (8/10/09)	Recommended (19/10/09)	Plus 2 weeks (2/11/09)
Line 1 (L)	1.39	64	98	94	81.1	87	91	100
PBA Rana⁽ᵖ⁾	1.56	49	84	92	83.9	83	89	99
Line 2 (E)	1.14	73	87	107	62.3	80	96	103
Line 3 (E-M)	1.39	61	90	91	75.8	82	94	101
Line 4 (M)	1.30	53	82	81	62.1	85	88	99
Doza⁽ᵖ⁾	1.19	67	89	102	56.0	85	92	103
Farah⁽ᵖ⁾	1.22	63	92	79	65.8	88	92	99
Fiesta VF	1.46	51	84	101	65.1	84	90	103
Fiord	1.18	67	80	103	52.3	73	87	101
Line 5 (E)	1.24	21	74	71	65.6	74	85	94
Manafest	1.48	66	73	79	84.5	90	90	101
Nura⁽ᵖ⁾	1.43	58	87	96	63.3	86	91	99
Mean (t/ha)	**1.33**	**0.80**	**1.13**	**1.22**	**68.1**	**16.3**	**15.9**	**18.2**
Mean (g/100)						56.8	61.7	68.2

Shading denotes significantly different to the nil treatment
(E) = early maturing breeding line, (M) = medium maturing, (L) = late maturing
* Recommended is the date that is ideal for crop topping ryegrass

Source: A Ware, M Lines and L McMurray (SARDI) Southern Pulse Agronomy Research Trials via Pulse Australia (2016) Southern faba & broad bean best management practices training course

MORE INFORMATION

AVPMA Webpage: PubCRIS database, https://services.apvma.gov.au/web/guest/pubcris

11.6 Chemical products registered for use in faba bean

Pre-harvest chemical application to crops increases the risk of detectable herbicide residues in harvested grain, potentially leading to breaches of maximum residue limits (MRLs).[14] MRLs vary according to herbicide, crop and market and these need to be understood. Detection of chemical residues above MRLs will jeopardise market access and the future of the Australian grains industry. See http://www.agriculture.gov.au/ag-farm-food/food/nrs for details of the National Residue Survey conducted annually across all grains.

Follow product labels correctly and adhere to withholding periods for harvest and grazing or cutting for stock feed (GSF) (Table 3).

Glyphosate is not registered for seed crops and should not be used in pulses intended for seed production or sprouting

Table 3: Registered products for desiccation and crop-topping of faba bean.

Herbicide	Example trade names	Operation	Rate	Withholding period
Diquat 200 g/L	Reglone®	Desiccation	2—3 L/ha	Grazing/stock feed (GSF*): 1 day Harvest: 2 days
Paraquat 250 g/L	Gramoxone®	Crop-topping	400—800 mL/ha	GSF: 1 day (7 days for horses) Stock must be removed from treated areas 3 days before slaughter Harvest: 7 days
Glyphosate 500 g/L	Touchdown Hi Tech®	Crop-topping	300—700 mL/ha	GSF: 7 days Harvest: 7 days
Glyphosate 570 g/L	Roundup Ultra Max®	Crop-topping	300—645 mL/ha	GSF: 7 days Harvest: 7 days
		Desiccation	645 mL/ha to 1.7 L/ha	GSF:7 days Harvest: 7 days

* GSF = withholding period for grazing or cutting for stock feed
Observe the harvest withholding period and GSF for each crop.
Always read the label supplied with the product before each use.
Source: Pulse Australia (2016) Pulses: Desiccation and crop-topping

14 GRDC (2014) Pre-harvest herbicide use Fact Sheet. GRDC, October 2014, www.grdc.com.au/GRDC-FS-PreHarvestHerbicide

Harvest

Key points

- **Harvest early for better quality and to avoid physical damage during the process. Managing for an early harvest begins with sowing on time.**
- **Windrowing or desiccation helps to enable an earlier harvest date.**
- **Faba bean is marketed on visual appearance and maintaining a high-quality product is essential to Australia being able to compete on the international market.**
- **The large grain of faba and broad bean is easy to crack and needs to be harvested gently. Adjust harvester settings to minimise cracking and blockages.**
- **Harvest at moisture levels up to 12—14% to avoid damage to the grain. Harvest in humid conditions early in the day or into the evening. When harvesting in extreme heat. or when the crop is too dry. makes the lower pods prone to shattering and the grain vulnerable to cracking.**

MORE INFORMATION

See the GroundCover™ article: Profitable pulses – it's all about the harvest window, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-118-sep-oct-2015/profitable-pulses-its-all-about-the-harvest-window

The key to maximising profit from pulses is grain quality.[1] Human food markets demand a quality sample without cracking, staining, de-hulled seeds or insect damage. Visual appearance is everything. Therefore, the most important factors when harvesting faba bean are to harvest early for better quality and to avoid physical damage during the process.

12.1 Harvesting for seed crops

When harvesting for seed, choose an area of the paddock where there has been minimal disease, pest and weed infestation. This will maximise germination and minimise weed and disease carryover. The middle of the crop is likely to be the best area for seed production as weed and insect problems are usually worse at the edges.

A gentle harvest will provide the best seed quality.[2] It is important to minimise grain cracking even if it results in a poor sample. The seed can always be cleaned before sowing. Rotary harvesters are more gentle and will cause less damage to the seed than conventional harvesters.

Germination rates are improved if seed is harvested at 12–14% moisture and stored in mesh silos, aerated, or immediately graded and bagged. Ensure headers, bins, augers and other equipment are free of grain contaminants.

Seed harvested earlier is less likely to harbour diseases such as Ascochyta.

Avoid desiccating or crop-topping of seed crops as this can reduce germination rate. (Also see Section 3.10 Seed quality).

12.2 The impact of delayed harvest on profitability

If managed correctly, pulses can be more profitable than cereals. Sow and harvest on time to maximise returns.

Some reasons why people delay harvest of pulses include:

- When there is a clash with cereal harvest, bean crops are often treated as second best compared with cereals.
- Perceived better chance of achieving premiums for Prime Hard or Australian Hard wheat or malting for barley. In reality, the premiums for harvesting pulses at the optimum time are often greater, or the penalties more severe from delays.
- The false perception that pulses tolerate weathering.
- Uneven ripening if not desiccated or windrowed, especially when grown on heavy clay or variable soils.
- The false belief that pulses are slower or more difficult to harvest. Desiccation or windrowing and careful harvest set-up can overcome these difficulties.

Despite these beliefs, delaying harvest is not recommended. The impact of delays include:

- yield loss;
- deterioration in grain quality;
- missed marketing opportunities; and
- a more difficult harvest.

1 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba Beans: The Ute Guide. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide/

2 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

MORE INFORMATION

The Pulse Australia Visual guide 'Common defects of beans' can be found at http://pulseaus.com.au/storage/app/media/markets/2009_FabaBroadbean-visual-quality.pdf

Pulse Australia webpage: Receival and trading standards, http://www.pulseaus.com.au/marketing/receival-trading-standards

12.2.1 Yield losses

It is not unusual to see a 4–6 week spread in the harvesting of faba and broad bean crops planted on the same sowing rain. Many late-harvested crops are often down around 8% moisture content, whereas the maximum moisture content for receival is 14% and preference is for 12%.

Grain with a lower moisture content at delivery will weigh less and return less money to the grower, for example:

- 500 tonnes of faba bean at 14% grain moisture and $450/t is worth $225,000
- the same grain harvested at 8% moisture delivers 470 t, and at $450/tonne is worth $210,600
- this is a loss to the grower of $14,400.

Delaying harvest can lead to an increase in lodging, shattering and pod loss. Yield losses of up to 30% have been recorded in the field.

Most of the losses were either due to pod loss at the header front, or as unthreshed pods lost out the back of the machine. Field-weathered faba and broad beans after rain are also more difficult to thresh out at harvest, and often contain much higher levels of unthreshed pods and pod material.

Lodging can increase the longer faba and broad beans are left standing, and the risk is higher if the crop is high yielding and has been planted on wide rows.

Photo 1: *Harvest as soon as beans are mature.*

Photo: Wayne Hawthorne, formerly Pulse Australia, via Yeatman *et al* (2009)

12.2.2 Quality losses

Early-harvested grain is of better quality in terms of colour, weathering and disease. Early-harvested seed is also more resilient against breakage during harvesting and subsequent handling, even at low moisture contents.

Marketing

Faba bean is marketed on visual appearance and maintaining a high-quality product is essential to Australia being able to compete on the international market. Some beans are sold for processing into dahl or flour by removing the seed coat and splitting the cotyledons. Older seed splits better than newer grain but the seed coat is more likely to crack before processing. As the milling process relies on the seed coat remaining firmly attached to the cotyledons this can reduce the percentage of splits and the quality of the final product.

Faba and broad beans that do not meet the Number 1 Receival Standard of 6% defective beans will need to be graded or downgraded. (See Section 12.13 Receival standards). This incurs a cost to the grower of:

- $15—$25/t grading costs; and
- downgrading of the seconds into the stockfeed market at a value of $120—$140/t.

Cracking

The seed coat of faba and broad beans is very prone to cracking if it has been exposed to wetting and drying events, due to rain or heavy dew. The seed expands as it absorbs moisture and contracts as it dries, weakening the seed coat. This makes it much more vulnerable to mechanical damage during harvest and handling operations.

Levels of cracked and damaged grain can be as high as 50% in extreme cases of field weathering and prolonged rainfall.

Darkening

Darkening of the seed coat is caused by oxidation of polyphenol compounds (tannins). Darkening of the seed coat is a natural process, but is accelerated by:

- rainfall;
- cool-mild temperatures;
- high humidity; and
- sunlight.

While there is usually no direct penalty or discount for a moderate degree of seed-coat darkening, it does have a significant impact on the marketability of the product and the reputation of the Australian industry as a supplier of quality product. Quality is becoming increasingly important as Australian traders attempt to establish market share against other bean-exporting countries, such as France and the UK. Because of the darkened seed coat, carrying faba bean over from one season to the next limits its marketability to either feed markets or to a processor that can dehull them.

It is highly likely that there will be greater segregation and premiums paid for lighter-coloured, large-seeded faba and broad bean as new varieties with these traits are developed. The Australian industry, through our overseas markets, has become more quality conscious. Newer, lighter-coloured varieties do darken slower than the older varieties and are well accepted in the main Middle Eastern markets.

Pests and diseases

Weathering increases the potential for diseases and pest damage.

Humid and wet conditions favour mould infection, most commonly *Alternaria*, but also *Aspergillus*, *Cladosporium* and *Penicillium*. High levels of mould infection will also cause darkening of the seed coat.

Late infection of Ascochyta can develop on dry, senescing pods under wet conditions, and can penetrate through to the seed in susceptible varieties. Receival standards for visible Ascochyta is a maximum of 1%.[3]

Native budworm can occasionally attack rain-softened pods. Insect-damaged seeds are classified as defective beans with a maximum tolerance of 3%.

Early harvest is recommended for crops with high snail populations. As the season progresses, snails are harder to dislodge from the canopy and are less likely to move down the canopy after light rain.

Pulse Australia has produced a visual guide to the common quality defects in beans (Figures 1–3).

3 Pulse Australia (2016) Receival & trading standards. Pulse Australia, http://www.pulseaus.com.au/marketing/receival-trading-standards

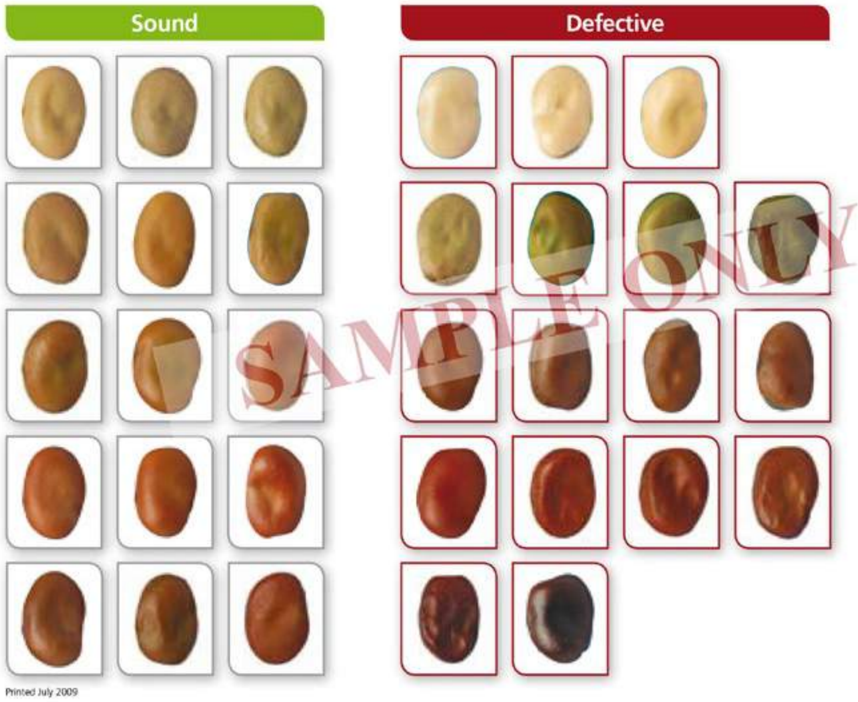

Figure 1: *Common quality defects of beans – colour.*

Source: Pulse Australia (2016)

Figure 2: *Common quality defects of beans – bin-burnt, heat-damaged, mould-affected, insect-damaged and sprouted.*

Source: Pulse Australia (2016)

MORE INFORMATION

For more information see the Visual Recognition Standards Guide 2017/18 http://www.graintrade.org.au/fact-sheets-publications

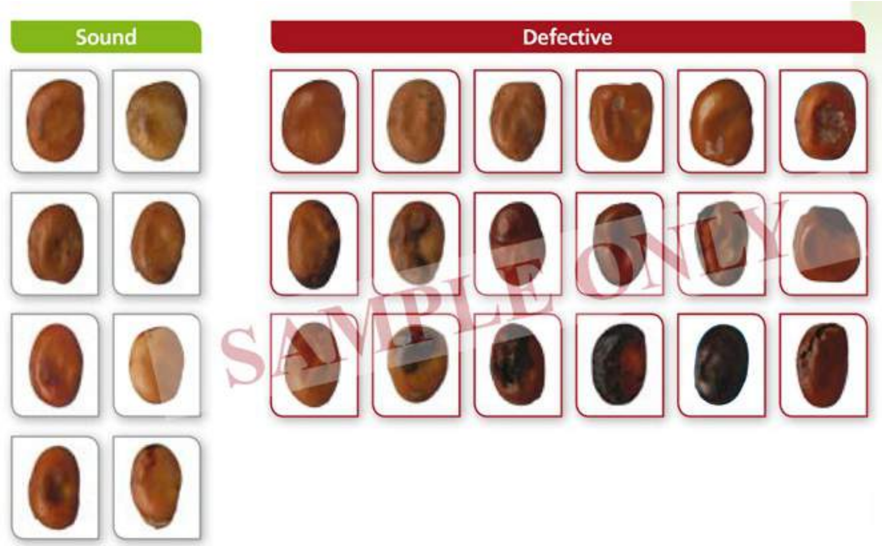

Figure 3: *Common quality defects of beans – insect-damaged and sprouted.*

Source: Pulse Australia (2016)

12.2.3 Missed marketing opportunities

Early-harvested crops usually attract a premium price. By harvesting early growers have better control over how and when a crop is marketed. Those who harvest late are often price-takers in a falling market or may encounter delivery delays.

12.2.4 A more difficult harvest

Early harvesting also means there may be fewer summer weeds to clog the harvester, stain the seed or contaminate the sample.

Late-sown bean crops are more likely to carry pods close to the ground, especially if seeding rates were low. When pods are low the harvest comb needs to be set close to the ground to avoid grain loss. This will increase the risk of soil, sticks and stones contaminating the sample or damaging the header.

12.3 Plan ahead for successful early harvest

Harvesting early is not a choice that can be made at the last minute. It requires careful planning from the beginning of the season. There are three broad areas that contribute to a successful early harvest: sowing, in-crop management and harvest management.

Sowing

- Sow at the earliest opportunity but within the preferred planting window for your area. This may involve dry sowing by a particular calendar date.
- Use adapted varieties that meet your target for early harvesting.
- Moisture-seeking equipment and/or press-wheels can significantly enhance seeding opportunities under marginal soil moisture conditions.
- Using precision planters or machines with automatic depth control will often achieve more uniform plant establishment and crop development, and consequently more even crop maturity. This is particularly so when sowing into marginal soil moisture and drying conditions.

In-crop management

- Control native budworm during flowering to maximise early podset.

Harvest management

- Windrowing can enable earlier maturity and harvest date.
- Desiccation can be used to dry late maturing plants and green weeds.
- Be aware that chemicals used to desiccate or crop-top may reduce seed yield and quality.
- Set up the header to operate efficiently at 14–15% grain moisture content. High moisture harvesting can commence earlier in the season and earlier each day. Harvesting at 14% moisture content, as compared to 12%, can effectively double the harvest period available on any one day in hot environments.
- Blend, aerate and/or dry the sample to the required receival standard of 14% moisture. (See Section 12.13 Receival standards).

More information on windrowing, desiccation and crop-topping is in Section 11 Pre-harvest treatments. Information on managing weeds at harvest is in Section 7.4.6 Managing weeds at harvest.

