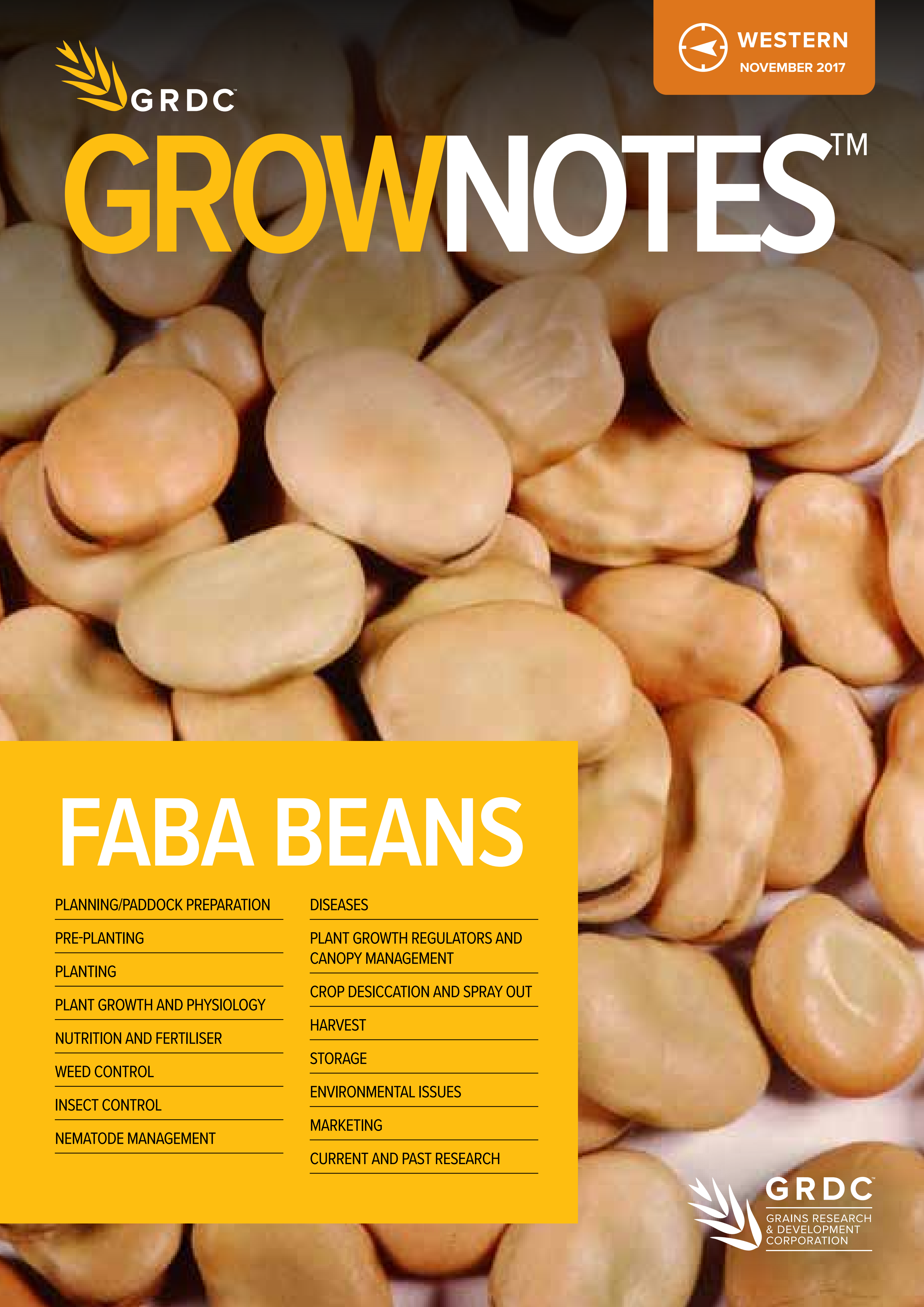

WESTERN
NOVEMBER 2017

GRDC

GROWNOTES™

FABA BEANS

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

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

What market options are there for faba beans?

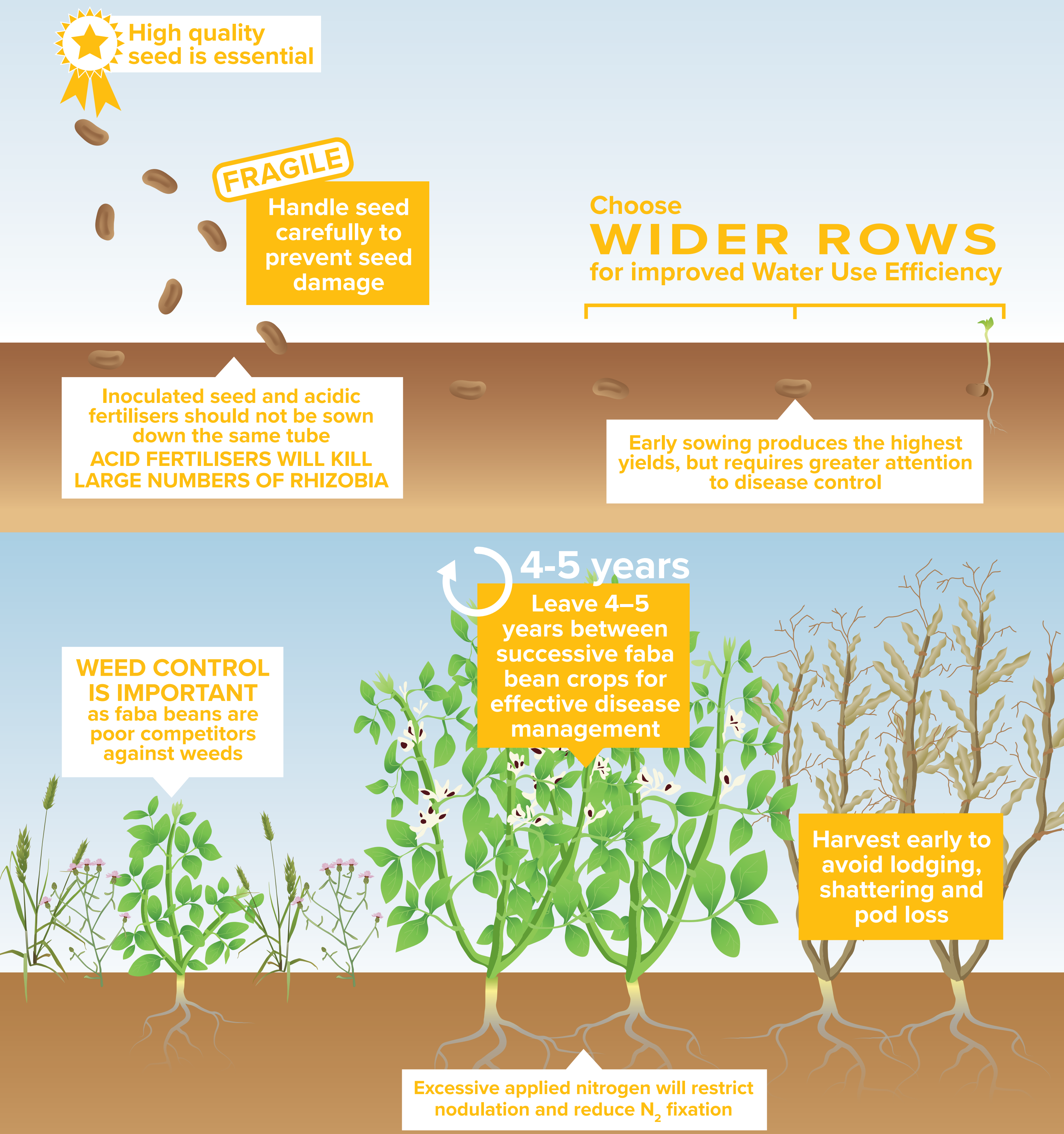
What conditions do faba beans prefer?

What about inoculation? What inoculant group do I use?

What weed control strategies do I need to employ?

How can I manage chocolate spot infection in faba beans?

If harvest is delayed what are the costs?


High quality seed is essential
FRAGILE
Handle seed carefully to prevent seed damage
Choose WIDER ROWS for improved Water Use Efficiency
Inoculated seed and acidic fertilisers should not be sown down the same tube
ACID FERTILISERS WILL KILL LARGE NUMBERS OF RHIZOBIA
Early sowing produces the highest yields, but requires greater attention to disease control
4-5 years
Leave 4–5 years between successive faba bean crops for effective disease management
WEED CONTROL IS IMPORTANT as faba beans are poor competitors against weeds
Harvest early to avoid lodging, shattering and pod loss
Excessive applied nitrogen will restrict nodulation and reduce N_2 fixation

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Introduction

A.1 Crop overview

A.1.1 The role of pulses in farming systems

In WA, faba beans is a niche crop and production currently stands at around 6,000 tonnes (DAFWA). *Vicia faba* minor is grown under broadscale farming conditions in WA.