12.4 Paddock preparation

The harvester will need to cut the stem below the lowest pod, which may be close to the ground. To minimise the risk of soil and other debris entering the harvester it may be worthwhile to roll the soil after sowing, to flatten and firm the soil and depress obstacles like stumps and stones. Harvest early while the crop stands more erect to minimise dirt, rocks and sticks entering the harvester.

When sowing wide rows, use inter-row sowing into standing stubble to encourage early erectness.[4] This means that the lowest pods will be higher, making for an easier harvest. Note that wide rows can also make the crop more vulnerable to lodging.

12.5 Moisture content and temperature

Harvest faba and broad bean as soon as the crop is ready. A black hilum is the best indicator of grain maturity. Harvest when the upper pods turn black and the stems are brittle enough to feed through the harvester. There are often a few green parts scattered in the crop.

The varied ripening of bean stalks within a bean canopy can create difficulties direct harvesting beans at the 14% moisture limit. Green bean stalks can be a greater problem in rotary harvesters as they wrap around rotors, reducing rotor speed and overloading rotor drives.

Aim for moisture levels up to 12—14% to avoid damage to the grain.

If the crop is left until it is too dry the lower pods will become prone to shattering and the grain vulnerable to cracking.

Harvest in humid conditions early in the day or into the evening, when pods are less prone to shatter. This can lead to more unthreshed pods in the grain sample. Also avoid harvesting in extreme heat when the grain is drier and more easily damaged.

Depending on how level the paddock is, it is unwise to harvest faba and broad bean at night, unless using a pick-up front or some positive height control that will stop the front from digging into the dirt. Some farmers have fitted wheels on the outer end of their fronts, as a depth stop. Others have bought ultra-sonic automatic depth controls to control header height.

4 Pulse Australia (2016) Wide row pulses and stubble retention. Pulse Australia, http://pulseaus.com.au/growing-pulses/publications/wide-rows-and-stubble-retention

12.6 Harvester set-up

Excessive harvester speeds will cause large grain losses and may force more dirt into the harvester. Generally, speeds greater than 8 km/hour are not recommended, irrespective of the type of harvester front used.

The large seed of faba bean are prone to mechanical damage. It is better to take more care and prevent cracking, even if this means some grain is missed. A gentle harvest with a rotary harvester will generally cause less damage than the older style conventional harvester. The preferred harvester settings are listed in Table 1.

Table 1: A guide to harvester adjustments for faba bean.
Source: Lamb and Poddar (2008)

Reel speed:	slow	**Fan speed:**	high
Spiral clearance:	high	**Top sieve:**	32—38 mm
Thresher speed:	400—600 rpm	**Bottom sieve:**	16—19 mm
Concave clearance:	As wide as possible (e.g. 15—35 mm)	**Rotor speed (rotary machine):**	Depending on the model may be as low as 400—600 rpm, or up around 700—900 rpm

The pod height varies from 15—80 cm with pods held up in the canopy. Direct heading with crop lifters is possible, but should not be needed unless the crop is badly lodged, late-sown or drought affected.

Open-front or pick-up front machines will give the best result.[5] To reduce losses from vibration use double acting cutter bars and four finger guards with open second fingers (Photo 2).

On open-fronts, Vibra-mats can be used to improve the flow of cut material from the knife to the table augur especially in light crops. Plastic extension fingers fitted to the knife of a harvester can save significant losses for little financial outlay. Pods that would have fallen in front of the knife are caught on the fingers and pushed into the comb by the incoming crop (Photo 3).

If harvesting low and in uneven situations perforated screens may be used to remove the dirt before it enters the main working mechanism of the harvester.

Faba beans are easily threshed, so use a wide concave (15–35 mm). Try a concave setting fully open at the front, and half closed at the back.

Use a low thresher speed (400–600 rpm). Where there are a lot of summer weeds the speed may need to be increased to prevent blockages.

Use maximum wind and wide sieve or barley sieve settings. Bean seed is heavy compared to stem and leaf trash, so use draft to remove trash. Pulses are larger than wheat so a concave with many wires or blanked-off sections can stop grain separation. Alternating wires and blanking-off plates should be removed as they can prevent separation of large-seeded crops like faba bean.

The rake at the back of the sieve may need to be turned off to stop weeds entering the returns. Weeds blocking the walkers and sieves completely can lead to substantial grain losses.

5 T Weaver (2015) Profitable pulses – it's all about the harvest window. GRDC GroundCover™, Issue 118, September—October 2015, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-118-sep-oct-2015/profitable-pulses-its-all-about-the-harvest-window

Photo 2: *Four finger guards with open second fingers will reduce vibration to limit damage during harvest.*

Photo: Pulse Australia via Weaver (2015)

Photo 3: *Extension fingers can be fitted to the knife to prevent pods from falling in front of the blade.*

Photo: Pulse Australia, via Weaver (2015)

Harvester modifications need to be carefully assessed as the benefits may not justify the costs. Some modifications that may be useful for pulse harvest include:

- Flexible cutter-bar fronts (flexi-fronts) are hinged in short sections allowing harvest close to the ground.
- Aussie-air directs a blast of air through the reel fingers for both light and heavy crops.
- Harvestaire replaces the reel with a manifold to direct a blast of air into the front and is more effective in light crops.
- Vibra-mat vibrates with the knife to prevent bunching on open front headers. It is cheap and most effective for light crops, but speed needs to be carefully managed.
- Crop lifters are a knife attachment designed to lift lodged crops. Height control is important as they can bring in more sticks and soil.
- Extension fingers are plastic fingers approximately 30 cm long that are fitted over existing fingers to prevent pods from falling in front of the knife.
- Extended fronts extend the distance between the knife and the auger to a maximum of 760 mm to minimise losses from bunching at the auger.
- Platform sweeps are used with extended fronts and are fingers that rake material towards the auger to minimise bunching. They can be used with conventional fronts.

- Draper fronts (e.g. MacDon and Honey Bee) have large clearances behind the knife and carry the crop to the elevator.
- Disrupter kits can be fitted to a rotary harvester to reduce cracked grain and rotor speed loss. They are more suitable for an early harvest and immature green bean stalks as the disrupter can crack mature bean stalks leading to higher grain losses.

12.7 Harvesting windrows

Pick-up fronts can be used to harvest windrowed faba and broad bean. They greatly reduce the amount of dirt entering the harvester and make harvesting easier because the harvesting height is not as critical. The fingers on the pick-ups are closely spaced and will gather the entire crop, so crop losses are reduced.

There are different types of pick-ups. Some have fingers attached to rotating belts (draper pick-ups) and others have fingers attached to rotating drums (peg roller pick-ups). The peg roller types are similar and cheap but tend to shatter pods and cause slightly higher grain losses than the draper type. The draper types are more expensive but will reduce losses if harvesting late.

Crop lifters used close together on open fronts have been used with some success.

12.8 Lodged crops

Lodging can be an issue in good seasons when bean crops are tall or when sowing into wide rows.

If the crop has lodged it is usually best to harvest into the opposite direction, or at right angles, to the direction the crop has fallen. Crop lifters may help but have been known to dig in and bend the front. If sown on wide rows, use crop lifters and harvest up and back in the rows. The crop usually feeds in better over the knife section, and also provides the header operator with a better view of any rocks or sticks in the paddock.

12.9 Managing snails

Snails can build up more rapidly in faba bean, field pea and canola compared with other crops.[6] They can clog up and damage harvesting machinery, causing delays while snail pulp is removed from sieves and other parts of the machinery. If allowed to dry, crushed snail guts and dust can set like concrete.

A rule of thumb is that snail numbers above 5/m^2 in pulses will contaminate grain at harvest.

Faba and broad bean receival standards require no more than 2 (whole or more than half) dead or alive snails per 400 grams. (See Section 12.13 Receival standards).

Snails need to be managed throughout the season using integrated management (see Section 8.3 Key pests of faba bean).

12.9.1 Plan ahead for harvesting crops with snails

Stop baiting 8 weeks before harvest to avoid bait contamination in grain. There is zero tolerance for bait contamination at delivery.

Plan for an early and strategic harvest. As the summer progresses snails are harder to dislodge from the canopy and are less likely to move down the canopy after light rain.

Leave badly infected areas until cool or damp weather when snails are more likely to be down off the plants.

MORE INFORMATION

GRDC Fact Sheet: Snail management www.grdc.com.au/GRDC-FS-SnailManagement

Booklet: *Bash 'Em, Burn 'Em, Bait 'Em*, https://grdc.com.au/GRDC-Snails-BashBurnBait

6 GRDC (2012) Snail management Fact Sheet. GRDC, Southern and Western Regions, September 2012, https://grdc.com.au/GRDC-FS-SnailManagement

Windrow when cool and earlier in the season. Snails will invade windrows unless they are harvested early. Harvest windrows with an open front, fitted with crop lifters and PVC pipe covers to mask the unused width of the cutter bar.

12.9.2 Limiting intake of snails at harvest:

Header modifications and grain cleaning may be required to eliminate snail contamination in grain. These measures usually mean some grain will be lost. Harvester modifications require a trade-off between reduced throughput and increased grain losses.

- Use a dislodge bar about 2 m in front of the knife.
- Minimise the entry of dirt into the header by using a grate in the bottom of the front elevator.
- Increasing threshing intensity is not recommended as it will crush snails and damage grain.
- Scalp or screen: if there is a significant size difference you can scalp large snails and sieve smaller snails. Adjustable louvre sieves are suitable for faba bean.
- Use a smaller top sieve, or 10 mm punch hole or octagonal top sieve.
- Weld a lip onto the front of the top sieve to stop snails falling off.
- Add removable panels to the header to allow easy cleaning.
- Add a steel slat in the elevator to keep the elevator clean.
- Slow down the speed of the grain elevators.
- Loosen grain conveyor belts to allow them to stop before clogging and harvester damage occurs.
- Harvest with the repeat door open to prevent clogging where repeat ratios are high in snails and low in grain. Monitor grain losses as you move through different parts of the paddock.

Screens need to be cleaned regularly. Screens with large openings have quickly clogged with smaller beans and become ineffective (Photo 4). Screens with smaller openings are more effective in reducing snail and other contaminants in beans, but still need regular cleaning to maximise results.

Photo 4: *Screen blocked by beans if opening is too large.*

Photo: M Richards, via Pulse Australia (2016)

Assess the size and spread of the snail population as the margins of the paddock are more likely to be heavily infested than the interior.[7] Harvest modifications such as a dislodger bar may only be required on the margins.

7 SARDI. Management in Crops and Pastures. SARDI, https://grdc.com.au/GRDC-Snails-BashBurnBait

Dislodger bars can remove snails but will result in some yield loss. Research has shown that a rigid bar fitted with dangling V-belts at 100 mm spacing can dislodge 60% of round snails with 2–3% grain loss. Dangling chains (450 g/m chains at 50 mm spacing) caused 85% dislodgement but 7% yield loss. A rotary brush used at low rpm brushing against the direction of travel can also be effective.

Dislodging is most suitable when windrowing crops or for crops which are harvested early. As the harvest season progresses the force required to dislodge snails from crops increases. In a 7-week period, a 7–10-fold increase in the dislodging force required to remove snails from a faba bean crop was recorded.

IN FOCUS

12.9.3 Post-harvest grain cleaning

Samples with high numbers of snails will require cleaning. These steps can remove high numbers of snails with very little grain loss:

- Scalping.
- Use a soft snail-crushing roller on faba bean of 14–15% moisture content and with a roller clearance of less than half the width of the seed.
- Screening.

Gravity separation may be effective for grain coming out of storage as dead snails are lighter in weight.

12.9.4 Post-harvest paddock management for snails

- Burning stubbles in autumn is effective if a complete burn of the paddock is achieved.
- Control grass along fence lines where snails can remain undisturbed.
- Roll, slash, cable or trash harrow stubbles so snails cannot get above 5 cm off the ground.
- Beware of erosion.

MORE INFORMATION

GroundCover™ article: Careful harvester set-up puts more grain in the bin, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-95-november-december-2011/gc95-careful-harvester-setup

12.10 Assessing harvest loss

Grain can be lost at a number of places during harvest and each loss needs to be assessed so that corrective action can be taken. Grain can be lost:

- Before harvest (due to pod shedding, Figure 4(A)).
- At the harvester front (due to the front type or set-up, Figure 4(B)).
- In the thrashing system of the machine (due to drum, concave and sieve settings Figure 4(C)).

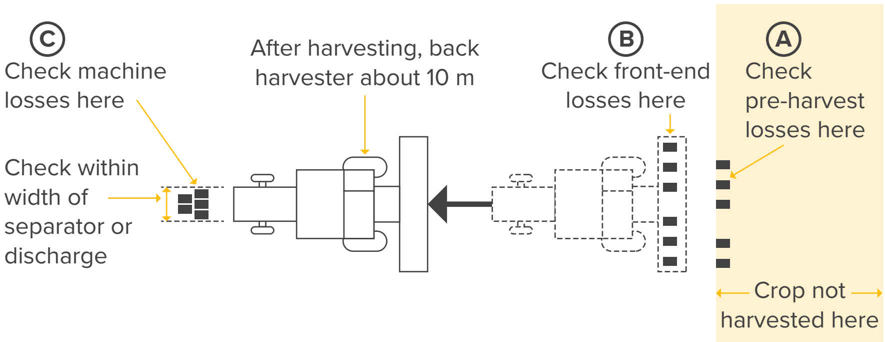

Figure 4: *Sampling places for estimating pre-harvest (A), front (B) and machine (C) losses.*

Source: The Chickpea Book, via Pulse Australia (2016) Southern faba & broad bean best management practices training course

To determine harvest losses:

1. Harvest a typical area without stopping the machine, then stop and allow the machine to clear itself of material.
2. Back the harvester about 10 m and shut down the machine.
3. Sample grain losses in each of the following three areas:
   » pre-harvest (that is in the standing crop in front of the harvester 'A');
   » front (in the cut crop in front of the harvester 'B'); and
   » machine (in the cut crop behind the harvester including trash 'C').
4. Sampling is best done using a quadrat with an area of 0.1 m^2:
   » count the number of seeds on the ground within the 0.1 m^2 quadrat. Ideally take 10 quadrats for each of the three locations (A, B and C); and
   » average the number of seeds per 0.1 m^2 quadrat for each area. Multiply by 10 to get the number of seeds/m^2.

Grain losses on the ground can be estimated by counting the seed/m^2 and calculating the weight per hectare based on the 100 seed weight of your grain.

Example: A typical 100 seed weight of PBA Samira⁽ᵈ⁾ is 71 g/100 seeds

If the seed on the ground is 25/m^2

$$\text{Seed loss} = \frac{\text{No. of seed/m}^2 \times 100 \text{ seed weight}}{10}$$

$$= (25 \times 71)/10$$

$$= 177.5 \text{ kg/ha}$$

It is important to take a number of samples across the paddock.

12.11 Harvest fire risk

According to Kondinin Group research, an average of 7% of harvesters will start a fire each year.[8] Of these fires, around one in 10 will cause significant damage to the machine or the surrounding crop.

Chickpea and lentil crops have residue that has a higher fire risk than other crops.[9] Faba bean, field pea and lupin also have a fine residue that powders easily and creates a higher risk of ignition. Canadian advice suggests that diseased crop leaves have a higher risk of fire.

A 2010 report on harvester fires estimated that three-quarters of fires started in the engine bay, with the remainder resulting from failed bearings or brakes, electricals, rocks strikes, etc.[10] The key to avoiding harvester fires is regular and thorough cleaning and inspection, and to postpone work when conditions provide a high fire risk.

When harvesting pulses it is important to clean down with a high pressure air compressor more frequently than with cereals. Harvesters can be modified to provide easier access for regular cleaning.

12.12 Handling and moving faba bean

Faba and especially broad beans are a very large, plump grain and are very prone to mechanical damage during handling. This especially applies to:

- overly dry grain (<10% moisture content); and
- crops that have been exposed to weather damage prior to harvest.

More information is in Section 13 Storage.

MORE INFORMATION

GRDC booklet: *Reducing harvester fire risk: The Back Pocket Guide*, https://grdc.com.au/GRDC-BPG-ReducingHarvesterFireRisk

Pulse Australia: Avoiding harvester fires, http://pulseaus.com.au/blog/post/avoiding-harvester-fires

GroundCover™ article: A few steps to preventing header fires, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-101/a-few-steps-to-preventing-header-fires

VIDEO

Watch GRDC video: Reducing the risk of harvester fires, https://youtu.be/WqTfR2ifM1I

8 GRDC (2013) Reducing harvester fire risk: The Back Pocket Guide. GRDC, https://grdc.com.au/GRDC-BPG-ReducingHarvesterFireRisk

9 Pulse Australia (2016) Avoiding harvester fires. Pulse Australia website, http://pulseaus.com.au/blog/post/avoiding-harvester-fires

10 G Quick (2010) An investigation into combine harvester fires. GRDC, Pulse Australia website, http://pulseaus.com.au/storage/app/media/blog%20assets/HARVESTER%20FIRES%20-%20Graeme%20Quick%20-%20Final%20Report.pdf

12.13 Receival standards

Table 2: Summary of National Faba bean receival standards Maximum moisture content (%)

	Maximum moisture content (%)	Minimum Purity (%)	Maximum defective plus poor colour (% by weight)	Screen size for defective (mm)	Poor colour maximum (%)	Foreign material maximum in total (%)
No 1 grade receival standard	14	97	6 includes: 3 Poor Colour; 3 total of all other defects except Mould	3.75 slotted	3 Includes ascochyta. Mould 1 per 400g	3
No 2 grade receival standard	14	97	10 includes: 7 Poor Colour; 3 total of all other defects	3.75 slotted	7 Includes ascochyta. Mould 1 per 400g	3
	Unmillable material maximum (%)	**Snail maximum**	**Insect maximum**	**Nominated weed seed maximums**		
No 1 grade receival standard	0.5 (0.3% soil)	2 per 400g	30 per 400g Grasshopper/locusts 4 per 400g	See receival standards appendix for amounts allowable		
No 2 grade receival standard	0.5 (0.3% soil)	2 per 400g	30 per 400g Grasshopper/locusts 4 per 400g	See receival standards appendix for amounts allowable		

Source: Compiled from national receival standards (2016/17)

Table 3: Summary of National Broad bean receival standards Maximum moisture content (%)

	Maximum moisture content (%)	Minimum Purity (%)	Maximum defective plus poor colour (% by weight)	Screen size for defective (mm)	Poor colour maximum (%)	Foreign material maximum in total (%)
No 1 grade receival standard CSP-2.1.1	14	97	7 Includes: 1.5 Insect Damaged 6 Mechanical Damage 3 Poor Colour 3 Ascochyta	6.0 mm slotted	3 Includes ascochyta. Mould 1 per 400g	3 including 0.5 max. unmillable
	Unmillable material maximum (%)	**Snail maximum**	**Insect maximum**	**Nominated weed seed maximums**		
No 1 grade receival standard	0.5 (0.3 soil)	2 per 400g	30 per 400g Grasshopper/locusts 4 per 400g	See receival standards appendix for amounts allowable		

Source: Compiled from national receival standards (2016/17)

MORE INFORMATION

For receival standards, please see: http://www.pulseaus.com.au/marketing/receival-trading-standards

See the Visual Recognition Standards Guide 2017/18 http://www.graintrade.org.au/fact-sheets-publications

12.14 Grain Delivery

12.14.1 Faba bean

On delivery, faba bean types are segregated on variety type (based on seed size). Off-types or small sized beans become part of the defective count. The majority of deliveries continue to be into the Australian faba bean number 1 grade receival (CSP-5.2.1) which requires low insect damage and breakages (defectives 6% maximum) and minimal foreign material or impurities (3% maximum). Discolouration or seed staining of grain is a specified rejection in bean grades number 1 and 2 grades. Failure to achieve the required receival standard may mean price discounts at the discretion of the buyer or re-cleaning to make grade.

The Australian faba bean canning grade receival (CSP-5.1.1) may be applied by a few buyers who supply premium human consumption markets. This tighter receival grade requires minimal insect damage and breakages (defectives 2% maximum) and minimal discolouration or staining of grain (1% maximum). See pulse receival and export standards at http://www.pulseaus.com.au/storage/app/media/markets/20160801_Pulse-Standards.pdf.

Cash buying at harvest or warehousing options are not necessarily always available, close or desirable for faba bean growers at harvest. Depending on the location, variety/type, market outlet or grower choice, grain may need to be stored on farm. Sales must therefore be made privately to processors, agents or direct to the end-user.

Like with most pulse grains, there are bulk handling storage locations that handle faba bean grain for warehouse storage or storage on behalf of buyers. .There are also an increasing number of processors that receive faba bean at harvest or after storage. Bulk storage most likely will not be for all grades of faba beans or their grades. Receival grades are usually based on the national standards receival grade 1 farmer dressed (CSP-5.2.1).

See Section 12.13 Receival standards.

Delivery locations

Each year before harvest, bulk handling facilities usually publish a list of locations, segregations and grades of products that they will receive. These segregations reflect the national receival standard for faba bean as well as anticipated locations and volumes of production.

Glencore/Viterra in South Australia publish segregations they accept for faba bean each year pre-harvest. See http://www.viterra.com.au/index.php/classification/. Look for "grade segregations", which are predominantly for medium sizes ("Fiesta types"), based on approved varieties of the appropriate medium size (eg Fiesta VF, Farah⁽ᵈ⁾, Nura⁽ᵈ⁾ and PBA Samira⁽ᵈ⁾).

Look also for "receival standards" which are updated annually pre-harvest. See http://www.viterra.com.au/index.php/receival-standards/.

Faba bean growers in Victoria and southern NSW likely will need to be in touch with the many private storage facilities and pulse processors direct. See a list at http://www.pulseaus.com.au/marketing/pulse-traders. Graincorp handle some faba beans at specified locations, but check for specific details. See www.graincorp.com.au/storage-and-logistics/.../technical-documents-and-information.

12.14.2 Broad bean and other faba bean classes

Broad bean, canning grade faba bean and larger sized faba beans (eg PBA Rana⁽ᵈ⁾, PBA Zahra⁽ᵈ⁾ will need specific arrangements with buyers or processors because bulk storage facilities for these types are usually unavailable or rare, unless traded as livestock feed. See a pulse trader list at http://www.pulseaus.com.au/marketing/pulse-traders.

Broad beans on delivery to a processor are classified based on their size. They are then graded for sizing by the processor. Price paid and marketing is based on seed size classes. Grades are either to a mm size (eg greater than 14mm) or grains per 100 g (eg 65-70 grade).

Storage

Key points

- Faba and especially broad beans are a very large, plump grain and are very prone to mechanical damage during handling.
- Harvest faba bean at 14% moisture content to minimise the risk of damage to grain during handling, but do not store above 12% moisture.
- Pulse grain placed in storage with high germination and vigour can remain viable for at least 3 years, providing the moisture content of the grain does not exceed 11%.
- Store grain at a low temperature and low moisture content for maximum storage time.
- When storing for longer than 3 months only use storage that is suitable for aeration cooling and gas-tight fumigation.
- Hygiene is the first and most important step in protecting pulse grain from insect pests.
- Fumigation options are limited for pulses; successful fumigation requires a gas-tight, sealable silo.

MORE INFORMATION

GRDC Grain storage Fact Sheet Pressure testing sealable silos, http://www.grdc.com.au/GRDC-FS-PressureTestingSilos

Website: Stored Grain information hub, http://storedgrain.com.au/

Grain Stoage GrowNotes™, https://grdc.com.au/resources-and-publications/grownotes/technical

VIDEO

GRDC Video: Storing pulses, https://youtu.be/CeWA-OdhhSk

VIDEO

GRDC Video: Oilseed & Pulse Storage, https://youtu.be/JvzfJ2Xo6Sg

VIDEO

GRDC Video: Stay safe around grain storage, https://youtu.be/CM2mgmo3jWU

CASE STUDIES

GRDC Video: Over the Fence: On-farm storage pays in wet harvest – May 2011, https://youtu.be/ejywX-WytTs

GRDC Video: On-farm storage delivers harvest flexibility and profit, https://youtu.be/UWr7CTMxVMg

GRDC Video: On-farm storage in the SA Mallee with Corey Blacksell, https://youtu.be/fFKJYylp0hk

GRDC Video: On-farm storage in SA with Lindon Price, https://youtu.be/V9pSYmh_cO0

Harvesting pulses at 14% moisture content preserves grain quality and reduces mechanical damage.[1] However, pulses should not be stored at moisture contents above 12%. To successfully store pulses:

- Avoid mechanical damage to pulse seeds to maintain market quality and seed viability and to ensure they are less attractive to insect pests.
- Pulses above 12% moisture content can be held safely with aeration cooling for up to 3 months.
- Pulses above 12% moisture content will require aeration drying to maintain quality over 3 or more months.
- Prevent pests with careful hygiene and aeration cooling.
- Control pests with fumigation in gas-tight, sealable storage.

Regular monitoring is required to ensure grain quality in storage is maintained.[2] Check monthly taking samples from the bottom and, if safe, from the top. Monitor:

- insect pests;
- grain temperature;
- grain moisture content; and
- grain quality and germination.

13.1 Handling faba and broad bean

Faba and especially broad beans are a very large, plump grain and are very prone to mechanical damage during handling.[3] Human food markets demand a quality sample without cracking, staining, de-hulled seeds or insect damage. Harvest at the right time to ensure that the seed is not too dry (<10% moisture content). Crops that have been exposed to weather damage prior to harvest will be more vulnerable to mechanical damage.

Grain can be handled up to six times before delivery to receival points, so it is important to minimise the number of times grain is augured or handled and use efficient handling techniques.[4] Move seed gently to minimise cracking.

If using augers:

- Ensure augers are full of grain and operate at slow speeds.
- Use large-diameter augers.
- The flight pitch should be greater than the auger diameter.
- The length of the auger should be no longer than is necessary. The shorter the better.
- Operate augurs as close as possible to their optimal efficiency – usually at an angle of 30 degrees.
- Check flight-to-barrel clearance to minimise lodging and damage – the optimum clearance between the flight and tube is half the grain size.
- Auger drives should be at the discharge end, and not on the intake.

1 Stored Grain Project (2014) Storing pulses. Grain Storage Fact Sheet, GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

2 GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions, GRDC, June 2013, https://grdc.com.au/GRDC-FS-GrainStoragePestControl

3 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

4 Pulse Australia (2015) Southern faba & broad bean best management practices training course – 2015. Pulse Australia

MORE INFORMATION

Stored Grain Project (2013) *Grain storage facilities: Planning for Efficiency and Quality, A Grains Industry Guide*. GRDC, June 2013, http://storedgrain.com.au/grain-storage-facilities/

Economics of on-farm grain storage booklet and cost-benefit analysis spreadsheet from the Stored Grain information hub (http://storedgrain.com.au/economics-booklet/).

13.2 Grain cleaning

Re-cleaning of samples after harvest is sometimes necessary. Cereals can be cleaned from most pulses (not lentil) with a 3 or 4 mm rotary screen. The 3.75 mm slotted screen is popular and will help screen out split grain. The paddles or agitators in rotary screens should be either new or sufficiently worn so that the grain being harvested cannot jam between the outside of the paddle and the rotary screen.

Screens or paddles can be damaged beyond repair if the grain jams. Fitting the screens with a spacer will provide additional clearance to overcome this problem.

Milk thistle buds can be difficult to separate if they contaminate the sample because they are similar in size and weight to peas. However, if desiccated or given time to dry, the buds disintegrate when put through an auger and can be easily separated.

Dirt and most small weed seeds can be separated in rotary screens. However, the dirt will increase component wear.

13.3 Comparing storage options

As pulses are sold into the human food market protecting grain quality is vital. There are many options to consider when selecting appropriate storage for grain and growers will need to consider the advantages and disadvantages of different types of storage options (Table 1).

For growers considering investing in new storage to protect their pulse crop a benefit-cost analysis is useful to compare the expected return from investing in good-quality grain storage with other farm investments. Growers can download the *Economics of on-farm grain storage* booklet and cost-benefit analysis spreadsheet from the Stored Grain Information hub.

Table 1: Advantages and disadvantages of grain storage options.

Storage type	Advantages	Disadvantages
Gas-tight, sealable silo	• Gas-tight, sealable status allows phosphine and controlled atmosphere options to control insects • Easily aerated with fans • Fabricated on-site or off-site and transported • Capacity from 15 t up to 3,000 t • Up to 25-year + service life • Simple in-loading and out-loading • Easily administered hygiene (cone base particularly) • Can be used multiple times in-season	• Requires foundation to be constructed • Relatively high initial investment required • Seals must be regularly maintained • Access requires safety equipment and infrastructure • Requires an annual test to check gas-tight sealing
Non-sealed silo	• Easily aerated with fans • 7–10% cheaper than sealed silos • Capacity from 15 t up to 3,000 t • Up to 25-year + service life • Can be used multiple times in season	• Requires foundation to be constructed • Silo cannot be used for fumigation — see phosphine label • Insect control options limited to protectants in eastern states and Dryacide™ in WA • Access requires safety equipment and infrastructure
Grain storage bags	• Low initial cost • Can be laid on a prepared pad in a paddock • Provide harvest logistics support • Can provide segregation options • Are all ground operated • Can accommodate high-yielding seasons • Grain is untreated for wider market access	• Requires purchase or lease of loader and unloader • Increased risk of damage beyond short-term storage (typically 3 months) • Limited insect control options; fumigation only possible under specific protocols • Requires regular inspection and maintenance, which need to be budgeted for • Aeration of grain in bags currently limited to research trials only • Must be fenced off • Prone to attack by mice, birds, foxes, etc • Limited wet weather access if stored in paddock • Need to dispose of bag after use • Single-use only
Grain storage sheds	• Can be used for dual purposes • 30-year + service life • Low cost per stored tonne	• Aeration systems require specific design • Risk of contamination from dual purpose use • Difficult to seal for fumigation • Vermin and bird control is difficult • Limited insect control options without sealing • Difficult to unload

Source: Kondinin Group via Stored Grain Project (2013) Grain storage facilities: Planning for Efficiency and Quality, A Grains Industry Guide. GRDC, June 2013, http://storedgrain.com.au/grain-storage-facilities/

MORE INFORMATION

For details on comparing storage costs, please see the 2013 booklet by C Warrick *"Economics of on-farm grain"* at: http://storedgrain.com.au/economics-booklet/

13.4 Silos

Silos are ideal for storing pulses, particularly those with a cone base as there is less likely to be grain damage at out-loading.[5] When storing for longer than 3 months only use storage that is suitable for aeration cooling and gas-tight fumigation. Ideally, an aeration controller should be used to optimise aeration efficiency and cooling of the grain. It is especially important with pulses to always fill and empty silos from the centre holes because they have a high bulk density. Loading or out-loading off-centre puts uneven weight on the structure and may cause it to collapse.

The approximate weight of grain stored in a cubic metre of silo is shown below. The actual figures can vary as much as 6–7% in wheat and barley and 15% in oats. In pulses the variation is likely to be less (3–4%), and will vary with the grain size, variety and season.

One cubic metre of faba bean = 750 kilograms of faba bean (or 9.2 x 3-bushel bags)

Calculating silo capacity

Calculating the volume of a cylinder

Volume = area of base (diameter squared x 0.7854) x height

Calculating the volume of a cone

Volume = 1/3 (area of base x height)

MORE INFORMATION

GRDC Fact Sheet: Storing pulses, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

13.5 Grain quality

Grain quality is at its highest when first loaded into storage, but can steadily deteriorate if the storage environment is not well managed. A combination of good farm hygiene, storage choice and aeration cooling are important for maintaining grain quality and overcoming many problems with pests associated with storage.

Quality in storage can be reduced by:

- weather damage prior to harvest;
- moisture;
- heat; and
- pests including insects, mould and fungi.

Growers should avoid even short to medium storage of weather-damaged grain. Seed that has weathered prior to harvest will deteriorate a lot quicker in storage, even if stored under ideal conditions.

All faba and broad beans will darken considerably in storage, and the rate of seed coat darkening is accelerated by:

- high seed moisture content;
- high temperatures;
- high relative humidity;
- condition of the seed at harvest; and
- sunlight.

Faba and broad bean seed stored for more than 9 months is usually unsuitable for the export market.[6]

5 Stored Grain Project (2014) Storing pulses. Grain Storage Fact Sheet. GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

6 A Ware, R Kimber, J Paull, W Hawthorne (2013) Bean variety trials. Conmurra MFMG Bean Variety Trial 2012. Online farm trials website, http://www.farmtrials.com.au/trial/16758

13.6 Moisture content and temperature

Store grain at a low temperature and low moisture content for maximum storage time.

Cooler grain temperatures have several advantages:

- seed viability (germination and vigour) is maintained longer;
- moist grain can be safely held for a short time before blending or drying;
- moisture migration is reduced;
- insect breeding cycles are slowed (or cease in some instances) and 'hot spots' are prevented;
- mould growth is reduced; and
- darkening of the seed coat is slower.

Accurately check the moisture content of all grain entering storage with a moisture meter. Moisture content of grain during harvest can change during the day and evening. Fumigation as soon as the silo is filled can stop any insects that are present from creating additional moisture.

The maximum moisture content set in the national receival standards for pulse receival is 14%, but bulk handlers may have receival requirements down to 12%.

Harvesting pulses at the higher moisture content (around 14%) reduces field mould, mechanical damage to the seed, splitting and preserves seed viability. However, pulse grain must be dried before going into storage to preserve seed germination and viability.

Pulse grain placed in storage with high germination and vigour can remain viable for at least 3 years providing the moisture content of the grain does not exceed 11%.

As a general rule, every 1% rise in moisture content above 11% will reduce the storage life of pulse seed by one-third. Any pulse stored above 12% moisture content will require aeration cooling to maintain quality.

High temperatures in storage will cause deterioration in grain viability. Temperatures of stored pulse grain should not exceed an average of 25°C and preferably the average temperature should be below 20°C. In general, each 4°C rise in average stored temperature will halve the storage life of the grain.

Typical harvest temperatures of 25°C–35°C and grain at a moisture content greater than 13–14% can provide the ideal condition for mould and insect growth (Figure 1 and Table 2).[7] High-moisture grain will generate additional heat when in confined storage, such as a silo, further encouraging mould and insect growth. Without aeration grain can maintain its warm harvest temperature for a long time.