In modern farming systems pulses have a role that is far greater than the traditional ones of 'nitrogen fixation' and 'disease break'. They can be a cash crop in their own right, and also a valuable part of the whole farming system, especially for weed control within crop rotations.

A diversity of crops in a rotation is important for continuous cropping systems:

- to handle herbicide-resistant weeds or delay the onset of herbicide resistance by varying herbicide options and timings for weed control
- to control disease of all crops in the rotation
- to spread the timing of farm operations
- to spread risks across commodities
- to minimise the impact of increasing costs of fertiliser nitrogen (N) and fuel. [1]

It is usual practice to deep-sow legumes, because they have great ability to emerge from depth (Photo 1). Faba bean seed inoculated with rhizobium (Group F) should be planted into moist soil, and can be planted to 15–20 cm depth. [2]

Photo 1: *Faba beans have the ability to emerge from sowing of up to 20 cm deep.*

Photo: Drew Penberthy, Penagcon

Pulses can be sown in wide rows if required, enabling non-selective weed control between the rows by using hooded shields. Sowing the pulse crop between the standing rows of cereal stubble is beneficial and can be done with GPS guidance and

1 GRDC (2008) *Grain Legume Handbook*. GRDC.

2 Pers comms G Onus. Fababean Growing Program. Landmark Moree.

auto-steer sowing systems. [3] This enables the cereal crop in the following season to be planted down the legume row to separate it from the previous cereal stubble and reduce the crop's exposure to crown rot fungus.

Planting faba beans with the cereal stubble standing also helps to protect the seedling faba beans from aphid infestations, which in turn can reduce the incidence of viruses in the crop. [4] Figure 1 shows the areas of WA that are suitable for growing faba beans.

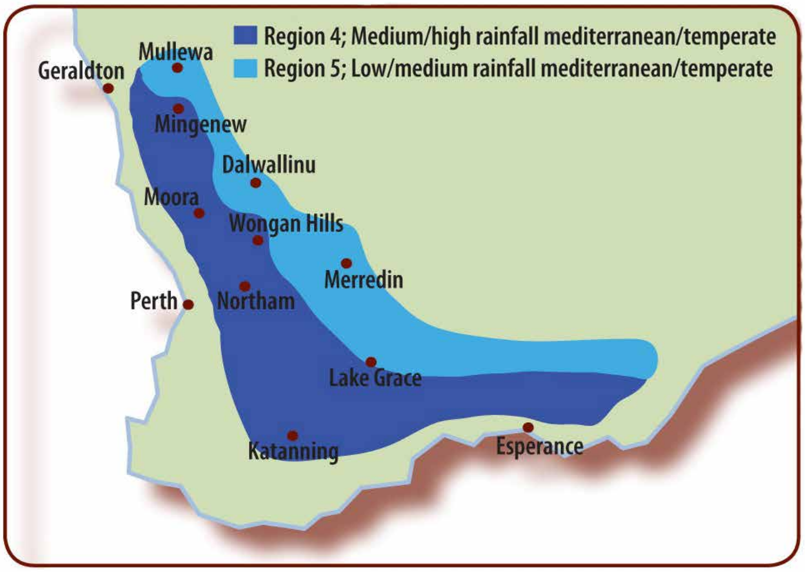

Figure 1: *WA areas suitable for growing faba beans.*

Source: Pulse Breeding Australia

A.1.2 About faba bean

Faba beans were first grown commercially for grain in northern New South Wales in the early 1980s, and are now grown in all Australian grain production regions, particularly in Victoria, New South Wales and Western Australia. Small areas are cultivated in Tasmania and southern Queensland. It is a cool-season crop in Australia, planted in autumn and harvested in late spring–early summer, and is a valuable crop for livestock nutrition and crop rotation. [5] The Australian faba bean industry has grown steadily to be the world's number one exporter, on average more than 307,000 tonnes per year over the last five years.

This large-seeded bean is well adapted to higher-rainfall areas because of its higher yield potential, better disease and waterlogging tolerance, and virtue of being able to attract higher prices. [6]

Growing faba beans

The faba bean plant is tall: it may grow a height of 2 m at maturity under optimum conditions, although plants in Australian crops are usually <1.5 m tall. It is erect and multi-stemmed from basal branches. The leaves are compound, having 2–7 leaflets. The first leaves have only two leaflets, but there are seven in the last-formed leaves. It has a well-developed taproot, which bears a profusion of fibrous roots in the top

3 GRDC (2008) *Grain Legume Handbook*. GRDC.

4 G Onus. Fababean Growing Program. Landmark Moree.

5 P Matthews and H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

6 Pulse Australia (2016) Faba bean production: southern and western region. http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide#australian-industry

30 cm of soil. Plants will flower profusely and under cool, moist conditions may flower over a five to ten week period.

Flowering in early varieties begins from about the 5th to 7th leaf-bearing stem node (joint), and up to the 15th or higher node in late varieties. Flowers are borne in clusters (inflorescences) comprising 3–8 flowers (depending on variety) in the angle between leaf and stem (axil) at each node (Photo 2). Inflorescences form in succession up the stem as each new node is produced, over a period of six to ten weeks, or at ~15 flowering nodes. [7]

Photo 2: *Faba bean flowering. Like many legumes, excess flowers are produced and <15% will develop to produce pods.*

Photo: Gordon Cumming, Pulse Australia

Honeybees seek nectar from the flowers and in the process pick up pollen, transferring it between plants and causing cross-pollination to occur at rates commonly in the range 25–30%.

Flowering finishes once the maximum average weekly temperatures reach >25°C and/or moisture becomes limited, after which an extra few leaf-bearing nodes are produced.

Pods in a well-grown crop are borne from ~20 cm above ground to ~30 cm below crop height (Photo 3). Each pod contains 2–6 seeds. As pods mature, they turn black, as do the stems and leaves of the plant.

7 P Matthews and H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

Photo 3: *Podded faba bean plant.*

Photo: Pulse Australia

Seeds vary in size depending on the variety, from large flattened beans (also known as broad beans) through medium sizes to smaller, rounded seeds that are like field peas (Photo 4). Varieties with medium-sized seed are the main types grown in Australia, whereas the smaller-seeded types are common in Europe.

Photo 4: *Faba bean seeds come in different colours and sizes.*

Photo: Pulse Australia

A.1.3 Suitable environments

Faba beans are not well suited to lower-rainfall areas. If moisture is limited, the plants do not grow to full height and the pods set close to the ground. They do not tolerate hot conditions during flowering, which can result in poor podset and premature termination of flowering. Hot and dry conditions during flowering usually result in a severe reduction in yield. However, stubble retention and planting in wider rows can ameliorate these limitations a little, and enable faba beans to be grown in lower-rainfall areas and seasons.

Faba beans prefer well-drained loam to clay soils with a pH in the range of 6–9. They will not grow as well in light or acidic soils.

Under WA conditions, faba beans do well in less windy areas and in heavier soils. Pulse crops tend to be grown in the medium to low rainfall (350–250 millimetres (mm)) environments with chickpea sown at the start of the growing season in May and field peas towards the end of the planting season in June.

They are known for being the pulse that is most tolerant of waterlogging; however, to survive prolonged waterlogged conditions the plants must be well nodulated and foliar diseases must be controlled. Waterlogging will still attenuate crop growth, so although the plants will grow and set seed, they are likely to be stunted and will yield less than plants growing in well-drained soil.

Faba beans and broad beans are moderately susceptible to hostile sub-soils, and boron toxicity, sodicity and salinity can cause patchiness in affected paddocks. Faba beans do not tolerate exchangeable aluminium in soil. [8]

A.2 Products and uses

All seed types are used as dry beans for human consumption or for livestock feed. Value-adding in the form of canning, splitting, and preparation as snack foods services niche markets. For example, in China, faba beans are used to make extruded starch products (e.g. vermicelli) and sauces. [9]

Faba beans are sometimes used as a green manure crop, as they are capable of producing a large amount of N-rich biomass.

A.3 Market

The market for WA-produced faba beans is largely restricted to the Middle East, principally Egypt.

World production of faba beans now exceeds 4 million tonnes annually, but only about 2% of this production is traded internationally. The major exporting countries are Australia, France, and the United Kingdom. China was a major exporter of faba beans but has recently become an importer.

All faba beans grown in Australia are targeted at human-consumption markets. Countries in the Middle East, specifically Egypt, Saudi Arabia, and the United Arab Emirates, are the major buyers of faba beans. Faba beans are generally consumed whole, canned, or split, or milled into flour.

Producing a high-quality product with continuity of supply is important for current access to world faba bean markets, and to increase Australia's market share.

International trade in food-quality faba beans is dominated by Egypt as the major importer, with several other countries importing smaller but still significant amounts. In addition, several countries are significant importers of faba beans for livestock feed.