7 Stored Grain Project (2013) Dealing with high-moisture grain, Grain Storage Fact Sheet. GRDC, June 2013, https://grdc.com.au/GRDC-FS-HighMoistureGrain

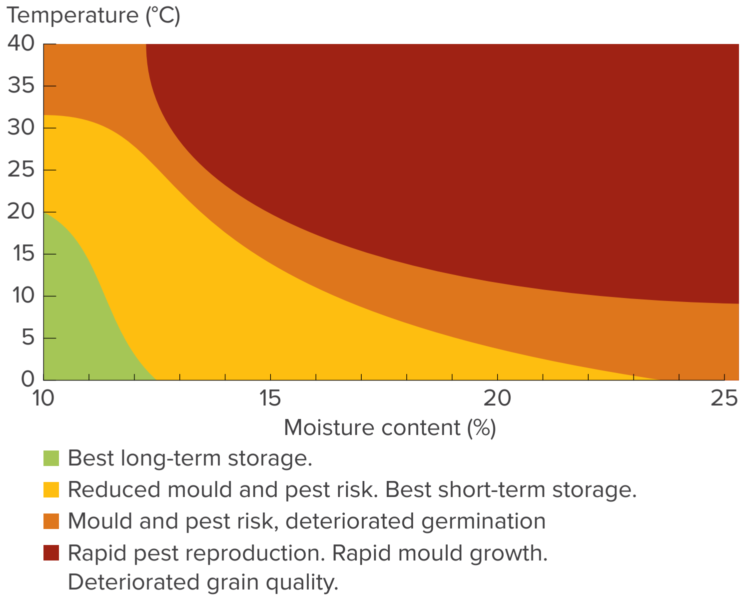

Figure 1: *Effects of temperature and moisture on stored grain.*

Source: CSIRO Stored Grains Research Laboratory via Stored Grain Project (2013) Dealing with high-moisture grain fact sheet

Table 2: The influence of temperature and moisture on stored grain Insect and mould development.

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

Source: Kondinin Group via GRDC (2013) Grain storage pest control guide

MORE INFORMATION

Booklet: *Aerating stored grain*, www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

13.7 Cooling and drying pulses

Grain with a higher moisture content can be stored for longer if the temperature is cool (Table 3). Options for grain that is above the standard safe storage moisture content of 12.5% include:[8]

- **Blending** with low-moisture grain, then aerating. Blending can be used for grain up to 13.5% moisture content. Blending is less suitable for pulses because the additional handling can damage the seed.
- **Aeration cooling** – grain up to 15% moisture content can be held short term until drying equipment is available.
- **Aeration drying** – large volumes of air are pumped through the grain gradually reducing moisture. Additional heating can be used.
- **Continuous flow drying** – grain is transferred through the dryer, which pumps a high volume of heated air through the continual grain flow. This is a highly efficient way to dry large volumes of grain.
- **Batch drying** 10–20 t of grain at a time with a high volume of pre-heated air, usually using a transportable trailer.

8 Stored Grain Project (2013) Dealing with high-moisture grain, Grain Storage Fact Sheet, GRDC, June 2013, https://grdc.com.au/GRDC-FS-HighMoistureGrain

VIDEO

GRDC Video: Grain Storage with Philip Burrill — Using Aeration Controllers, https://youtu.be/vxoBO71rTDg

VIDEO

GRDC Video: Grain storage cooling aeration, https://youtu.be/qb3WAXZOl1g

VIDEO

GRDC Video: Pressure testing sealed silos, https://youtu.be/BHKUNjnnhIE

Table 3: Maximum storage period for grain by temperature and moisture content.

Moisture content (%)	Grain temperature (°C)	
	20°C	30°C
14%	3 months	n/a
13%	9 months	3 months
12%	>9 months	9 months

Source: CSIRO Stored Grains Research Laboratory via Stored Grain Project (2014) Storing pulses

To store pulses without reducing quality, growers should assess what storage they currently have, identify gaps in best practice and work out a plan to meet current and future needs.[9]

A practical way of reducing temperatures is to paint the silo white, as dark-coloured silos will absorb more heat. Silos aligned in an east—west orientation rather than north—south provide extra shading and can reduce heating of the silos.

Grain in large silos (>75 t) will remain cooler as grain is a poor conductor of heat and day-night temperature fluctuations rarely reach 15 cm beyond the silo wall. Small silos (<20 t) and field bins will have larger temperature fluctuations and can cause deterioration in grain quality.

13.8 Aeration cooling

Aeration cooling is a vital tool when storing pulses in a silo.[10] It allows grain to be harvested earlier and at higher moisture levels, preserving grain quality and reducing mechanical seed damage.

Aeration cooling is suitable for longer-term storage of low-moisture grain by creating cool, uniform conditions.

High-moisture grain can be safely held for a short time (1–2 months) with aeration cooling before blending or drying. Run fans continuously to prevent self-heating and quality damage.

Samples with green pods and grains are at increased risk of mould developing, even at low moisture contents, and aeration cooling can reduce this risk. The space at the top of the silo will heat and cool each day and if moisture contents are greater than 12% condensation can form and wet the grain at the top of the stack.

Aerated silos are fitted with fans that push air through the grain to cool the grain and equalise the moisture and temperature throughout the silo. With an aeration system, a waterproof vent on the top of the silo allows air forced from the base of the silo to escape. During fumigation this vent needs to be replaced with a sealed lid or a capped venting tube.

It is important to know the capacity of any existing aeration system. Aeration cooling can be achieved with airflow rates of 2–3 litres per second per tonne of grain delivered from fans driven by 0.37 kilowatt (0.5 horsepower) electric motor for silos around 100 t.

It is also important to know how fans will perform when pushing air through the grain. Grain exerts a back pressure on the airflow. Whilst larger grains exert less back pressure knowing the performance of the fans is important to ensure the correct amount of air is pushed through the grain. Fans should have a rating for this and reputable suppliers will be able to show pressure curve performance for fans.

9 J Severs (2016) Grain storage is about food and safety. GroundCover™, Issue 123, July—August 2016, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-123-julyaugust-2016/grain-storage-is-about-food-and-safety

10 Stored Grain Project (2014) Storing pulses. Grain Storage Fact Sheet. GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

MORE INFORMATION

GRDC Fact Sheet: Performance testing aeration systems, https://grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

Website: Agridry, http://agridry.com.au/

VIDEO

GRDC Video: Aeration drying – getting it right, https://youtu.be/vzMHzyHCWuw

Have the necessary fans for each storage dedicated to each silo. If a fan is ducted to more than one silo the silo with the least airflow resistance will get the majority of the airflow.

Correctly controlled aeration should aim to reduce grain temperature to less than 23°C in summer and less than 15°C in winter. Cooling achieved during storage depends on the moisture content of the grain and the humidity and temperature of the incoming air. Automatic aeration controllers that select optimum fan run times are the most reliable and convenient to use.

13.9 Aeration drying

If high-moisture-content (>14%) pulses are to be stored for longer than 3 months they require drying or blending to maintain seed quality.[11] Aeration drying is the preferred method as it has a lower risk of cracking or damaging pulses than using hot-air dryers.

Careful selection of conditions using dry ambient air (using an automated controller) can remove moisture from the stored grain over a period of weeks.

Unlike aeration cooling, drying requires higher air-flow rates or at least 15–25 litres per second per tonne of grain. Aeration drying is a slow process that also relies on well-designed ducting for even air flow, exhaust vents in the silo roof and warm, dry weather conditions.

Supplementary heating can be used to aid the drying process by removing moisture more effectively than cold air and by reducing the relative humidity of the air.[12]

Once drying is complete all grain needs to be cooled regardless of whether supplementary heat was used. Storage pests stop breeding at temperatures below 15°C (Table 2). Aim for less than 23°C in summer and less than 15°C in winter.

13.10 Heated air drying

Use heated air with caution for drying pulses. Do not exceed 45°C when using heat to dry faba and broad bean.

Continuous-flow or batch dryers provide reliable drying, although they can reduce quality if run at too high a temperature. Check the specifications or talk to the manufacturer about safe conditions for drying pulses.

11 Stored Grain Project (2014) Storing pulses. Grain Storage Fact Sheet. GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

12 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

13.11 Preventing moisture migration

Grain stored in sealed silos must be of sufficiently low moisture content to prevent moisture migration. Use an aerated silo with adequate ventilation fitted.

Do not load grain with excess moisture (>12%) into a sealed store where there is no escape of moisture. In a sealed silo moisture can migrate to condense in upper grain layers. This top area of the grain is at high risk from mould and insect colonisation.

Moisture sources include grain, insects, any green material, immature seeds, condensation and leaks.

13.11.1 Grain

Grain and seed are living and release moisture as they respire. This moisture moves upwards by convection currents created by the temperature difference between the grain in the centre of the silo and the walls which can be either warmer or cooler.

13.11.2 Insects

Insects or mites in the grain respire and release moisture and heat into air spaces. If grain is stored at less than 14% moisture and is free of insects the increase in moisture content in the upper layers of the grain will be insignificant. If grain is stored above 14% moisture content, there may be enough moisture in the upper grain layers to cause mould. Moisture builds up quicker and to higher levels from insect respiration than from grain respiration alone. There is no moisture migration in an aerated silo as the entire stack is normally cooled to an even temperature (20°C or less).

13.11.3 Condensation

Moisture carried into the silo headspace can condense on a cold roof and fall back as free water. This can cause a circle of mould or germinated grain against the silo wall. Moist grain can also contain greater numbers of insects.

13.11.4 Leaks

Water entering through structural damage will increase grain moisture content to a level where mould and insect growth can occur.

MORE INFORMATION

Pulse Australia: Grain Bags, http://pulseaus.com.au/growing-pulses/publications/grain-storage-bags

GRDC Fact Sheet: Successful storage in grain bags, https://grdc.com.au/Resources/Factsheets/2012/03/Grain-Storage-Fact-Sheet-Successful-storage-in-grain-bags

VIDEO

GRDC Video: Grain bags: best practice, https://youtu.be/Ab-A2Il6b1Q

VIDEO

GRDC Video: Grain bags – a grower's perspective, https://youtu.be/cLRgjjdEr0U

MORE INFORMATION

Booklet: *Stored Grain Pests Identification: the Back Pocket Guide*, https://grdc.com.au/GRDC-BPG-StoredGrainPests

GRDC Fact Sheet: Stored Grain Pests Identification, https://grdc.com.au/GRDC-FS-StoredGrainPestID

VIDEO

GRDC Video: Stored grain: managing sealed & unsealed storage, https://youtu.be/TIs0S-7DwxA

13.12 Pulse quality risks with grain bags

Grain bags (also known as silo, sausage or harvest bags) are only recommended for short-term (3-month) storage as a harvest buffer (Photo 1).[13] Storage of high-value pulses or pulse seed crops in grain bags is not recommended.[14]

Storing pulses in grain bags is a bigger risk than storing other crops. Pulse grain from grain bags has been rejected because of objectionable taints and odours resulting from improper storage in grain bags.

Grain bags are effectively sealed storage without aeration.

In theory, grain in a correctly sealed bag will convert residual oxygen into carbon dioxide (hermetic conditions), which will asphyxiate insects and inhibit fungal growth. However, CSIRO research has shown that it is difficult to achieve these conditions, particularly with high grain temperatures and the relatively dry grain harvested in Australia.[15] It is unlikely a bag will not have some holes, tears or punctures throughout the storage period, which will allow air to enter and compromise the hermetic environment.

Grain must be below 14% moisture content and the bag must remain sealed and undamaged, preventing moisture from entering during storage.

Punctures need to be sealed quickly and correctly. Inspect bags weekly or more often. Damage by vermin, birds and other pests is common.

The risks of storing pulses in grain bags are:

- Pulse grain may not retain its quality, colour or odour, especially if the seal is breached.
- Contamination and moisture can enter bags from tears or where vermin and other pests create holes in the bag.
- Excessive grain moisture can result in condensation within the bag causing localised areas of mould and an offensive, distinctive mouldy odour throughout. Marketers have rejected pulse grain because of objectionable moulds, taints and odours acquired through storage in grain bags. Such taints and odours are not acceptable in pulse markets, particularly human consumption end uses.
- Grain moisture content is critical. Pulses, particularly the larger-seeded ones like faba bean or kabuli chickpea, have bigger airspaces between grains than cereals, so moisture can move more freely through them.
- Removing taints and odours in affected grain is often not possible, even with further aeration.
- An overall offensive, distinctive 'plastic' odour that requires considerable periods of aeration to remove. There is nil tolerance of odours in pulse receival standards. (See Section 12.13 Receival standards).
- Storage at harvest temperatures of more than 30°C favours high insect reproduction rates so hygiene and monitoring are vital. Achieving a low-oxygen environment (hermetic conditions) under Australian conditions is difficult and should not be relied upon as the only source of storage insect control.

13 Pulse Australia (2016) Grain bags for pulse storage. Pulse Australia website, http://pulseaus.com.au/growing-pulses/publications/grain-storage-bags

14 Stored Grain Project (2014) Storing pulses. Grain Storage Fact Sheet. GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

15 JA Darby, LP Caddick (2007) Review of grain harvest bag technology under Australian conditions. CSIRO Entomology, Technical Report No. 105, https://publications.csiro.au/rpr/pub?list=BRO&pid=procite:d0d57771-ffbb-4ffd-8fd4-de675a9a0448

Photo 1: *Grain bags are only suitable as temporary storage for pulses.*

Photo: Unknown

13.13 Insect pests in storage

Insects are not considered a major problem in stored faba and broad bean. While seed beetles or bruchids (Bruchinae) are considered primary pests of pulse crops, very few bruchid species present in Australia attack faba bean.

There are exotic bruchids that attack faba bean, but they are not currently present in Australia (see Section 8.6.1 Exotic seed beetles/bruchids (*Coleoptera*: Family: *Chrysomelidae*, sub-family: *Bruchinae*)).

If faba and broad bean are loaded into storages containing residues of cereal grain already infested with cereal pest insects, these infestations can spread into the beans.[16] These include flour beetles (*Tribolium* spp.) and grain borers (*Rhyzoptherha* spp.).

Damaged seed is more vulnerable to insect pests.

The tolerance for live pests sold off-farm is nil. Growers need an integrated approach to pest control.[17] Prevention is better than a cure. Grain hygiene and aeration cooling can overcome 85% of pest problems. Insect control options are limited for pulses making hygiene, aeration and regular monitoring essential.

Most insect development ceases at temperatures below 20°C (Table 2). Freshly harvested grain usually has a temperature of around 30°C, which is an ideal breeding temperature for many storage pests. Aeration fitted to stores will rapidly reduce grain temperatures, reducing insect breeding and aiding grain quality.

16 GRDC (2015) GCTV Stored Grain: Storing pulses. GroundCover™ TV, theGRDC Youtube channel, https://youtu.be/CeWA-OdhhSk

17 GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions. GRDC, June 2013, https://grdc.com.au/GRDC-FS-GrainStoragePestControl

MORE INFORMATION

GRDC Fact Sheet: Hygiene and structural treatments for grain storages, www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

VIDEO

GRDC Video: Grain silo hygiene, https://youtu.be/3VU7qJCoCwI

VIDEO

GRDC Video: Applying diatomaceous earth demonstration, https://youtu.be/L-lyCgstkc0

13.14 Farm and grain hygiene

Hygiene is the first and most important step in protecting pulse grain from insect pests as other opportunities for control are limited. Many growers do not have the gas-tight, sealed storage required to manage insects with fumigation. One bag of infested grain in the yard can produce more than one million insects over a year that can walk and fly to other grain storages.

If insects have nowhere to hide when grain storages are empty the risk of them infesting freshly harvested grain placed into storage is low.

Clean silos and storages thoroughly.[18] This includes cleaning up spillage and minimising places where insects can collect. Clean after harvest to prevent insect build-up during the year. Areas to clean include:

- empty silos and grain storages;
- augers and conveyers;
- harvesters;
- field and chaser bins;
- spilt grain around grain storages;
- leftover bags of grain; and
- equipment brought onto the farm from outside.

If an insect infestation is found, destroy all grain residues to prevent re-infestation.

Using chemicals for structural treatment is not recommended. They do not list the specific use before storing pulses on their labels and maximum residue limits (MRLs) are either extremely low or nil. There is a high risk of exceeding MRLs.

Diatomaceous earth (DE) as a structural treatment can be used to treat storages after cleaning, but it is essential to wash and dry the storage and equipment before using for pulses. This will ensure the DE does not discolour the grain surface.

Check with grain buyers before using any product that will come into contact with the stored grain.

18 Stored Grain Project (2014) Storing pulses. Grain Storage Fact Sheet. GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

13.15 Fumigation in sealed silos

Pulses are a food product and need to be protected from insects, mould, fungi and chemical residues.[19] Forty per cent of growers store their products on-farm so understanding how to use fumigants safely is vital.

Even grain sold to dairy farmers can potentially impact on the safety of milk products. Traceability along the supply chain is important.

Fumigation options are limited for pulses.[20] Phosphine fumigation is used in most situation. Controlled atmosphere (such as carbon dioxide and nitrogen) may be suitable. Other grain protectants are not registered for pulses.

Successful fumigation requires a gas-tight, sealable silo (Photo 2). To be effective against all insect life stages, as well as insects with resistance, fumigants must be held in the silo at a given concentration for a certain period of time. This is only possible in gas-tight, sealable silos.

Photo 2: *Using an unsealed silo for fumigation is both ineffective and dangerous.*

Photo: Grain Legume Handbook (2008)

According to Australian Standard AS2628, a silo is only truly sealed if it passes a 5-minute half-life pressure test. During testing oil levels in the pressure relief valve must take a minimum of 5 minutes to fall from 25 mm to a 12.5 mm difference. Pressure testing of silos should be carried out:

- When a new silo is erected on-farm.
- When full of grain and before fumigation.
- As part of the annual maintenance routine.