Suppliers of faba beans to Egypt include the United Kingdom and the European Union (predominantly France), both of which have a geographical advantage over Australia in shipping. Additionally, the harvest of European faba beans is completed by September, giving Europeans a three to four month advantage before the Australian harvest is ready for export.

Markets prefer the green seed-coat colour of new-crop faba beans. It is critical Australia produces a high-quality product with excellent colour and uniformity of size. As the seed coat oxidises and browns, buyer acceptance declines, along with the price. Storage facilities with a controlled temperature can increase the time before oxidation starts to occur. The European faba beans can be of lesser

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8 Pulse Australia (2016) Faba bean production: southern and western region. Website, http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide#australian-industry

9 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course.

quality, often because of bruchid damage (a similar effect as pea weevil in Australian field peas).

Faba beans that have a minor seed-coat blemish (e.g. wrinkling, staining or darkening with age) can be split to produce a quality product if the defect does not damage the kernel. There is, however, a more limited market for these seeds.

Factors which should influence Australian farmers to grow faba beans include:

- forecasted planting intentions of European farmers, particularly in France and UK
- Egyptian imports from the previous season
- export activity from Australia and potential carryover stocks.

The outlook for Australian faba beans is influenced by:

- the crop harvest in Egypt, UK and France (before the Australian harvest)
- the prospects of Chinese exports (before and at the Australian harvest). [10]

A.4 Faba bean research

All varieties released have been developed from genetic material introduced to Australia, mostly from an international genetic resources centre in Syria (the International Center for Agricultural Research in the Dry Areas, ICARDA), with the best germplasm so far originating from the Mediterranean, southern China and South America.

Pulse Breeding Australia (PBA) runs a world-class, Australian breeding program for chickpeas, field peas, faba beans, lentils and lupins.

PBA is developing a number of improved varieties for Australian growers that achieve higher yields, have resistance to major diseases and stresses, and have grain qualities that enhance Australia's market competitiveness. PBA is an unincorporated joint venture between:

- Grains Research and Development Corporation (GRDC)
- Department of Agriculture and Food Western Australia (DAFWA)
- Department of Primary Industries, Victoria (DPI Vic)
- South Australian Research and Development Institute (SARDI)
- Department of Agriculture, Fisheries and Forestry, Queensland (DAFF Qld)
- New South Wales Department of Primary Industries (NSW DPI)
- University of Adelaide
- University of Sydney
- Pulse Australia

MORE INFORMATION

GRDC Final Reports: Australian Faba Bean Breeding Program

Pulse Australia: Faba Bean Production: Southern and Western Region

10 Pulse Australia (2015) Pulses: Understanding global markets. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/marketing-pulses#faba-beans

Planning/Paddock preparation

Key messages

- Pulse and cereal crops are complementary in a cropping rotation.
- Pulses fix their own nitrogen (N), leaving available nitrogen in the soil for the following crops.
- Faba beans are more efficient at fixing N than most legumes, principally because of their nitrate tolerance.
- Avoid soils that are shallow, acidic or very light and sandy in texture.
- If sowing more than one variety, ensure there is at least 500 metres between them.

1.1 Paddock selection

Uniformity of soil type, paddock topography, and the surface condition of the paddock are preferable for faba bean production. Use a roller after sowing where needed to level the soil surface.

Harvest losses are much higher in rough or uneven paddocks, particularly in dry seasons when crop height is reduced. Sticks or rocks, eroded gullies or gilgais ('melon' or 'crab' holes) will prevent headers from operating at a low cutting height. Uneven paddocks can also increase the risk of contamination in the sample. The smoother the paddock the better the harvesting result, particularly when using headers with wide fronts.

Faba beans are easier to harvest than chickpeas or field peas in these conditions, but can be prone to lodging when planted too early. Frost can cause 'hockey stick', which can also lead to some harvesting difficulties, although newer varieties have better tolerances to this phenomenon.

Management of the fallow after wheat or barley should start when the cereal is harvested, ensuring that stubble from the previous cereal crop is best kept at ~30 cm height to maintain a suitable environment for planting faba beans. [1]

Aim to direct-drill faba beans into standing cereal stubble. Crops reliably yield 10% higher when established this way.

The presence of thick stubbles at sowing can cause stubble bunching and clumping which can affect the evenness of faba bean plant emergence and performance of pre-emergent herbicides.'

Management options for dealing with stubble clumping include:

- Use a no-till (disc) seeder or other seeder capable of handling heavy stubble.
- Modify existing air seeders (altering tine shape and lifting some tines).
- Sow before soil and stubble become too wet.
- Use rotary harrows to spread and level stubble.
- Standing stubble can be slashed or burnt if sowing equipment with good trash flow is not available.
- Planting between standing cereal stubble protects the young faba bean plants from early frosts and helps to prevent the spread of viruses from thrips and aphids [2] (Photo 2).

1 P Matthews and H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

2 G Onus. Fababean Growing Program. Landmark Moree.

- Harvest low the previous year's cereal crop to lower stubble and increase stubble flow through seeders. [3]

Crop maturity can be significantly affected by moisture supply during the growing season. Any major changes in soil type and moisture-storage capacity across a paddock can lead to uneven crop maturity, delayed harvest, and increased risk of weather damage and/or high harvest losses due to cracking and splits. Uneven crop development also complicates the timing of insecticide sprays, timing of desiccation, and disease management.

The best soils for faba beans are deep neutral to alkaline, well-structured soils with high clay content. Avoid soils that are shallow, acidic (pH in $CaCl_2$ <5.2), or very light and sandy in texture. Growers considering planting faba beans on lower pH soils need to check for aluminium (Al) and manganese (Mn) levels, because these will adversely affect plant growth. If soil pH is <5.2, an application of lime should be considered. Avoid soils that are acid at depth, i.e. (pH in $CaCl_2$ <5.2) at 20–30 cm. [4]

Soil sodicity should also be checked, and soils with high exchangeable sodium percentages (ESP) should be avoided as crop establishment and development is poor in these soil types. (Photo 1).

Photo 1: *Soils with high exchangeable sodium percentages (ESP) should be avoided.*

Photo: Drew Penberthy, Penagcon

Weed management for all pulses should involve particular attention to controlling broadleaf weeds in the preceding crop to minimise broadleaf weed pressure in the pulse crop due to the lack of broadleaf selective herbicide options. Be aware of any residual herbicide usage. [5]

3 Pulse Breeding Australia (2013) Southern/Western Faba Bean—Best Management Practices Training Course. Module 1–Rotational Benefits.

4 DEPI (2013) Growing faba bean. Note number AG0083. Rev. edn. Department of Environment and Primary Industries Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

5 Pulse Breeding Australia (2013) Southern/Western Faba Bean—Best Management Practices Training Course. Module 1–Rotational Benefits.

Photo 2: *Planting between standing cereal stubble protects the young faba bean plants from early frosts and helps to prevent the spread of viruses from thrips and aphids.*

Photo: Drew Penberthy, Penagcon

FAQ

1.2 Key requirements for faba beans

Faba beans prefer well-drained loam to clay soils with a pH in the range 5.4–8.0.

They can grow in areas prone to waterlogging, and are the pulse most tolerant of waterlogging (Photo 3). However, they must be well nodulated and have foliar diseases controlled to survive prolonged, waterlogged conditions.

Photo 3: *Faba beans prefer well-draining loam to clay soils but are considered the pulse most tolerant to waterlogging.*

Faba beans are moderately susceptible to hostile subsoils, with boron toxicity, sodicity and salinity perhaps causing patchiness in affected paddocks. Faba beans have very low exchangeable Aluminium tolerance.

Tolerance to sodicity in the root-zone (to 90 cm) is: <5% ESP on the surface and <10% ESP in the subsoil (Table 1).

Broadleaf weeds and herbicide-resistant ryegrass can cause major problems in faba beans, and a careful management strategy must be worked out well in advance of sowing. It may be possible to control the weeds in the year prior to cropping. However, it is best to avoid paddocks with specific weeds that cannot be controlled by herbicides. Foliar zinc (Zn), manganese (Mn) and perhaps iron (Fe) may be needed where deficiencies of these micronutrients are known to occur. [6]

If planning to grow faba beans long term, wide rows and hooded sprays should become part of the system.

Agronomist's view

Table 1: *Pulse crop soil requirements.*

Crop	Soil type	Soil pH ($CaCl_2$)	Exchangeable aluminium (%)	Drainage tolerance and rating (1–5)	Sodicity in root-zone (90 cm) (ESP)
Lupins, narrow leaf	Sandy loams	4.2–6.0	20% tolerant	Sensitive (2)	<1 surface <3 subsoil
Lupins, albus	Sandy loams–clay loams	4.6–7.0	Up to 8%	Very sensitive (1)	<1 surface <3 subsoil
Field peas	Sandy loams–clays	4.6–8.0	Up to 5–10%	Tolerant (3)	<5 surface <8 subsoil
Chickpeas	Loams–self mulching clay loams	5.2–8.0	Nil	Very sensitive (1)	<1 surface <5 subsoil
Faba beans	Loams–clay loams	5.4–8.0	Nil	Very tolerant (4)	<5 surface <10 subsoil
Canola	Loams–clay loams	4.8–8.0	0–5%	Tolerant (3)	<3 surface <6 subsoil
Lucerne	Loams–clay loams	5.0–8.0	Nil	Sensitive–tolerant (1–3)	<3 surface <5 subsoil

ESP, Exchangeable sodium percentage. Drainage tolerance: 5, no hardpans and good drainage (no puddles after 24 h from a 50-mm rain event); 1, hardpans—can aggravate waterlogging and cause artificial waterlogging

Source: C. Mullen (2004) NSW DPI Central NSW soils

1.3 Benefits of faba beans as a rotation crop

Pulses and cereals

Pulses and cereal crops are complementary in a cropping rotation. The ways in which a crop affects following crops include well-recognised processes related to disease, weeds, rhizosphere microorganisms, herbicide residues, and residual soil water and mineral nitrogen (N).

6 Pulse Breeding Australia (2013) Southern/Western Faba Bean—Best Management Practices Training Course. Module 1–Rotational Benefits.

MORE INFORMATION

GRDC (2011) Break crop benefits: western region–why make the break? Fact sheet.

GRDC (2014) Nitrogen fixation of crop legumes: Basic principles and practical management. Factsheet.

Pulses fix their own N, leaving available N in the soil for the following cereal crop. Pulses also play a vital role in controlling major cereal root diseases, particularly take-all.

The combination of higher soil N and reduced root diseases is cumulative and can result in a dramatic increase in subsequent cereal yields. [7]

Disease management

Increased levels of plant-available N are only part of the story. Some of the increases in cereal yield can be attributed to the break effect of the legumes on soil- and stubble-borne diseases.

Crop legumes make generally effective disease breaks, and are usually more effective than a pasture phase because of the potential for grasses to provide alternative hosts for disease. Diseases cause yield loss of cereals, with estimates of losses varying with site, season, species and cultivar.

Quantifying break crop yield increases

Yields of wheat grown after a broadleaf break crop generally exceed yields of wheat grown after wheat or other cereals. The presumed reasons for the yield benefit vary between break crops. They include reduced root and foliar disease, increased supply of soil water and mineral N, reduced assimilate loss to mycorrhizae and, after legumes, growth stimulation following hydrogen gas release.

Angus et al. (2008) quantified the value of break crops by compiling data from published experiments on the additional yield of wheat following oilseeds, pulses or alternative cereals grown in the previous year. Generally, yield increase was not proportional to yield, and the yield contribution of break crops is best expressed in absolute terms, not percentage.

The data suggested control of take-all and residual N after legumes are the largest benefits from break crops (Table 2).

Table 2: *Sources of the break crop effect and estimates of their value at a wheat yield level of 4 t/ha.*

Mechanism for wheat yield increase	Additional wheat yield (t/ha)
Take-all suppression	0.5
Suppression of other root diseases	0.3
Net nitrogen benefit of canola	0.1
Hydrogen fertilisation by legumes	0.4
Suppression of AMF by non-host crops	0.0–0.1
Net nitrogen benefit of legumes	0.5

Hydrogen fertilisation is from increased soil hydrogen after legumes and is assumed at 10%; AMF, arbuscular mycorrhizal fungi

Source: Angus et al. 2008

Legumes such as faba beans, lupins, chickpeas and field peas offer the benefit of hydrogen fertilisation, which stimulates growth by 0–15% due to increased hydrogen in the soil. Estimates of the yield effect of hydrogen fertilisation by legumes are ~10%. [8]

The impacts of a pulse crop on farm profits is a real one with results across 900 experimental comparisons showing that, on average, wheat yields increased by 0.5 t/ha following oats, 0.8 t/ha following canola and 1.0 t/ha following grain legumes (0.7–1.6 t/ha) compared with wheat on wheat. This break-crop effect often extended

7 Pulse Breeding Australia (2013) Southern/Western Faba Bean—Best Management Practices Training Course. Module 1–Rotational Benefits.

8 Pulse Breeding Australia (2013) Southern/Western Faba Bean—Best Management Practices Training Course. Module 1–Rotational Benefits.

to a second wheat crop in the sequence, especially following legumes (benefit of 0.2–0.3 t/ha), but rarely to a third except under dry conditions. [9]

The effect of the break crop should be considered over the life of the rotation.

Nitrogen fixation

A pulse crop does not necessarily add large quantities of N to the soil. The amount of nitrogen gas (N_2)fixed is determined by how well the pulse crop grows, reflecting the effectiveness of nodulation, seasonal conditions, crop management, and the level of nitrate in the soil at sowing. Soil nitrate suppresses nodulation and N_2 fixation. Thus, high soil nitrate means low N_2 fixation.

Pulses are usually able to fix sufficient N_2 from the air for their own needs, but a large amount is removed with the grain when crops are harvested.

To understand N budgets for pulse crops, it is important to understand the terminology (Table 3):

Table 3: *Terms used to describe legume N_2 fixation and N-cycling in farming systems.*

Term	Meaning
N fixation	The reduction of atmospheric nitrogen gas to ammonia (NH3). Nitrogen fixation in legumes is a biological process in which root nodule bacteria (rhizobia) fix N_2 via the enzyme nitrogenase.
Total crop N fixed	The total contribution of N_2 fixation to legume biomass, including above-ground vegetation and below-ground roots and nodules. In legumes, 30 to 50 per cent of total crop N is in the below-ground portion of the plant.
Crop N balance	The difference between N inputs and N outputs. N inputs are N_2 fixation and fertiliser N (if applied). Outputs are the N in harvested grain or hay/fodder plus N lost through volatilisation and leaching.
Nitrate-N benefit	The extra nitrate N available after a legume crop; best described as the difference between soil nitrate N when the legume was sown and nitrate N at sowing of the following crop.

Source: GRDC

Soil N levels following a pulse crop usually remain undepleted, so it is the available N that is high.

Where a pulse crop grows well but produces a poor yield, i.e. low harvest index, there may be an increase in total soil N levels. Crops producing average or above average yields are likely to remove as much N as they produce. Generally, then, soil N levels following a pulse crop are the result of a carryover effect of residual N rather than a net gain from the crop (Table 4). In low-yielding cereal–pulse rotations, the pulse may provide enough N for the following crop. [10]

9 J Kirkegaard (2015) Grain legumes can deliver an extra 1 t/ha yield to wheat crops. GRDC, http://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

10 Pulse Breeding Australia (2013) Southern/Western Faba Bean—Best Management Practices Training Course. Module 1–Rotational Benefits.

Table 4: *Nitrate-N benefit (kg N/ha) from chickpeas and faba beans over a range of grain yields.*

Grain yield (t/ha)	Shoot dry matter (t/ha)	Low soil nitrate at sowing (50 kg N/ha)			Moderate soil nitrate at sowing (100 kg N/ha)		
		N fixed	N balance	Nitrate-N benefit	N fixed	N balance	Nitrate-N benefit
Chickpeas							
1.0	2.4	31	–3	16	13	–21	4
1.5	3.6	74	22	28	47	–5	13
2.0	4.8	120	49	44	84	12	24
2.5	6.0	157	66	48	111	21	38
3.0	7.1	198	88	52	141	31	52
3.5	8.3	231	102	57	164	35	64
4.0	9.6	264	116	61	188	39	69
Faba beans							
1.0	2.8	49	12	15	39	2	3
1.5	4.2	83	25	26	68	10	11
2.0	5.6	120	40	41	100	21	22
2.5	6.9	158	58	45	133	33	36
3.0	8.3	196	75	49	167	45	49
3.5	9.7	234	92	53	202	60	60
4.0	11.1	274	111	57	237	74	64

Source: Grain Legume Handbook, 2008

In a study which quantified nitrogen fixation, Turpin et al (2002) found faba beans fixed more N_2 than chickpeas. Values of N of the total plant including roots were 209–275 kg/ha for faba beans and 146–214 kg/ha for chickpeas. Faba beans fixed between 69-88% N and chickpeas fixed between 64-85% N (Figure 1). Soil N balances, which combined crop N fixed as inputs and grain N as outputs, were positive for the legumes, with ranges 80–135 kg N/ha for chickpeas and 79–157 kg N/ha for faba beans, and negative for wheat (–20 to –66 kg N/ha). [11]

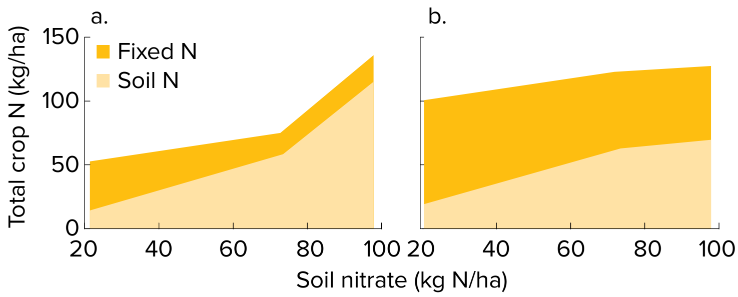

Figure 1: *Effects of soil N supply on soil-N use and N2 fixation of (a) chickpeas and (b) faba beans for days 0–64 of growth. Soil N supply varied with fertiliser N treatment. These data supports the need for early and effective nodulation in faba bean.*