19 J Severs (2016) Grain storage is about food and safety. GroundCover™, Issue 123, July—August 2016, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-123-julyaugust-2016/grain-storage-is-about-food-and-safety

20 GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions. GRDC, June 2013, https://grdc.com.au/GRDC-FS-GrainStoragePestControl

MORE INFORMATION

Booklet: *Fumigating with phosphine, other fumigants and controlled atmospheres*, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

GRDC Fact Sheet: Stay safe around grain storage, https://grdc.com.au/Resources/Factsheets/2011/11/Stay-safe-around-grain-storage

GroundCover™ article: Effective phosphine fumigation takes time, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-119-nov-dec-2015/effective-phosphine-fumigation-takes-time

Printable phosphine warning sign, http://storedgrain.com.au/phosphine-warning-sign/

13.16 Using phosphine

Phosphine is the only fumigant currently registered for use in pulses. It is illegal and highly dangerous to put phosphine into unsealed systems.

Phosphine is the single most relied upon fumigant in the Australian grains industry.[21] Continued misuse is leading to poor insect control and developing resistance (Figure 2). To kill grain pests at all stages of their life cycle (egg, larva, pupa, adult) the only option is to fumigate in a gas-tight, sealed silo.[22] A GRDC survey in 2010 showed that only 36% of users applied phosphine correctly in a gas-tight, sealed silo.

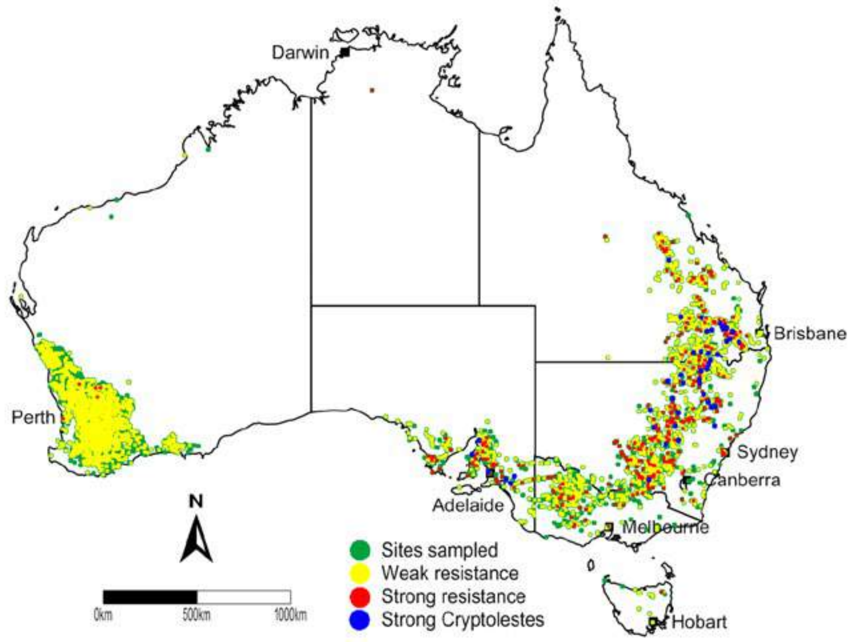

Figure 2: *Phosphine resistance in Australia 1986 to 2014.*

Source: DPIRD, via Emery (2014)

Minimum phosphine gas levels for fumigation are:

- 300 parts per million (ppm) for 7 days when grain is above 25°C; and
- 200 ppm for 10 days when grain is between 15°C and 25°C.
- Do not use phosphine below 15°C as insects are hard to kill at low temperatures.

Fumigant takes longer to distribute in storages with more than a few hundred tonnes capacity, unless forced circulation is used.

Fumigation trials in silos with small leaks show that phosphine levels can be as low as 3 ppm close to the leaks, making it impossible to kill insects at all life stages. Poor fumigation may appear successful with some dead adults found, but those that survive are more likely to carry increased phosphine resistance.

Always read and follow label directions when using phosphine. Arrange tablets evenly across trays to expose as much surface area as possible to air so that the gas can disperse freely. Trays should be hung in the head space or placed on the grain surface. Bag chains can be hung in the head space or rolled out flat on top of the grain. Bottom application systems require air circulation systems to carry the gas out of the confined space as phosphine can reach explosive levels if left to evolve in a confined space.

21 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

22 Stored Grain Project (2014) Grain Fumigation: a Guide. Grain Storage Fact Sheet. GRDC, January 2014, https://grdc.com.au/GRDC-FS-GrainFumigationGuide

After fumigation ventilate silos to remove harmful gas residues. Remove tablet residues and bag chains and leave silos open for no less than 5 days, or no less than 1 day with aeration fans operating. A further 2-day withholding period is required before delivering or using for human or animal consumption.

Aeration fans fitted on gas-tight, sealed silos provide a number of benefits including a shorter ventilation period following fumigation. Warning signs need to be displayed during fumigation (Figure 3).

Safety is important. Phosphine is a schedule seven (S7) poison. As a minimum requirement, the label directs the use of cotton overalls buttoned to the neck and wrist, eye protection, elbow-length PVC gloves and a breathing respirator with combined dust and gas cartridge. Operators should work in an open, well-ventilated area with the wind coming from the side.

Workers must not be exposed more than 4 times per day to more than 1 ppm for longer than 15 minutes, with at least 1 hour between each exposure. And workers must not be exposed to more than 0.3 ppm for more than 8 hours per day or 40 hours per week.

The odour threshold is 2 ppm, so once a worker can smell the phosphine they have already exceeded the safe exposure limit. Workers should wear a personal phosphine monitor that will sound an alarm if more than 0.3 ppm is detected.

Do not re-seal leftover phosphine tablets once they have been exposed to air as they can become explosive.

Always read the Safety Data Sheet (SDS) for more information and the required personal protective equipment (PPE).

Figure 3: *A phosphine warning sign must be clearly displayed. They can be downloaded from http://storedgrain.com.au/phosphine-warning-sign/.*

Source: Stored Grain

IN FOCUS

13.17 Alternative fumigants for pulses

If phosphine resistance is suspected other options for fumigation of pulses are limited. These options are more expensive than phosphine and still require a gas-tight, sealed silo.

Controlled atmosphere (CA) options change the balance of natural atmospheric gases to produce a toxic atmosphere. They have the advantage of being non-chemical control options. These are:

- Carbon dioxide (CO_2) – displacing air in storage with a high enough concentration of CO_2 to be toxic to pests. A minimum concentration of 35% CO_2 must be maintained for 15 days.
- Nitrogen – this method is currently under research and not recommended for on-farm use.

Other fumigants such as ProFume® and Vapormate® are not registered for pulses.

Environmental issues

Key points

- **Important environmental issues include: soil erosion management, responsible pesticide stewardship and biosecurity.**
- **Other issues include water use, managing nutrient losses, rhizobium activity with changed atmosphere, and integrated management of pests, weeds and diseases.**

Table 1: Environmental issues affecting the Australian grains industry, based on stakeholder consultation workshops.

Global	National/industry	State/regional	Local/farm
• Climate change • Water availability • Energy • Biosecurity	• Water • Drought • Land degradation • Biosecurity • Changing land use • Adoptable, adaptive farming systems • Genetically modified organisms (GMO) • Greenhouse emissions	• Resource condition and management targets • Environmental flow, water quality, sediments • Shifting production zones, changing farming systems, 'marginal cropping' • Biosecurity	• Healthy soils • Managing drought: variability • Managing pests and weeds • Balance • Local environment

Source: M Blumenthal, A Umbers, P Day (2008) GRDC A Responsible Lead: an Environmental Plan for the Australian Grains Industry. Grains Research and Development Corporation, https://grdc.com.au/uploads/documents/GRDC_Environmental_Plan.pdf

14.1 Abiotic stress

14.1.1 Drought and heat stress

For information on faba bean response to drought or moisture deficit, see Section 5.5.4 Drought.

For more information on faba bean response to heat stress, see Section 5.5.3 High temperature and wind.

14.1.2 Waterlogging

For information on faba bean response to waterlogging, see Section 5.5.7 Waterlogging.

14.1.3 Frost

For information on faba bean response to frost, see Section 5.5.2 Frost.

14.1.4 Lack of sunlight

For information on faba bean response to lack of sunlight, see Section 5.5.5 Low light.

14.2 Improving the farm resource base

One of the GRDC's six themes – 'Improving your farm resource base' – focuses on protecting and enhancing the farm's soil, water, habitat and atmospheric resources to maintain production performance under a variable climate and to demonstrate to consumers and the wider community the sustainable nature of Australian grains production.

Soil carbon is declining in many grains catchments, as is soil pH. Although water consumption by agriculture is being reduced and becoming more efficient, water quality in some key catchments requires further management. Native vegetation (plant) communities have become highly fragmented, affecting both biodiversity balance and the potential for exploitation as habitat for beneficial organisms.[1]

1 GRDC (2012) Investment themes and outcomes, Strategic plan, http://strategicplan2012.grdc.com.au/investment_themes_and_outcomes/part6_theme_5_improving_your_farm_resource_base.html

MORE INFORMATION

The GRDC has produced a booklet on environmental planning, *GRDC A Responsible Lead: an Environmental Plan for the Australian Grains Industry*, https://grdc.com.au/uploads/documents/GRDC_Environmental_Plan.pdf

Soil health is declining in many cropping areas. As soil organic carbon levels decrease, soil acidification increases and soil erosion can be a problem if stubbles are not retained during the cropping phase of rotations.

14.2.1 Environmental issues plan

The GRDC, in consultation with industry partners, has developed an environmental plan for the grains industry to help ensure that environmental issues are prioritised when developing research policy.

It should help equip Australian grain growers to manage a broad range of environmental challenges – including climate change – while continuing to develop a profitable, progressive and sustainable industry.[2]

14.2.2 Industry issues

Management of a number of environmental issues pertaining to faba bean are detailed in the guide *Growing Australian Grain: safely managing risks with crop inputs and grain on-farm* (http://grainsguide.grainproducers.com.au/). It includes information on:

- managing farm chemicals related to maximum residue limits (MRLs) and cross-contamination with handling equipment;
- harvest fire risk compliance;
- fertilisers free of excess contamination of heavy metals; and
- biosecurity.

14.3 Soil erosion

Information relating to crop nutrition, soil fertility and managing faba bean in hostile soils is found in Section 6 Nutrition and Fertiliser.

14.3.1 Reducing risk of soil erosion

Pulses can leave soils prone to water and wind erosion as they leave little to no stubble after harvest. Faba bean crops leave soil at less risk of erosion than chickpea, lentil and field pea.

Retaining cereal stubbles

Retaining cereal stubbles when sowing faba bean will protect soil and young crops from wind damage. Two tonnes per hectare of cereal stubble reduces the risk of wind and water erosion. Heavy stubbles need to be broken down into 10–15 cm lengths.

Retaining stubbles has a number of other environmental benefits. It provides a source of organic matter, allowing recycling of plant nutrients. Organic matter improves soil structure and earthworm activity and can increase grain yields and farm viability.

Faba bean stubble management

The presence of stubble can protect soil from rain impact and reduce water run-off and erosion. On sloping land, 3 t/ha is needed to reduce the erosion risk.

Pulse stubbles require careful grazing management on light soils. But careful grazing is also required on heavier soils, where overgrazing can create dust problems, in turn affecting clean fleece yields.[3]

2 M Blumenthal, A Umbers, P Day (2008) GRDC A Responsible Lead: an Environmental Plan for the Australian Grains Industry. Grains Research and Development Corporation, https://grdc.com.au/uploads/documents/GRDC_Environmental_Plan.pdf

3 Pulse Australia (2016) Rotational benefits and profitability. Southern Faba & Broad Bean – Best Management Practices Training Course Module 1. 65 pp, Pulse Australia.

Effect of soil type on erosion risk

An assessment of the erosion risk caused by break crops in the Mallee (which did not include faba bean) found that the majority of pulse crops had a very low risk of erosion on all soils but one in three pulse crops posed an unacceptable erosion risk in dune soils.[4]

For pulse crops, choose the more fertile paddocks with medium to heavy textured soils. Otherwise utilise stubble retention systems to minimise erosion risk in the pulse crop.

Poor emergence is more likely with pulses on hard-setting soils, which can lead to a greater potential for soil erosion.

Agronomic management to reduce erosion risk

Rolling after sowing a pulse crop can leave some soils prone to erosion; in these situations rolling after crop emergence is preferred.

Strip cropping may be used to protect the erosion prone crop with alternate strips of 'protective' crop.[5]

14.4 Water

Understanding climate and estimating target yields of faba bean, enabling tailored management decisions and benchmarking water use efficiency is detailed in Section 2.7 Yields and yield targets.

Details of stubble retention and controlling summer weeds to improve water use efficiency are found in Section 2.3 Stubble and summer weed management.

Management of irrigated faba bean to maximise grain yields and water use efficiency is covered in, Section 2.6 Irrigation layout and planning.

14.5 Nutrients

Growers aim to match the crop's nutrient requirements with fertiliser inputs. A study in the high-rainfall zone found that where growers optimise their gross margins they are likely to be optimising their environmental performance.[6] For more details on crop nutrition, including precision agriculture and nitrogen fixation in faba bean, refer to Section 6 Nutrition and Fertiliser.

14.5.1 Nutrient losses

In addition to removal of nutrients in produce, nutrients can be lost from farms through run-off, drainage beyond the root zone (leaching), soil erosion, lateral flow in the soil profile and emission of gases (including burning).[7]

An outcome of the major GRDC initiative More Profit from Crop Nutrition is better matching of nitrogen, phosphorus, potassium and sulfur inputs to meet crop demand and minimise losses and tie-up. A list of projects included in the initiative can be found at: https://grdc.com.au/Research-and-Development/Major-Initiatives/More-Profit-from-Crop-Nutrition.[8]

A study in Victoria's high-rainfall zone concluded that, overall, flexible cropping systems that maximise crop potential with a minimum of applied nitrogen at sowing, maximise both economic and environmental performance.

4 http://grainsguide.grainproducers.com.au/

5 Pulse Australia (2016) Rotational benefits and profitability. Southern Faba & Broad Bean – Best Management Practices Training Course Module 1. Pulse Australia.

6 D Nash (undated) Management of high rainfall cropping systems to improve water quality and productivity. GRDC Project Summary, DAV00059, https://grdc.com.au/uploads/documents/Project%20summary%20DAV00059%20FINAL.pdf

7 Australian Soil Information Resources System, www.asris.csiro.au/themes/nutrient.html

8 GRDC (undated) More profit from crop nutrition, https://grdc.com.au/Research-and-Development/Major-Initiatives/More-Profit-from-Crop-Nutrition

Monitoring run-off suggests that high-rainfall cropping in the southern region could adversely affect receiving waters. Soil studies of the long-term cropping trial site in north-east Victoria also suggest that nutrient concentrations in run-off may be higher from reduced-tillage systems. However, there was less drainage from these systems and therefore lower nutrient exports, overall.[9]

14.5.2 Nitrogen fixation and changing atmosphere

Research into the effects of elevated carbon dioxide (CO_2) on cropping systems has shown that higher CO_2 provides more nitrogen from pulse stubble but no increase in *Rhizobium* activity.[10]

14.6 Biology

14.6.1 Biosecurity

Biosecurity is the protection of farms, industries and the natural environment that could be harmed through the introduction of new pests.

Growers need to prevent exotic pests and diseases from entering their farm and detect new pests early with vigilant surveillance and excellent farm hygiene.

For details of pest-related biosecurity issues for faba bean, see Section 8.6 Exotic faba bean insects – biosecurity threats.[11]

For factsheets on biosecurity in grains farms, visit: www.planthealthaustralia.com.au/national-programs/grains-farm-biosecurity-program/grains-biosecurity-fact-sheets/

14.6.2 Integrated pest management

Integrated pest management aims to minimise the use of highly toxic pesticides, and/or those that are harmful to the predators and parasites that help keep pests in check.

Details of integrated pest management of invertebrate pests in faba bean can be found in Section 8.1 Integrated pest management (IPM).

14.6.3 Integrated weed management

An integrated weed management (IWM) system combines all available methods for control of weeds, including herbicide and non-herbicide options. For more information on IWM in faba bean, see Section 7.4 Integrated weed management (IWM).

Disease management in faba bean is critical, and relies on an integrated approach including variety choice, crop hygiene and strategic use of fungicides. For more information on integrated disease management, see Section 9.2 Integrated pest management (IPM) strategies.

14.6.4 Responsible pesticide stewardship

Legal considerations

Information on the registration status, rates of application and warnings related to withholding periods, OH&S, residues and off-target effects should be obtained before making decisions on which pesticide to use. This information is available from state department chemical standards branches, chemical resellers, the

9 D Nash (undated) Management of high rainfall cropping systems to improve water quality and productivity. GRDC Project Summary, DAV00059, 1 pp., https://grdc.com.au/uploads/documents/Project%20summary%20DAV00059%20FINAL.pdf

10 G Fitzgerald (undated) AGFACE: Elevated CO2 research in the great southern (dry) land.Presentation, AGFACE Crop Science Workshop, www.piccc.org.au/resource/agface-workshop-presentations/573

11 J Moran (2014) Biosecurity – local action to prevent exotic pest incursions. GRDC Update paper, 23 July 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Biosecurity-local-action-to-prevent-exotic-pest-incursions

Australian Pesticides and Veterinary Medicines Authority (APVMA) and the pesticide manufacturer.