Source: Turpin et al. 2002

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

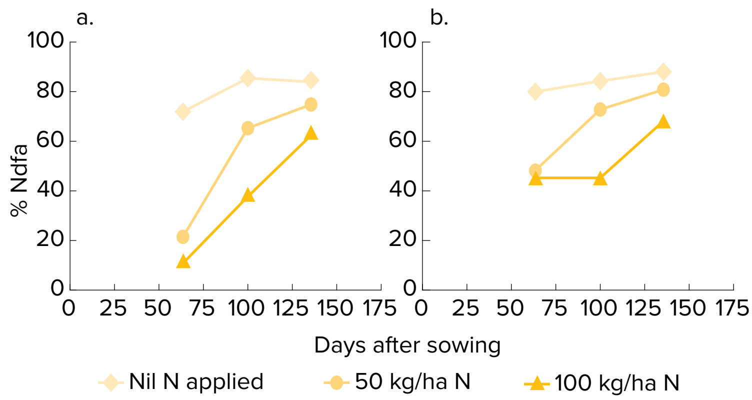

Figure 2: *Effects of available soil nitrogen (applied as N fertiliser) on the percentage of the N that was fixed (i.e. derived from the atmosphere; % Ndfa) over time for (a) chickpea and (b) faba bean. ◆, Nil N applied; ●, 50 kg/ha N; ▲, 100 kg/ha N applied.*

Source: Turpin et al. 2002

1.4 Disadvantages of faba bean as a rotation crop

A disadvantage of faba beans is that they often struggle to provide an economic return as a 'stand-alone' crop. However, this disadvantage is usually minimised by the benefits they provide to other crops in the rotation. Often, economic benefits realised in the following crops can be attributed to the preceding faba beans and should be compared over a 5-year period not just year by year.

Faba beans have a few other disadvantages. Diseases in wet years are also a concern where the cost of fungicide can out weight the net return. Spraying with a tow-behind spray rig is also an issue later in the season because they grow so tall; a self-propelled spray rig or a plane is usually required after mid-flower. In addition, high water rates for effective prophylactic fungicide application means slow spraying.

There are a limited amount of options for broad leaf weed control in faba beans especially wild radish. This can result in major weed infestations if weed seed banks are high. Volunteers can appear after the crop is harvested.

1.5 Fallow management

Effective weed management in faba beans involves planning at least a season before sowing. Few herbicides are registered for the control of broadleaf weeds, so paddocks must have a low broad leaf weed burden or they must be controlled in the preceding crop and fallow.

Benefits of fallow weed control include:

- Conservation of summer rain and fallow moisture
- Summer fallows conserve valuable nutrients for the crop being sown

Modelling studies show that the highest return on investment in summer weed control is for lighter soils, or where soil water is present that would support continued weed growth. [12]

MORE INFORMATION

GRDC (2014) Nitrogen fixation of crop legumes: Basic principles and practical management. Fact sheet.

GRDC (2015) Inoculating legumes: A practical guide.

12 C Borger, V Stewart, A Storrie. Double knockdown or 'double knock'. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/objtwr/imported_asets/content/pw/weed/iwm/tactic%202.2doubleknock.pdf

Use of best management practices such as timely sowing, optimal plant population and adequate nutrition are valuable for weed management, because faba beans compete strongly once canopy closure has occurred. [13]

1.5.1 Fallow chemical plant-back effects

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

When planning weed-control programs in crops and fallow prior to faba beans, be cautious about the use of herbicides with damaging residues. Many of the Group B herbicides have long plant-back periods—up to 24 months for faba beans—which are prolonged on dry soils with pH($CaCl_2$) >6.5. [14]

Residues of sulfonylurea herbicides can persist in some soils and can last for several years, especially in more alkaline soils and where there is little summer rainfall. The pulses emerge and grow normally for a few weeks and then start to show signs of stress. Leaves become off-colour, roots may be clubbed, and plants stop growing and eventually die. Unlike other pulses, faba beans are more sensitive to triasulfuron than to chlorsulfuron residues. Faba beans are one of the least-sensitive pulses to chlorsulfuron residues in soil. Refer to the labels for recommendations on plant-back periods for pulses following the use of any herbicides.

Residues of picloram (e.g. Tordon® 75-D) from spot-spraying can stunt any pulse crop grown in that area. This damage is especially marked in faba beans, where plants are twisted and leaves are shrunken (Photos 4 and 5). In severe cases, bare areas are left in the crop where this herbicide has been used, sometimes >5 years ago. Although this damage usually occurs over a small area, correct identification of the problem avoids confusion with some other problem such as disease.

Herbicides such as Broadstrike®, Eclipse®, Flame®, Grazon® DS, Lontrel® and metsulfuron (Ally®, Associate®, Lynx®, Harmony® M) should all be avoided, particularly during the summer fallow or weed-control period (after November).

The use of long-term residual sulfonylurea herbicides such as Monza®, chlorsulfuron, and triasulfuron should be avoided in wheat when re-cropping to faba beans. [15]

13 P Matthews and H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

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

15 Pulse Breeding Australia (2013) Southern/Western Faba Bean—Best Management Practices Training Course. Module 1–Rotational Benefits.

Photo 4: *Previous year's Tordon® spot spray effect. Plants in the affected area are stunted.*

Photo: Grain Legume Handbook, 2008

Photo 5: *Tordon® soil residues affecting faba bean. Note the stem distortion and severe leaf curl.*

Photo: Grain Legume Handbook, 2008

MORE INFORMATION

Pulse Australia (2015): Residual Herbicides and Weed Control.

1.6 Soil moisture

Faba bean varieties should be grown only in areas where the rainfall is >350 mm; they are not well suited to lower-rainfall areas. They are very responsive to moisture, and will grow very short with pods close to the ground if moisture is severely limiting. In addition, faba beans do not tolerate hot conditions during flowering; hence, pod set can be poor and flowering terminated prematurely when the weather is hot. Yield potential is therefore severely penalised by adverse hot and dry conditions during flowering.

Cool conditions are ideal for flowering and podset. Cool and wet conditions are more likely to stimulate foliar diseases if protection is not provided, and foliar disease can adversely affect seedset and yield. Chocolate spot *(Botrytis fabae)* and, in some areas, rust (*Uromyces viciae*-fabae) are now the highest priorities for control in medium- and high-rainfall areas.

Variety choice, crop hygiene, and fungicide choice and timing are all important in a management strategy for foliar diseases of faba beans.

1.7 Yield and targets

Under ideal conditions, pulse crops should be able to produce 12–15 kg/ha of grain for every mm of growing season rainfall over 130 mm. By comparison, wheat can produce 20 kg/ha for every mm of rainfall over 110 mm (Figure 3).

Different pulses have varying yield potentials under different yielding situations, based on yield potential under adequate moisture or drought tolerance (Figure 4).

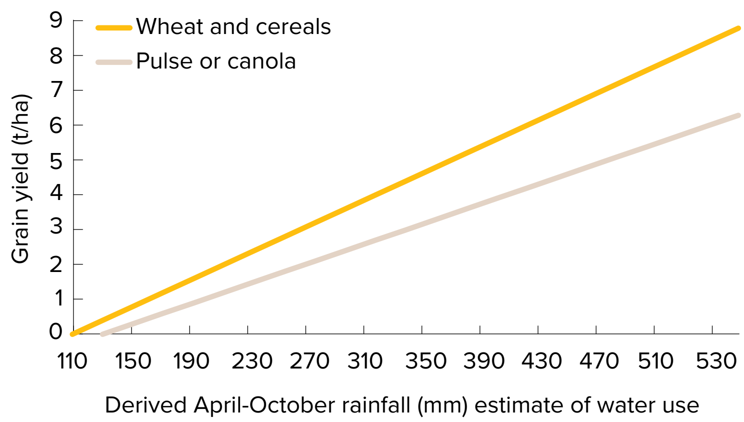

Figure 3: *Relationship of grain yield (t/ha) to estimated water use April–October. Pulses, 15 kg/ha/mm water available over 130 mm; cereals, 20 kg/ha/mm available over 110 mm.*

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

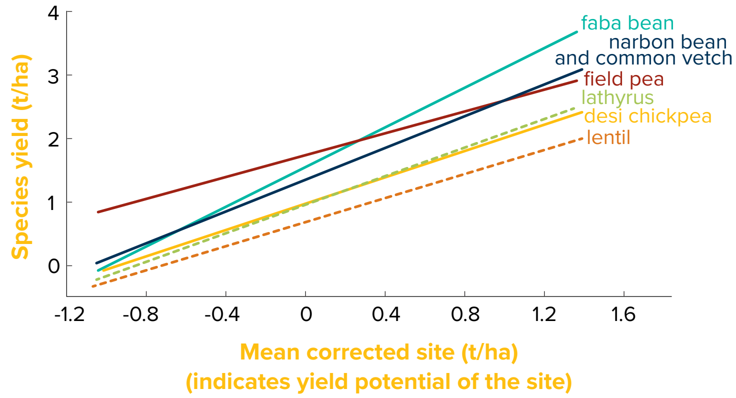

Figure 4: *Variation in grain yield of different grain legume species across sites with different yield potential in Western Australia.*

Source: Adapted from K. Siddique et al. 1999

Ratio of water use to evaporation

The average pulse crop is subjected to an evaporation stress of 600–650 mm from sowing to harvest.