All pesticides go through a registration process, where they are formally authorised (registered) by the APVMA.[12] Details of product registrations and permits are available on the APVMA's website.[13]

The approved product label is a legal document that prescribes the pest and crop situation where a product can be legally used, and how. Using products for purposes or in manners not on the label involves potential risks. Guidelines on the label protect product quality and Australian trade by keeping pesticide residues below specified maximum residue limits (MRLs).

Material Safety Data Sheets (MSDS) document the hazards posed by the product, and the necessary and legally enforceable handling and storage safety protocols.

In some cases a product used on faba bean may not be fully registered but is available under a permit with conditions attached, which often require the generation of further data for eventual registration.

National residue survey

Pesticide residue levels in products must comply with maximum residue levels (MRLs) set in Australia and internationally (CODEX).

Australian grain samples are monitored as part of the National Residue Survey (NRS), conducted by the Department of Agriculture, Fisheries and Forestry (DAFF), for managing the risk of chemical residues and environmental contaminants in Australian food products.

Participation in the NRS is voluntary, and many of the pulse industry marketers and handlers participate. Failure to comply with safe pesticide use could jeopardise Australia's faba bean industry and markets.[14] See the NRS website (http://www.agriculture.gov.au/ag-farm-food/food/nrs) or call 1800 420 919.[15]

12 Pulse Australia (2016) Chemical application. Southern Faba & Broad Bean – Best Management Practices Training Course Module 1. 37 pp, Pulse Australia.

13 Australian Pesticide and Veterinary Medicine Authority (APVMA)

14 Pulse Australia (2016) Chemical application. Southern Faba & Broad Bean – Best Management Practices Training Course Module 1. 37 pp, Pulse Australia.

15 Department of Agriculture, Forestry and Fisheries, National Residue Survey

MORE INFORMATION

GRDC Fact Sheet: Spray right to avoid spray drift: best management practices, https://grdc.com.au/Resources/Bookshop/2008/12/Managing-Spray-Drift-fact-sheet

See the Spray Application Manual GrowNotes™

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Prevention of spray drift

GRDC-funded research into managing spray drift is continuing, including use of shielded sprayers in wide row cropping.

For information on nozzle selection to reduce the risk of drift, see: https://grdc.com.au/Resources/Publications/2015/08/Nozzle-Selection-Guide. This nozzle selection guide includes litres per hectare at various speeds based on 50-cm nozzle spacing.[16]

For details of the effects of surface inversion layers on spraying, go to https://grdc.com.au/Resources/Factsheets/2014/08/Surface-temperature-inversions-and-spraying[17]

Other on-farm issues, including drought, moisture stress, waterlogging, frost and lack of sunlight, also impact on farm productivity. Information on these issues can be found in Section 5 Plant growth and physiology.

16 GRDC (2015) https://grdc.com.au/Resources/Publications/2015/08/Nozzle-Selection-Guide

17 GRDC (2014) Surface temperature inversions and spraying, fact sheet. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2014/08/Surface-temperature-inversions-and-spraying

Marketing

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

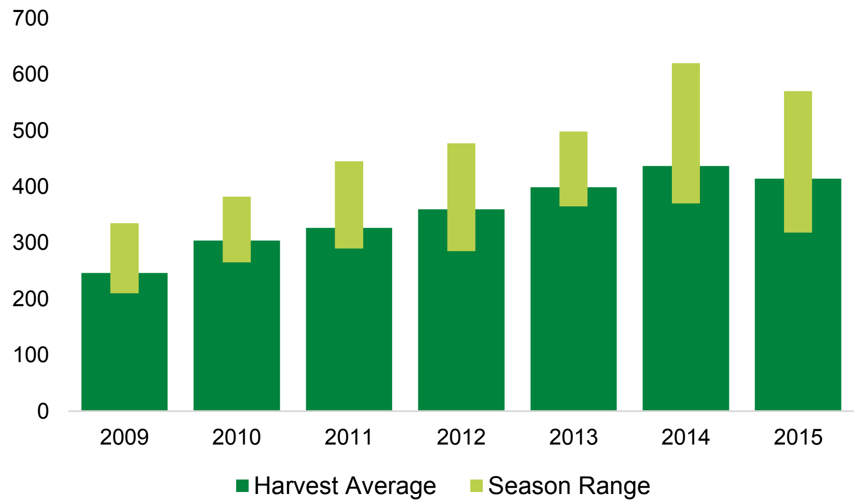


Figure 1: *Intra-season variance of Port Adelaide faba bean values.*

Note: Port Adelaide faba bean values have varied from A$115/t to $250/t over the past 7 years (representing variability of 30—60%). For a property producing 200 tonnes of faba bean this means $23,000—$50,000 difference in income, depending on timing of sales.

Source: Profarmer Australia

15.1 Selling principles

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

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

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

15.1.1 Be prepared

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

A selling strategy consists of when and how to sell.

1. When to sell

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

1. production risk
2. a target price based on cost of production and a desired profit margin
3. business cash flow requirements.

2. How to sell?

This is more dependent on external market factors including:

1. time of year determines the pricing method
2. market access determines where to sell
3. relative value determines what to sell.

The following diagram lists key selling principles when considering sales during the growing season.

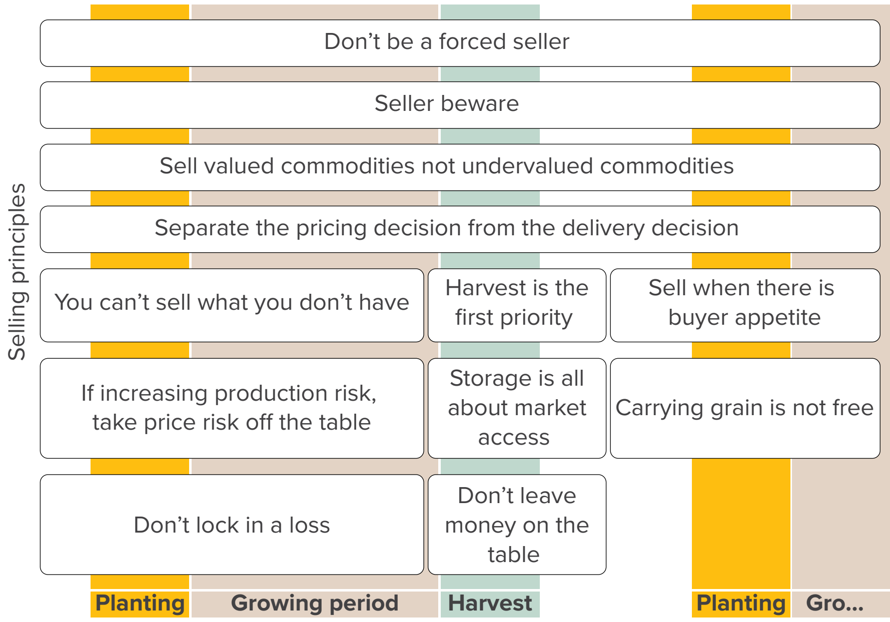


Figure 2: *Grower commodity selling principles timeline.*

Note: The diagram illustrates the key selling principles throughout the production cycle of a crop.

Source: Profarmer

15.2 Establish the business risk profile (when to sell)

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

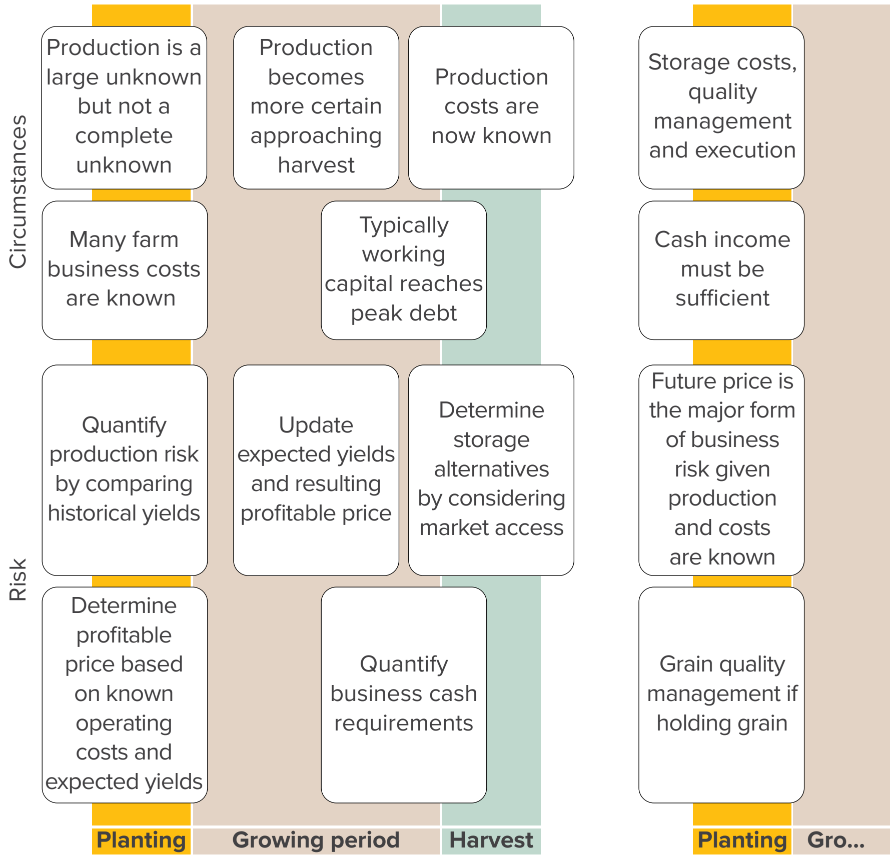


Figure 3: *Typical farm business circumstances and risk.*

Note: When does a grower sell their grain? This decision is dependent on:

a) Does production risk allow sales? And what portion of production?

b) Is the price profitable?

c) Are business cash requirements being met?

Source: Profarmer

15.2.1 Production risk profile of the farm

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

Principle: 'You can't sell what you don't have' – don't increase business risk by over-committing production.

Establish a production risk profile by:

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

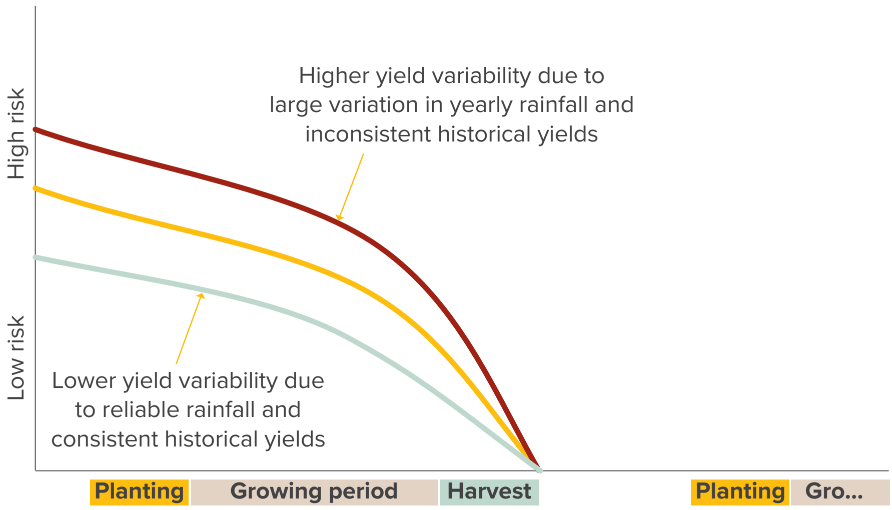


Figure 4: *Typical production risk profile of a farm operation.*

Note: The quantity of crop grown is a large unknown early in the year, however not a complete unknown. 'You can't sell what you don't have' but it is important to compare historical yields to get a true indication of production risk. This risk reduces as the season progresses and yield becomes more certain. Businesses will face varying production risk level at any given point in time with consideration to rainfall, yield potential soil type, commodity etc.

Source: Profarmer

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

A profitable commodity target price is the cost of production per tonne plus a desired profit margin. It is essential to know the cost of production per tonne for the farm business.

Principle: 'Don't lock in a loss' – if committing production ahead of harvest, ensure the price is profitable.

Steps to calculate an estimated profitable price based on total cost of production and a range of yield scenarios is provided in the GRDC's *Farming the Business Manual*, which also provides a cost of production template and tips on grain selling *v.* grain marketing.

15.2.3 Income requirements

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

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

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

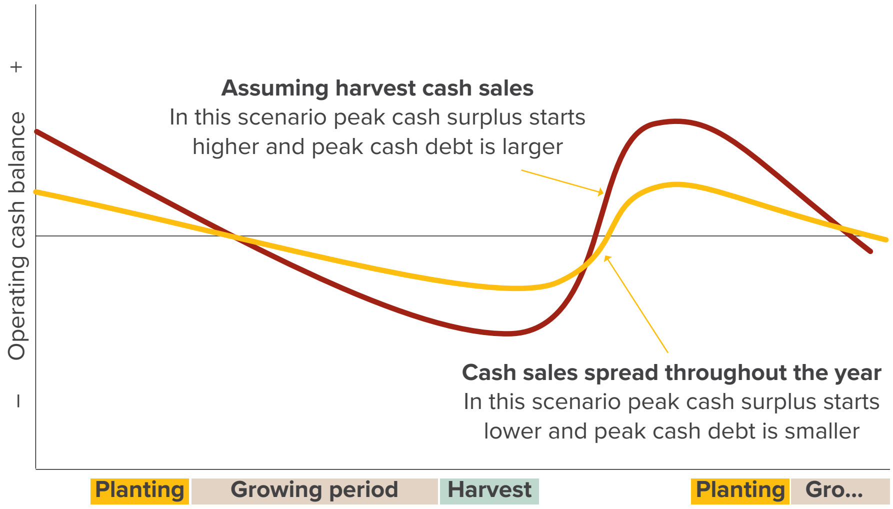


Figure 5: *Typical farm operating cash balance.*

Note: The chart illustrates the operating cash flow of a typical farm assuming a heavy reliance on cash sales at harvest *v.* a farm business that spreads sales out through the year.

When harvest sales are more heavily relied upon costs are incurred during the season to grow the crop, resulting in peak operating debt levels at or near harvest. Hence at harvest there is often a cash injection required for the business. An effective marketing plan will ensure a grower is 'not a forced seller' in order to generate cash flow.

By spreading sales throughout the year a grower may not be as reliant on executing sales at harvest time in order to generate required cash flow for the business. This provides a greater ability to capture pricing opportunities in contrast to executing sales in order to fulfil cash requirements.

Source: Profarmer

15.2 When to sell revised

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

15.3 Ensuring access to markets

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

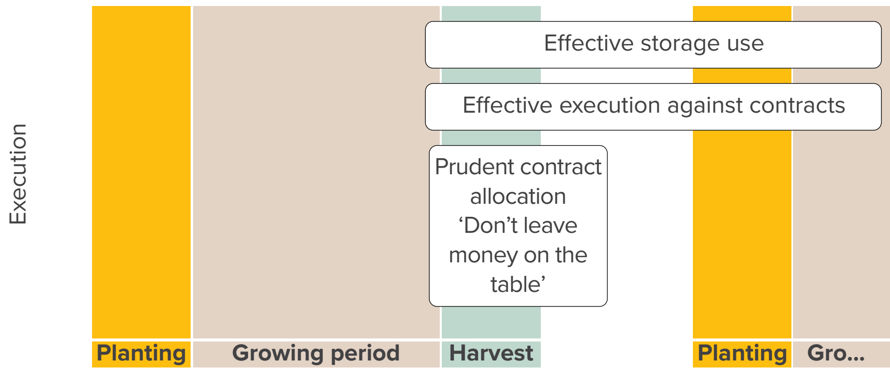


Figure 6: *Effective storage decisions.*

Note: Once a grower has made the decision to sell the question becomes how they achieve this. The decision on how to sell is dependent upon: a) The time of year determines the pricing method. b) Market access determines where to sell. c) Relative value determines what to sell.

Source: Profarmer

MORE INFORMATION

The Grain Storage GrowNotes™ is now available. Please see: https://grdc.com.au/grain-storage-grownotes

15.3.1 Storage and logistics

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

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

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

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

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

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

Principle: 'Storage is all about market access' – storage decisions depend on quality management and expected markets.