The best yields occur when water use by the crop is 0.7 times the evaporation level, i.e. 420–434 mm.

Temperature

One of the most critical factors affecting pulse yield is temperature. Temperature at flowering can be too high or too low for pollen survival, and hence fertilisation and podset.

Faba beans likely require temperatures ≥10°C (mean daily temperature) at flowering, which is similar to field peas, lentils, lupins and vetch, but lower than the 15°C required by chickpeas. Sunlight, and hence photosynthesis, is critical for podset in faba beans. At temperatures <–1.5°C, the bean plant tissue freezes.

High temperatures (>30°C) can cause flower abortion and cause flowering to cease, even with adequate soil moisture.

For maximum yield, flowering in faba beans and most other winter pulses should be completed by the week in which the average daily maximum temperature reaches 20°C. By comparison, the critical maximum temperature for wheat is 23°C and for chickpeas 30°C.

Cumulative maximum daily temperature (CMDT) can be used to determine the start and end of flowering as well as maturity date. CMDT is calculated by the progressive addition of individual daily maximum temperatures. Table 5 presents CMDTs that different crops need from sowing to reach flowering and harvest.

Table 5: *Cumulative maximum daily temperatures (CMDT) from sowing to various crop growth stages.*

	Beginning of flowering	End of flowering	Harvest
Faba beans	1300	2200	3300
Field peas	1600	2400	3300
Lupins	1600	2400	3600
Chickpeas and lentils			
Early cultivars	1600	2400	3200
Late cultivars	2000	2800	3400
Wheat	1900	2200	3300

Source: Grain Legume Handbook, 2008

The use of CMDT makes it possible to work out the ideal sowing time for pulse crops in a particular area from meteorological information, using the accumulation of maximum daily temperatures with time (i.e. CMDT) and the week that critical flowering temperature occurs.

The sowing time for highest yield in each area can be worked out by defining either:

- when the week of 20°C occurs; or
- when the average daily temperature is first warm enough (>15°C) for the crop to commence flowering and set pods.

Then having defined these dates, count back the CMDT days of cumulative temperature needed for the crop to develop from sowing to that date, using the CMDT units required by faba beans to achieve the start or end of flowering.

1.8 Disease status of paddock

Selection of the most appropriate paddock for growing faba beans requires consideration of several important factors, many of which relate to the modes of survival and transmission of pathogens such as chocolate spot.

Rotation

- Develop a rotation of no more than 1 year of faba beans in 4 years.
- Growers who plan to sow more than one variety of faba beans should ensure at least 500 m between different varieties. Faba beans cross-pollinate, increasing the risk of the breakdown of disease resistance, and of the production of mixed seed types that are difficult to market.
- Plant faba 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 (aphids may be vectors for viruses).
- Consider previous crops that may have hosted pathogens such as *Sclerotinia* spp., *Rhizoctonia solani*. and *Phoma medicaginis*.
- *Ascochyta fabae* and *Botrytis fabae* are faba bean-specific, whereas *Botrytis cinerea* has a wide range of hosts, including chickpeas.
- *Phoma medicaginis* var. *pinodella* can be hosted by lucerne, clover, field peas, lupins, chickpeas and *Phaseolus* spp. (various beans).

History of faba bean diseases

- A previous occurrence of soil-borne diseases (Sclerotinia stem rot, stem nematode or perhaps *Pratylenchus* nematodes) constitutes a risk for subsequent faba bean crops for up to 10 years.
- Reduce disease risk by avoiding sowing adjacent to vetch crops or stubble. They may harbour *Botrytis fabae*, the primary cause of chocolate spot in faba beans

- Plant at least 500 m (preferably more) away from the previous year's bean crop.

Weeds

- Almost all weeds host *Sclerotinia* spp.
- Some of the viruses affecting faba beans also have wide host ranges. Weeds, particularly perennial legumes, host viruses (e.g. Cucumber mosaic virus) and their aphid and leafhopper vectors.

Herbicide history

- Determine whether triazine, 'imi' or sulfonylurea herbicides been applied in the last 12 months
- The development of some diseases is favoured in herbicide-weakened plants.
- The presence of herbicide residues in the soil may cause crop damage and thus confusion over in-field disease diagnosis. It also has a major effect on nodulation. [16]

Faba beans are also at risk of getting sclerotinia, Growers should be aware of the sclerotinia risk of selected paddocks where the disease may be transferred between canola and lupins.

Agronomist's view

MORE INFORMATION

GRDC (2015) Root-lesion nematodes western region: Tips and Tactics.

K. Owen et al. (2013) Summer crop decisions and root lesion nematodes: GRDC.

G M Murray and J P Brennan (2012) The current and potential costs from diseases in pulse crops in Australia: GRDC.

Crown Analytical Services

1.9 Nematode status of the paddock

The root-lesion nematode (RLN) is a microscopic worm-like organism <1 mm in length that feeds in root tissues. These nematodes are found over 5.74 million ha, or approximately 65%, of the cropping area of WA. Populations potentially limit yield in at least 40% of these infested paddocks.

In Western Australia, *P. neglectus* is the main species of RLN, with P. *quasitereoides* (originally described as *P. teres*) the next prevalent and *P. thornei* rarely occurring. It is only *P. quasitereoides* that is known not to occur outside of Western Australia, and worldwide there is little information available for this nematode.

Identification of the nematode species is important to management decisions because varieties and crops species differ in their resistance or susceptibility to different members of the *Pratylenchus* genus. For example, field peas, lupins and faba beans are resistant to *P. neglectus* but susceptible to *P. penetrans*.

The most important management tool is the use of rotations that effectively reduce RLN populations. In heavily infested paddocks, resistant break-crops should be grown for one or two years to decrease the population. [17]

1.10 Insect status of paddock

Soil-dwelling insect pests can seriously reduce plant establishment and populations, and subsequent yield. Soil insects are often difficult to detect as they hide under trash or in the soil. Immature insects such as false wireworm larvae are usually found at the interface between moist and dry soils.

Soil insects include:

- cockroaches
- crickets
- earwigs
- black scarab beetles

16 Pulse Breeding Australia (2013) Southern/Western Faba Bean—Best Management Practices Training Course. Module 1–Rotational Benefits.

17 GRDC (2015) Root-lesion nematodes western region. Tips and Tactics, https://grdc.com.au/TT-RootLesionNematodes

- cutworms
- false wireworms
- true wireworms
- snails and slaters

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

- Weedy fallows and volunteer crops encourage soil insect build-up.
- Insect numbers decline during a clean long fallow due to lack of food.
- Summer cereals followed by volunteer winter crops promote the build-up of earwigs and crickets.
- High stubble levels on the soil surface can promote some soil insects due to the presence of a food source, but this can also mean that pests continue feeding on the stubble instead of germinating crops.
- Zero tillage encourages beneficial predatory insects and earthworms.
- Incorporating stubble promotes black field earwig populations.
- False wireworms are found under all intensities of cultivation but they decline if stubble levels are very low.

Soil insect control measures are normally applied at sowing. Since different insects require different control measures, the species of soil insects must be identified before planting. [18] For more information, see Section 7, Insect control.

18 DAFF QLD (2011) How to recognise and monitor soil insects. Department of Agriculture and Fisheries, Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects

Pre-planting

Key messages

- Faba beans have large flat seeds, which are predominantly a beige or buff colour.
- Colour, size, shape and texture are important attributes in the marketability of faba beans.
- Faba beans prefer well-drained loam to clay soils with a pH in the range of 5.4–8.0.
- When choosing varieties, consider their susceptibility to chocolate spot, Ascochyta and rust.
- PBA Samira⦻ is a high-yielding variety with widespread adaption and is the variety of choice in south-eastern WA.