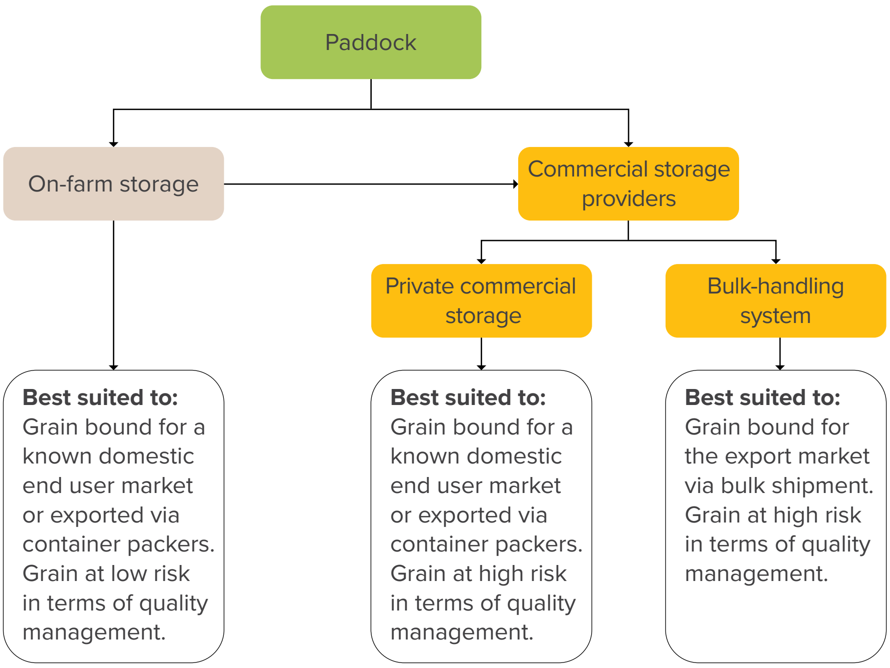


Figure 7: *Grain storage decision-making.*

Note: Decisions around storage alternatives of harvested commodities depend on market access and quality management requirements.
Source: Profarmer

15.3.2 Cost of carrying grain

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

Carry costs consist of:

i. monthly storage fee charged by a commercial provider OR capital cost allocation where on-farm storage is utilised; and

ii. the interest associated with having wealth tied up in grain rather than cash or against debt.

The price of carried grain therefore needs to be higher than what was offered at harvest. The cost of carry applies to storing grain on-farm as there is a cost of capital invested in the farm storage plus the interest component.

Principle: 'Carrying grain is not free' – the cost of carrying grain needs to be accounted for if holding grain and selling it after harvest is part of the selling strategy.

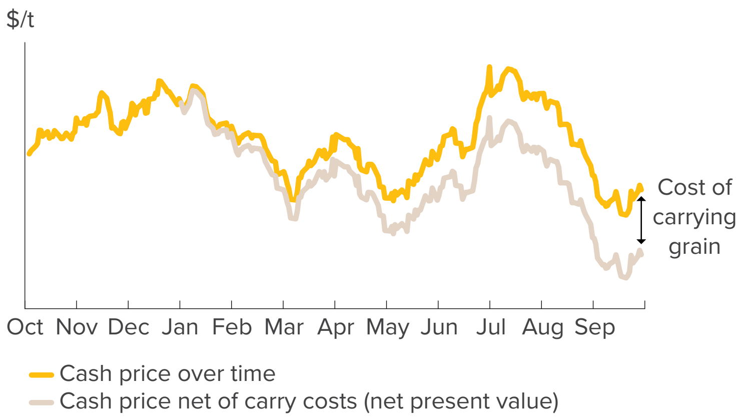


Figure 8: *Cash values v. cash adjusted for the cost of carry.*

Source: Profarmer

15.3 Ensuring market access

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

15.4 Executing tonnes into cash

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

15.4.1 Set up the tool box

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox includes:

1. Timely information

   This is critical for awareness of selling opportunities and includes:

   » market information provided by independent parties
   » effective price discovery including indicative bids, firm bids and trade prices
   » other market information pertinent to the particular commodity.

2. Professional services

   Grain selling professional service offerings and cost structures vary considerably. An effective grain selling professional will put their clients' best interest first by not having conflicts of interest and investing time in the relationship. Return on investment for the farm business through improved farm-gate prices is obtained by accessing timely information, greater market knowledge and greater market access from the professional service.

References:

The link below provides current financial members of Grain Trade Australia including buyers, independent information providers, brokers, agents, and banks providing over-the-counter grain derivative products (swaps).

http://www.graintrade.org.au/membership

15.4.2 How to sell for cash

Like any market transaction, a cash grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components with each component requiring a level of risk management:

- **Price**

  Future price is largely unpredictable hence devising a selling plan to put current prices into the context of the farm business is critical to manage price risk.

- **Quantity and quality**

  When entering a cash contract you are committing to delivery of the nominated amount of grain at the quality specified. Hence production and quality risk must be managed.

- **Delivery terms**

  Timing of title transfer from the grower to the buyer is agreed at time of contracting. If this requires delivery direct to end users it relies on prudent execution management to ensure delivery within the contracted period.

- **Payment terms**

  In Australia the traditional method of contracting requires title of grain to be transferred ahead of payment; hence counterparty risk must be managed.

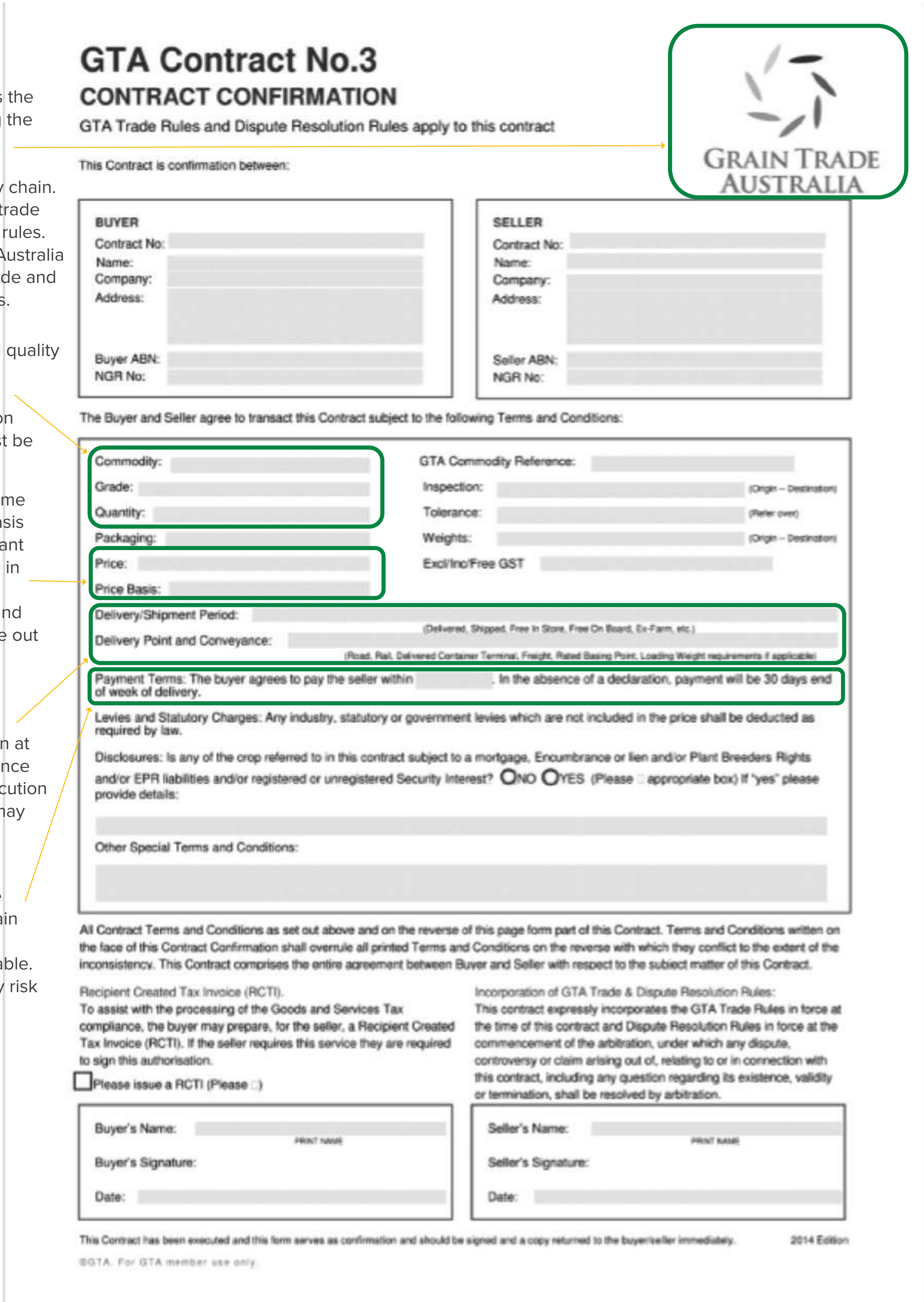
Grain Trade Australia is the industry body ensuring the efficient facilitation of commercial activities across the grain supply chain. This includes contract trade and dispute resolution rules. All wheat contracts in Australia should refer to GTA trade and dispute resolution rules.

Quantity (tonnage) and quality (bin grade) determine the actuals of your commitment. Production and execution risk must be managed.

Price is negotiable at time of contracting. Price basis or price point is important as it determines where in the supply chain the transaction will occur and so what costs will come out of the price before the growers net return.

Timing of delivery (title transfer) is agreed upon at time of contracting. Hence growers negotiate execution and storage risk they may have to manage.

Whilst the majority of transactions are on the premise that title of grain is transferred ahead of payment this is negotiable. Managing counterparty risk is critical.



GTA Contract No.3

CONTRACT CONFIRMATION

GTA Trade Rules and Dispute Resolution Rules apply to this contract

GRAIN TRADE AUSTRALIA

This Contract is confirmation between:

BUYER
Contract No:
Name:
Company:
Address:
Buyer ABN:
NGR No:

SELLER
Contract No:
Name:
Company:
Address:
Seller ABN:
NGR No:

The Buyer and Seller agree to transact this Contract subject to the following Terms and Conditions:

Commodity:
Grade:
Quantity:
Packaging:
Price:
Price Basis:

GTA Commodity Reference:
Inspection: (Origin – Destination)
Tolerance: (Refer over)
Weights: (Origin – Destination)
Excl/Inc/Free GST

Delivery/Shipment Period:
(Delivered, Shipped, Free In Store, Free On Board, Ex-Farm, etc.)
Delivery Point and Conveyance:
(Road, Rail, Delivered Container Terminal, Freight, Rated Basing Point, Loading Weight requirements if applicable)

Payment Terms: The buyer agrees to pay the seller within ______. In the absence of a declaration, payment will be 30 days end of week of delivery.

Levies and Statutory Charges: Any industry, statutory or government levies which are not included in the price shall be deducted as required by law.

Disclosures: Is any of the crop referred to in this contract subject to a mortgage, Encumbrance or lien and/or Plant Breeders Rights and/or EPR liabilities and/or registered or unregistered Security Interest? ○NO ○YES (Please □ appropriate box) If "yes" please provide details:

Other Special Terms and Conditions:

All Contract Terms and Conditions as set out above and on the reverse of this page form part of this Contract. Terms and Conditions written on the face of this Contract Confirmation shall overrule all printed Terms and Conditions on the reverse with which they conflict to the extent of the inconsistency. This Contract comprises the entire agreement between Buyer and Seller with respect to the subject matter of this Contract.

Recipient Created Tax Invoice (RCTI).
To assist with the processing of the Goods and Services Tax compliance, the buyer may prepare, for the seller, a Recipient Created Tax Invoice (RCTI). If the seller requires this service they are required to sign this authorisation.

□ Please issue a RCTI (Please □)

Incorporation of GTA Trade & Dispute Resolution Rules:
This contract expressly incorporates the GTA Trade Rules in force at the time of this contract and Dispute Resolution Rules in force at the commencement of the arbitration, under which any dispute, controversy or claim arising out of, relating to or in connection with this contract, including any question regarding its existence, validity or termination, shall be resolved by arbitration.

Buyer's Name:
PRINT NAME
Buyer's Signature:
Date:

Seller's Name:
PRINT NAME
Seller's Signature:
Date:

This Contract has been executed and this form serves as confirmation and should be signed and a copy returned to the buyer/seller immediately. 2014 Edition

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Figure 9: *Typical cash contracting as per Grain Trade Australia standards.*

Source: Grain Trade Australia

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. Figure 10 depicts the terminology used to describe pricing points along the grain supply chain and the associated costs to come out of each price before growers receive their net farm-gate return.

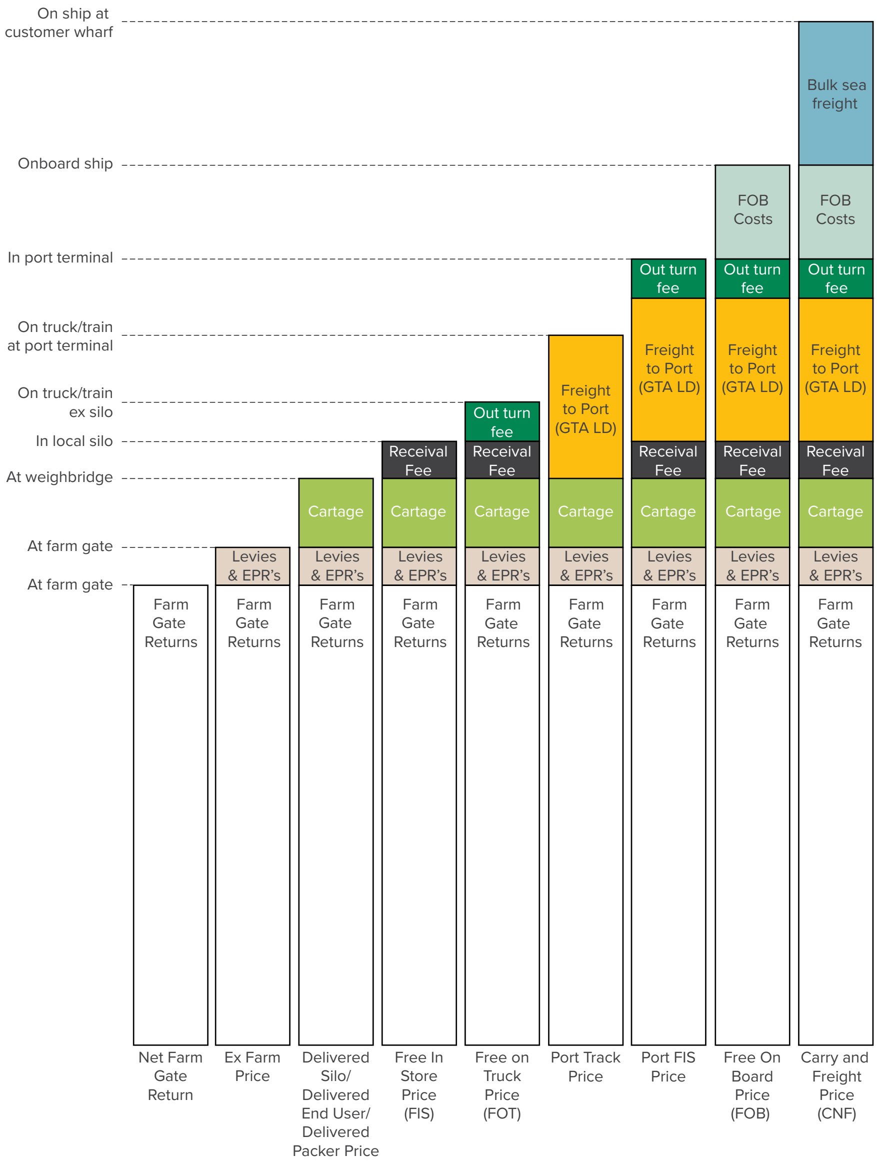

Figure 10: *Costs and pricing points throughout the supply chain.*

Source: Profarmer

Cash sales generally occur through three methods:

- **Negotiation via personal contact**

  Traditionally prices are posted as a 'public indicative bid'. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and available for all commodities.

- **Accepting a 'public firm bid'**

  Cash prices in the form of public firm bids are posted during harvest and for warehoused grain by merchants on a site basis. Growers can sell their parcel of grain immediately by accepting the price on offer via an online facility and then transfer the grain online to the buyer. The availability of this depends on location and commodity.

- **Placing a firm offer**

  Growers can place a firm offer price on a parcel of grain by approaching buyers with a set tonnage and quality at a predetermined price. The buyers do not have to accept the offer and may simply say no or disregard the offer.

  There are increasingly more channels via which to place a firm offer.

  One way this can be achieved anonymously is using the Clear Grain Exchange, which is an independent online exchange. If the firm offer and firm bid matches, the parcel transacts via a secure settlement facility where title of grain does not transfer from the grower until funds are received from the buyer. The availability of this depends on location and commodity.

  Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

  Some bulk-handler platforms are also providing facilities for sellers to place firm offers to the market. Including GrainCorp via their CropConnect product.

  Finally a grower can place a firm offer directly with an individual buyer.

15.4.3 Counterparty risk

Most sales involve transferring title of grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

Principle: 'Seller beware' – there is not much point selling for an extra $5/t if you don't get paid.

Counterparty risk management includes:

1. Dealing only with known and trusted counterparties.
2. Conduct a credit check (banks will do this) before dealing with a buyer they are unsure of.
3. Only sell a small amount of grain to unknown counterparties.
4. Consider credit insurance or letter of credit from the buyer.
5. Never deliver a second load of grain if payment has not been received for the first.
6. Do not part with title of grain before payment or request a cash deposit of part of the value ahead of delivery. Payment terms are negotiable at time of contracting, alternatively the Clear Grain Exchange provides secure settlement whereby the grower maintains title of grain until payment is received by the buyer, and then title and payment is settled simultaneously.

Above all, act commercially to ensure the time invested in a selling strategy is not wasted by poor counterparty risk management. Achieving $5/t more and not getting paid is a disastrous outcome.

15.4.4 Relative values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well and hold commodities that are not well priced at any given time. That is, give preference to the commodities of the highest relative value. This achieves price protection for the overall farm business revenue and enables more flexibility to a grower's selling program whilst achieving the business goals of reducing overall risk.

Principle: 'Sell valued commodities, not undervalued commodities' – if one commodity is priced strongly relative to another, focus sales there. Don't sell the cheaper commodity for a discount.

15.4.5 Contract allocation

Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (price, premiums-discounts, oil bonuses etc) and optimising your allocation reflects immediately on your bottom line.

Consideration needs to be made based on the quality or grades you have available to deliver, the contracts you already have in place and how revenues will be calculated on each contract. Key considerations include: does the contract calculate revenues based on a sliding scale or on predetermined quality 'buckets'. Whenever you have more grain to allocate than precommitted to contracts, don't forget to consider the premiums and discounts available in the current cash market as part of your contract allocation decision.

Principle: 'Don't leave money on the table' — contract allocation decisions don't take long, and can be worth thousands of dollars to your bottom line.

15.4.6 Read market signals

The appetite of buyers to buy a particular commodity will differ over time depending on market circumstances. Ideally growers should aim to sell their commodity when buyer appetite is strong and stand aside from the market when buyers are not that interested in buying the commodity.

Appetite in pulse markets can be fickle, erratic and the buy-side can be illiquid. Hence monitoring market signals is critical to achieving the best possible returns.

Principle: 'Sell when there is buyer appetite' – when buyers are chasing grain, growers have more market power to demand a price when selling.

Buyer appetite can be monitored by:

i. The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate buyer appetite is strong. However, if there is one buyer $5/t above the next best bid, it may mean cash prices are susceptible to falling $5/t if that buyer satisfies their buying appetite. In pulse markets the spread between the highest and the second highest bidder can be more than $100/t at times.

ii. Monitoring actual trades against public indicative bids. When trades are occurring above indicative public bids it may indicate strong appetite from merchants and the ability for growers to offer their grain at price premiums to public bids.

15.4 Sales execution revised

The selling strategy is converted to maximum business revenue by:

1. **Ensuring timely access to information, advice and trading facilities.**
2. **Using different cash market mechanisms when appropriate.**
3. **Minimising counterparty risk by effective due diligence.**
4. **Understanding relative value and selling commodities when they are priced well.**
5. **Thoughtful contract allocation.**
6. **Reading market signals to extract value from the market or prevent selling at a discount.**

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

15.5 Southern faba bean – market dynamics and execution

15.5.1 Price determinants for southern faba beans

Faba bean production in Australia has grown to become an important part of the Australian grains industry and an important part of many growers' rotations.

On average approximately 80% of Australia's faba bean crop is exported, principally for human consumption. The Middle East, particularly Egypt, is the main export market for Australian faba beans.

The main competitors to this market are the UK and France. While China is also a major producer, China is a net importer of faba beans. France and the UK have a geographical/freight advantage over Australian product into Middle Eastern markets; however, particular pests common in Europe and the UK, but not Australia, provide Australian product with a quality advantage.

The remaining 20% of the crop is used in the domestic stockfeed and aquaculture industries.

Hence the major price determinants for faba beans include:

- global supply and demand;
- quality of the global crop; and
- timing of Australian export program.

Due to the small relative size of pulse markets, markets can be illiquid. This may result in sharp spikes and reduction in prices from time to time.

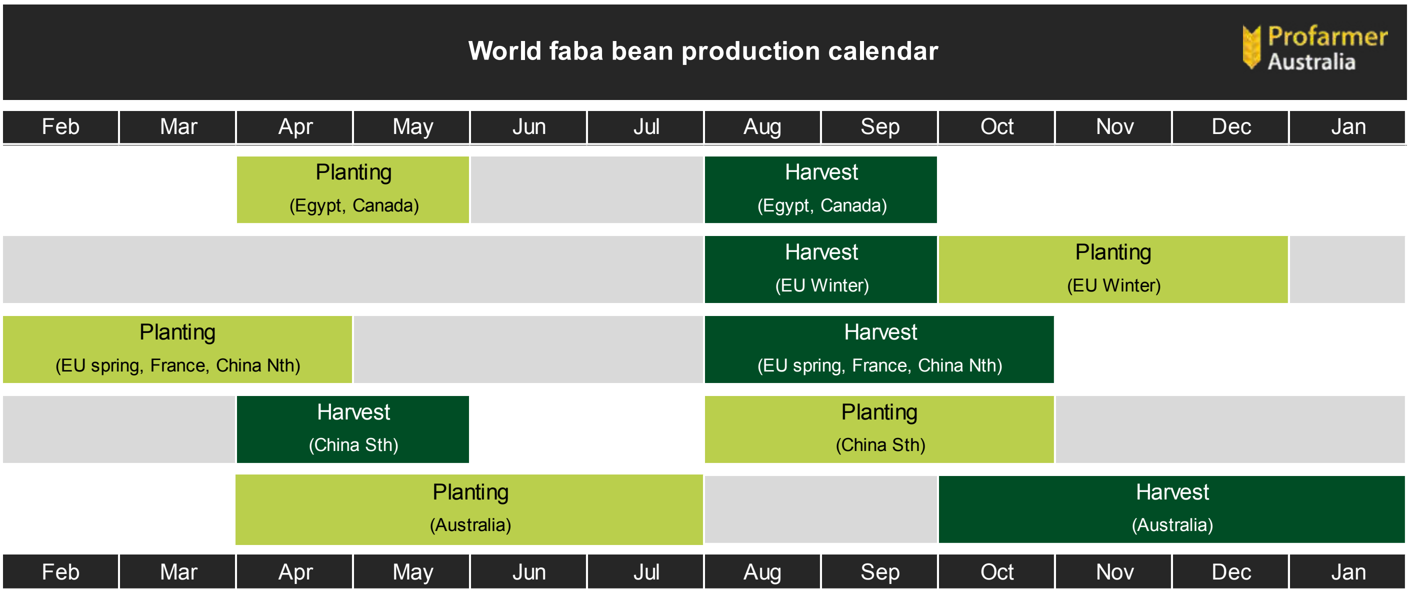

Figure 11: *Global faba bean production calendar.*

Note: This figure illustrates that when the Australian faba bean crop is sown (late April to the end of June for most areas), the areas and predicted yields for France and UK should be known. The sowing intentions in Egypt and Chinese southern production (mainly broad bean) should also be evident at that time.

When the Australian crop is harvested, the French, UK and Egyptian beans have been harvested; so too have the Chinese northern beans (small and broad bean types).

These world production and sowing areas can affect Australian crop demand, bean prices and market timings. French and UK harvest yields and quality expectations have the most impact on demand for Australian beans.

Source: Profarmer

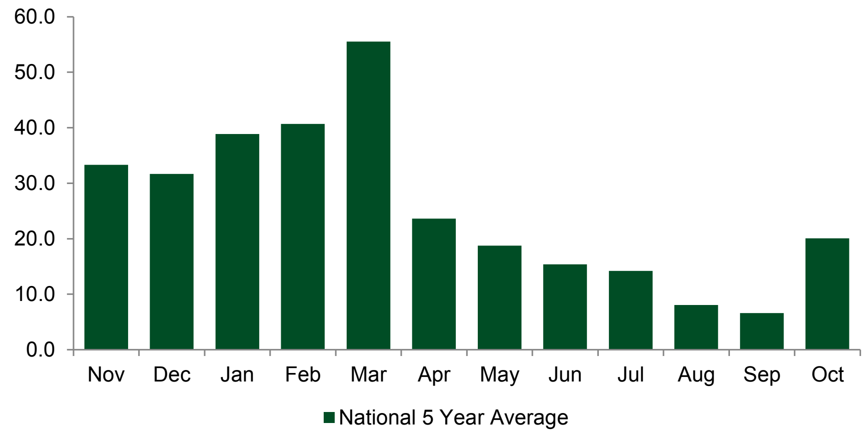

Figure 12: *Five--year average monthly export pace ('000 t) Australian faba beans and broad beans.*

Note: Australian faba bean export pace is typically strongest shortly after our harvest as buyers seek to move crop ahead of planting of the Egyptian new season crop as supplies of northern hemisphere old season crop become more scarce.

Source: Profarmer

15.5.2 Ensuring market access for southern faba bean

The major food markets for faba bean are in the Middle East, with Egypt being the largest importer. There are several other medium-size importers and many small importers. Quality requirements in terms of size and colour differ between end uses and between markets. Australia is one of the major exporters of faba bean, along with France and the UK.

The timing of Ramadan can also influence appetite for faba bean. Middle Eastern markets will tend to time purchases to arrive in advance of the Ramadan period, hence export activity can slow in the period before and during Ramadan.

For faba bean that are destined for export markets, understanding whether they are likely to ship via bulk export or in containers can help to inform storage decisions and ensure market access. While the bulk-handling system can provide a least-cost pathway for product destined for bulk export, storage on-farm and delivery direct to the end user can provide a lower cost and more flexible pathway to domestic and container export markets.

Most human consumption markets prefer faba bean that are >8 mm in size; smaller faba bean and broken bean (kibble) may be sold for production of bean flour or may be sold into the stockfeed markets. Tolerances for seed discolouration are also much lower for human consumption markets, especially for canning beans.

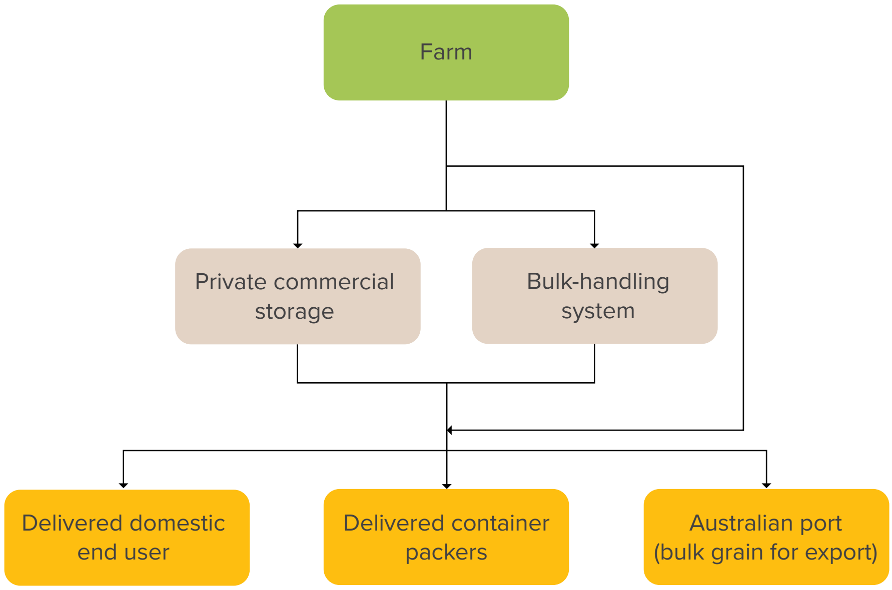

Figure 13: *Australian supply chain flow chart.*

Note: Storage decisions should be determined by assessing market access. The majority of Australian faba bean are exported in containers, with the remainder consumed in domestic stockfeed markets. Hence private commercial storage and on-farm storage can both provide efficiencies to market.

Source: Profarmer

15.5.3 Executing tonnes into cash for southern faba bean

Given the volatile nature of faba bean pricing, setting a target price using the principles outlined in Section 15.1 Selling principles minimises the risk of taking a non-profitable price or holding out for an unrealistically high price that may not occur.

There are some forward price mechanisms available for faba bean, including area contracts as well as a traditional fixed volume forward contract. While area-based contracts tend to price at a discount to fixed volume contracts, this discount needs to be weighed up against the level of production risk inherent in each contract.

As with all sales, counterparty risk and understanding the contract of sale is essential. Counterparty risk consideration is especially important for pulse marketing as there is often a higher risk of contract default in international pulse markets than for canola or cereals, this is due to the markets they are traded into, lack of appropriate price-risk tools (such as futures) and often the visual and subjective nature of quality determination. This can place extra risk on Australian-based traders endeavouring to find homes for your product.

With the majority of southern Australia's faba bean being exported in containers, growers should consider their access to these facilities as part of their overall marketing plan. Pulse Australia provide information about pulse exporters in Australia. If targeting homes in domestic stockfeed markets, again, proximity to these markets remains an important consideration.

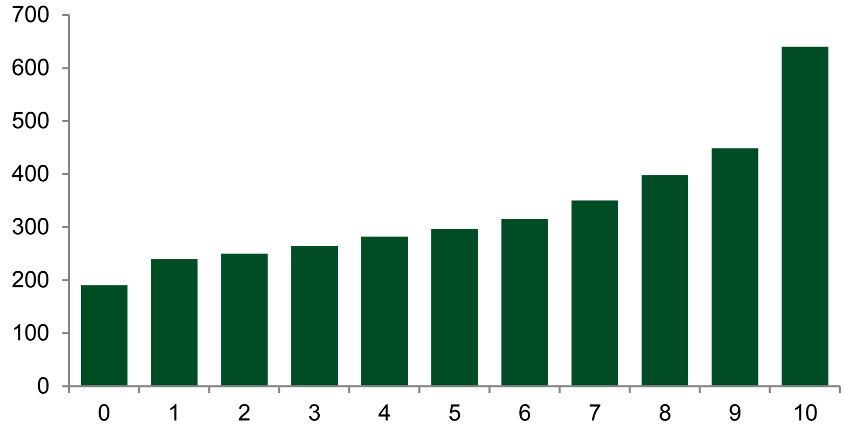

Figure 14: *Port Adelaide faba bean deciles.*

Source: Profarmer

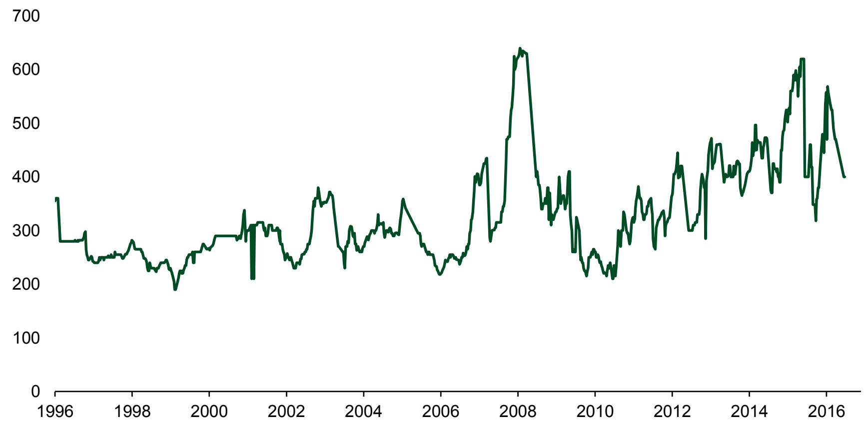

Figure 15: *Long-term Port Adelaide faba bean price history.*

Source: Profarmer

15.6 Marketing plan

Growers should consider their pulse marketing plan at the start of the season, rather than the end, for the best decision-making and results. A pulse marketing plan starts before a single seed is sown. A plan should contain:

- The pulse, and the best variety type to be grown.
- The marketer(s) to engage.
- Timing and schedule of delivery over the season.
- Delivery point and quality required for that product.
- Requirement for a forward contract.
- Ability to achieve the quality grade expected.
- Fall-back position if the quality grade cannot be achieved.

Global pulse markets are driven by factors each season in the major pulse growing countries, including Australia, Middle East, France and the UK for faba bean. The varieties planted, the environmental conditions and exchange rates will affect the prices – if there's an oversupply of one commodity the price could potentially drop while demand and price could increase on another commodity.

MORE INFORMATION

An update paper on the market and receivals by Wayne Hawthorne is at https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2012/08/pulse-market-and-receivals-update

Being aware and informed of the market trends means growers can make the best choices for their situation. For example, in some seasons, lentil and faba bean prices have increased towards and post-harvest, however this is coincidental, and it's not always likely to occur.

In these instances the prices have been driven upwards due to a combination of drought in parts of Australia along with international factors. It's important to keep abreast of these kinds of fluctuations in prices, so that growers can sell their product at the optimal time.

Engaging a pulse marketer can help growers get the best returns by developing answers to the following questions:

- Who is your target customer? Knowing your customer helps to direct efforts and costs towards what's actually important to them, so you can receive the best financial return.
- Who is your competitor? Consider both domestic and international competitors and what can be done to deliver a better proposal to the customer.
- When is the best time to sell your product? Does it make sense to build extra storage on-farm to sell at the highest price point? Alternatively are there cost-effective local storage options?
- What is your desired customers' quality specification? Quality is one of the best ways to set yourself apart from competitors. What farm practices should be put in place to ensure quality specifications are met?

Pulse growers are encouraged to build relationships with their grain marketer to understand global trends and be advised on the best-selling options. Growers will benefit from knowing which varieties will be in demand, timing of the sale to meet a gap in supply, and the commodities quality specifications to target to get the best return.

Certain premium or niche pulse products with limited markets can only realistically be grown through a relationship with a marketer who can identify the market to ensure the product can be sold.

Most importantly, pulse marketing is extremely unpredictable and growers should perform due diligence to ensure they're selecting an appropriate marketing company. Know whether the marketing company is a member of Grain Trade Australia (GTA); who is backing that company; and confirm that they are financially secure.

Key contacts

GRDC Contacts in the Southern Region:

Adelaide Office:

P: 08 8198 8400

Craig Ruchs
Senior Regional Manager – South
E: craig.ruchs@grdc.com.au

Stephen Loss
Manager Soils and Nutrition – South
E: stephen.loss@grdc.com.au

Andrew Etherton
Manager Agronomy and Farming Systems – South
E: andrew.etherton@grdc.com.au

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