2.1 Faba bean types

The *Vicia faba* varieties grown in Australia can be divided into two types: the smaller, faba bean types, and the larger, broad bean types. This large-seeded bean is well adapted to higher-rainfall areas because of its higher yield potential, better disease and waterlogging tolerance, and virtue of being able to attract higher prices. [1]

2.2 Choosing a variety

When choosing varieties to grow, consider their susceptibility to chocolate spot, Ascochyta blight and rust, along with yield potential, price potential, marketing opportunities, maturity timing, lodging resistance and other agronomic features relevant to the growing region. [2]

Faba bean varieties are bred for a range of environments. Hence, individual varieties have specific areas of adaptation for maximising yield and reliability. Specific adaptation of a variety depends on rainfall, geography, temperatures, disease pressure, and soil types at the site of cropping.

The national pulse production area has been categorised by Pulse Breeding Australia (PBA) into five regions based on rainfall and geographic location (see Figure 1 below):

- Region 1, low rainfall, tropical
- Region 2, medium rainfall, subtropical
- Region 3, low rainfall, subtropical
- Region 4, medium–high rainfall, Mediterranean–temperate
- Region 5, low–medium rainfall, Mediterranean–temperate

The regions cross state borders, and are target zones for national breeding and variety evaluation. Breeding trials and NVT results help to indicate specific adaptation even within a region. Some variety releases have been specific for northern Australia (e.g. Doza⦻ and PBA Warda⦻). Other varieties have been found to be better adapted to specific parts of regions (e.g. PBA Rana⦻ and PBA Kareema⦻ in southern high-rainfall areas).

The area of adaption is specified for each variety so that potential users are aware of the best fit. [3]

1 Pulse Australia (2016) Faba bean production: southern and western region. http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide#australian-industry

2 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 3–Varieties.

3 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 3–Varieties.

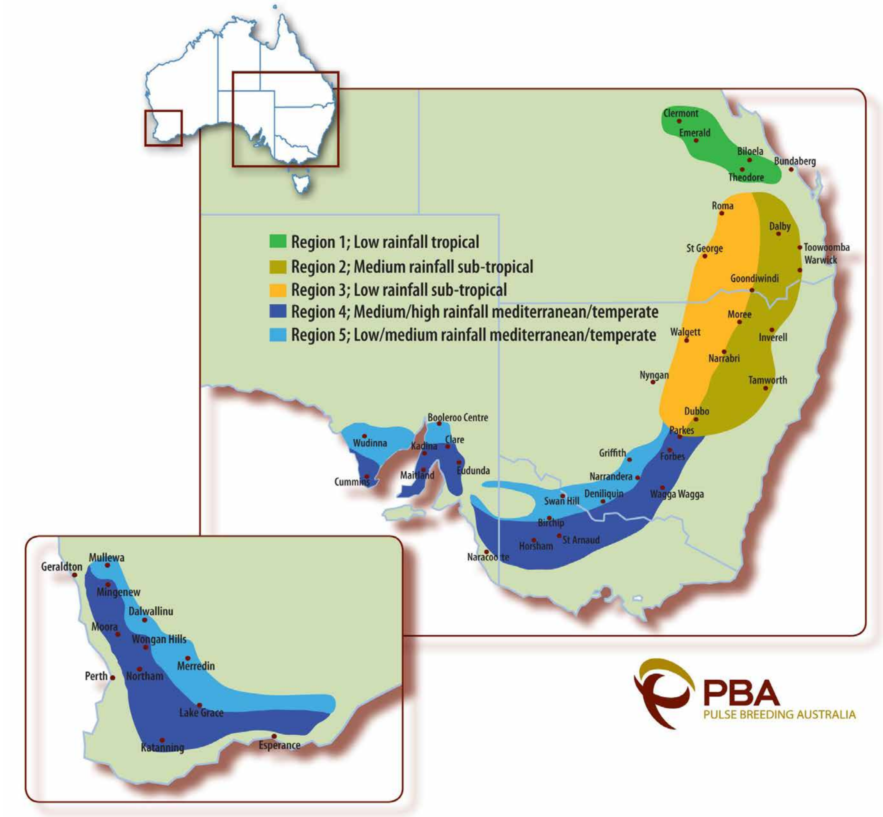

Figure 1: *PBA regions used to describe variety area of adaptation.*

Variety choice will be influenced by market acceptability and susceptibility to factors that downgrade grain quality, especially disease. Small beans such as the old variety Fiord(D are less acceptable in major export markets. Medium–small beans (e.g. Farah(D) are sought because of their size and light colour. Medium-sized beans and broad, large beans (e.g. Aquadulce) remain acceptable because of their size and colour.

2.3 Faba bean varieties

The following varieties are recommended for regions 4 and 5 which cover WA.

Fiesta VF(D

Fiesta VF(D became the standard faba bean variety for southern and western region farming systems and was a replacement for Fiord(D, especially where chocolate spot was a risk. A medium-sized bean, Fiesta VF(D has shown high yields and wide adaptation to conditions in southern Australia. It still remains the preferred variety for some growers over Farah(D, where Ascochyta is low risk or well managed. It also remains an option over Nura(D where chocolate spot and Ascochyta risk is low to medium. It can be used where sowing time is delayed or in low-rainfall areas where faba beans are not expected to grow very tall. It was released in 1998.

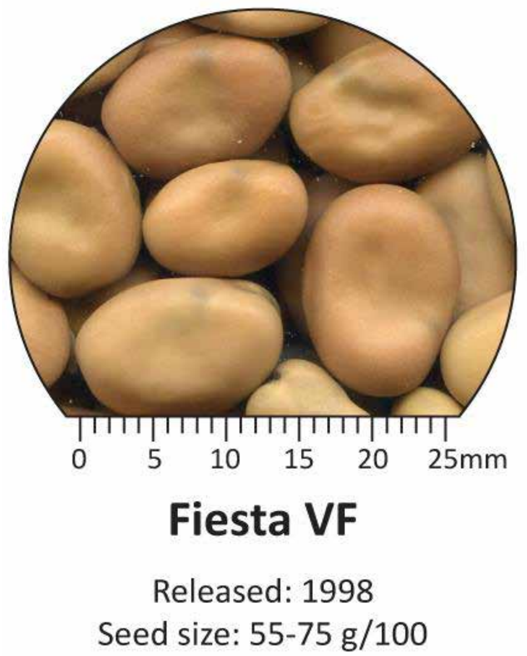

Figure 2: *Fiesta VFⒷ was released in 1998.*

FarahⒷ

FarahⒷ is a selection from Fiesta VFⒷ and was a replacement for this popular variety. While it has similar agronomic traits and yield, FarahⒷ has a more uniform seed size and improved Ascochyta blight resistance (resistant–moderately resistant) to both leaf and pod infection compared to Fiesta VFⒷ, and is similar to the variety Ascot. This higher resistance reduces grain staining from Ascochyta at harvest. FarahⒷ performs best in medium-rainfall environments. The name 'FarahⒷ' is a direct Arabic translation of the word 'fiesta'. It was released in 2003. [4]

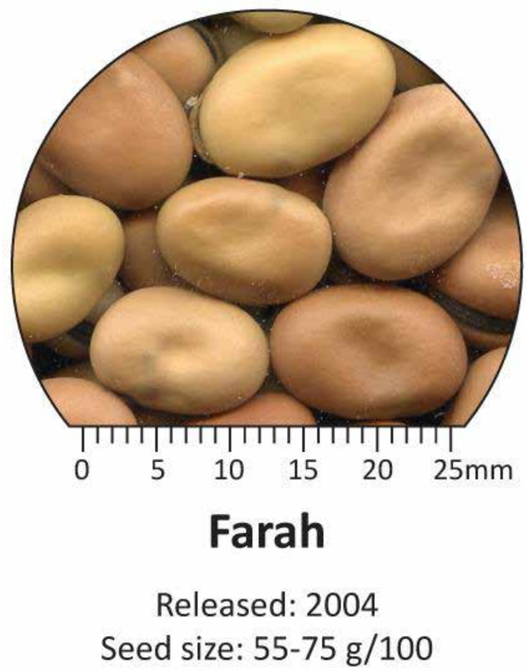

Figure 3: *FarahⒷ was released in 2004.*

MORE INFORMATION

FarahⒷ Variety Management Package

4 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 3–Varieties.

NuraⒹ

NuraⒹ is shorter than Fiesta VFⒹ and FarahⒹ and less likely to lodge; however the bottom pods are closer to the ground. It flowers about 7 days later than Fiesta VFⒹ, but matures at a similar time. It is rated as resistant–moderately resistant to Ascochyta blight, moderately susceptible to chocolate spot and moderately susceptible to rust. Seed size is slightly smaller than FarahⒹ and is light buff (brown) in colour. It was released in 2005.

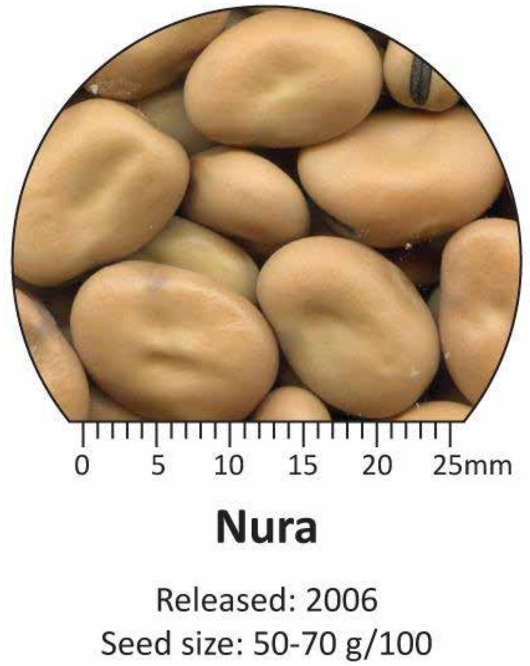

Figure 4: *NuraⒹ was released in 2006.*

PBA RanaⒹ

PBA RanaⒹ is a relatively late-flowering and late-maturing variety suited to higher rainfall regions with long seasons. Seed is larger than other current varieties and is considered high quality by the major Egyptian market. PBA RanaⒹ is resistant to both foliar and seed Ascochyta blight, and has improved resistance to chocolate spot compared to Fiesta VFⒹ and FarahⒹ. It was developed by PBA, tested as 974*(611*974)/15-1, and released in 2011. [5]

MORE INFORMATION

NuraP Variety Management Package

Seednet: NuraP Fact sheet

5 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 3–Varieties.

MORE INFORMATION

PBA Ranaⓓ Variety Management Package

PBA Samiraⓓ Variety Management Package

Pulse Australia: Faba and broad bean.

NSW DPI (2016) Winter crop variety sowing guide.

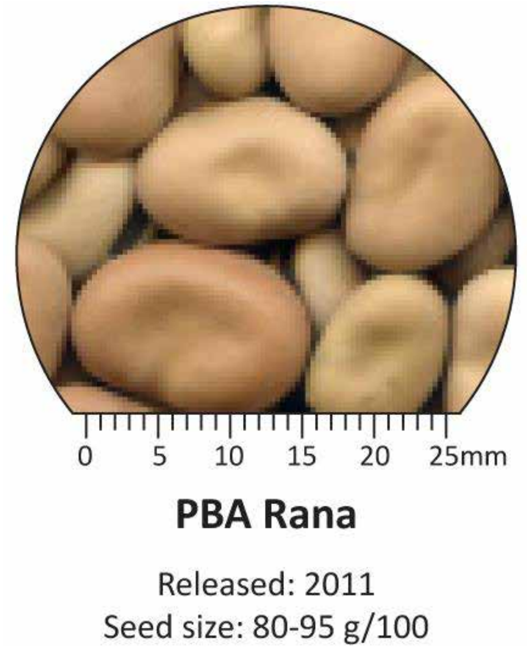

Figure 5: *PBA Ranaⓓ was released in 2011.*

PBA Samiraⓓ

PBA Samiraⓓ is a high-yielding variety with widespread adaption and is the variety of choice in south-eastern WA. Excellent disease resistance and later flowering means it can take advantage of late rainfall in longer season environments. Seed size is ideal for the Middle Eastern Markets, similar to Fiesta VFⓓ and Farahⓓ. Excellent Ascochyta resistance and improved resistance to chocolate spot and rust compared to Fiesta VFⓓ and Farahⓓ. It was developed by PBA, tested as AF05069-2, and released in 2014.

2.3.1 Faba bean variety agronomic traits

A summary of agronomic traits for the five varieties Fiesta VFⓓ, Farahⓓ, Nuraⓓ, PBA Ranaⓓ and PBA Samiraⓓ is provided in Table 1.

Table 1: *Faba Bean variety agronomic traits.*

Variety	Plant height	Flower time	Maturity	Lodging resistance	Ascochyta blight		Chocolate spot	Cercospora	Rust	PSbMV seed staining
					Foliage	Seed				
Fiesta VFⓓ	Medium	Early–mid	Early–mid	MR	MR	MS	S	S	S	S
Farahⓓ	Medium	Early–mid	Early–mid	MR	MR–R	MR–R	S	S	S	S
Nuraⓓ	Short	Mid	Early–mid	MR	MR–R	MR–R	MS	S	MS	VS
PBA Ranaⓓ	Med–tall	Mid	Mid	MR	R	R	MS	S	MS	MR
PBA Samiraⓓ	Medium	Mid	Early–mid	MR	R	R	MS	S	MS	S
PBA Zahraⓓ					R	R	MS	S	MS	S
PBA Samiraⓓ					R	R	MS	S	MS	S

R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible
Source: Pulse Breeding Australia trials program 2007–2013

2.4 Seed quality

High-quality seed is essential to ensure the best start for the crop. 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.

- All seed should be tested for quality including germination and vigour. The minimum germination requirement for certified pulse seed is 70% compared with 80% in cereals.
- If grower-retained seed is of low quality, then consider purchasing registered or certified seed from a commercial supplier. Regardless of the source, always ask for a copy of the germination report.
- Careful attention should be paid to the harvest, storage and handling of seed intended for sowing.
- Calculate seeding rates in accordance with seed quality (germination, vigour and seed size).

Good establishment with correct plant density and good seedling vigour is important to maximise yields of pulse crops. A slight variation in seed size due to seasonal conditions or an incorrect germination percentage can make a significant difference to the final plant density. [6]

The large size or fragile nature of pulse seed, particularly faba bean, Kabuli chickpea and lupin, makes them more vulnerable to mechanical damage during harvest and handling. This damage is not always obvious, and can be reduced by slowing the header drum speed and opening the concave, or by reducing auger speed and lowering the flight angle and fall of grain. The reduction in the amount of transfer through the augers is important. Rotary harvesters and belt conveyers are ideally suited to pulse grain. They can reduce seed damage that often results in abnormal seedlings, which germinate but do not develop further.

Under ideal conditions, abnormal seedlings may emerge but will lack vigour, making them vulnerable to other rigours of field establishment. Factors such as low temperature, disease, insects, seeding depth, soil crusting and compaction are more likely to affect the establishment of weak seedlings. Abnormal seedlings that do emerge are unlikely to survive for long, and those that survive are likely to have reduced biomass and make little or no contribution to the final yield. [7]

2.5 Handling bulk seed

The large size, awkward shape and fragile nature of many pulses means that every time the seed is handled, it can reduce seed quality. Seed grain, in particular, should be handled carefully to ensure good germination.

Plan so that handling is kept to a minimum to reduce damage between harvest and seeding.

Augers with steel flighting can damage pulses, especially larger-seeded types such as faba beans. This problem can be partly overcome by slowing down the auger. Augers with large flight clearances will cause less damage to large grains.

Tubulators or belt elevators are excellent for handling pulses, as they cause little or no damage. Cup elevators are less expensive than tubulators and cause less damage than augers. They have the advantage of being able to work at a steeper angle than tubulators. However, cup elevators generally have lower capacities.

Combine loaders that throw or sling, rather than carry the grain, can cause severe damage to germination. [8]

6 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

7 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

8 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

MORE INFORMATION

Factors affecting grain crop seed germination

2.6 Seed testing

2.6.1 Germination testing

Germination tests can be conducted by a simple home test or ideally, by sending a representative sample to a seed-testing laboratory for germination and vigour tests. For faba beans the sample size required is 1 kg for every 25 t of seed.

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

If there is an issue with kept grain, get a sample tested early. Testing prior to grading and seed treatment could provide savings if the quality is found to be unsatisfactory, allowing 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 is advisable to have it re-tested soon after storing, handling and grading have occurred.

2.6.2 Vigour testing

In years of drought or a wet harvest, seed germination can be affected but, more importantly, seedling vigour can also be reduced. Poor seedling vigour can heavily reduce establishment and early seedling growth. This can occur under difficult establishment conditions such as deep sowing, crusting, compaction, and wet soils, or when seed treatments have been applied.

Some laboratories offer a seed vigour test when doing their germination testing. Otherwise growers can conduct their own tests by sowing seeds into a soil tray that is kept cold (<20°C). Observe the germination, speed and uniformity of emergence, and any abnormal shoot and root development.

Vigour represents the rapid, uniform emergence and development of normal seedlings under a wide range of conditions. Tests such as the Accelerated ageing vigour test and Conductivity vigour tests, are used by seed laboratories to establish seed and seedling vigour.

2.6.3 Accelerated ageing vigour test

Accelerated ageing estimates the 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 reported as a percentage, and the closer the accelerated ageing number is to the germination result, the better the vigour. [9]

2.6.4 Conductivity vigour test

The conductivity test measures electrolyte leakage from plant tissues and is one of two vigour tests recommended by the International Seed Testing Association (ISTA). Conductivity test results are used to rank vigour lots by vigour level.

Information is interpreted for as follows:

- <25 µS/cm/g—nothing to indicate seed is unsuitable for early sowing or adverse conditions.
- 25–29 µS/cm/g—seed may be suitable for early sowing, but there is some risk of poor performance under adverse conditions.
- 30–43 µS/cm/g—seed is not suitable for early sowing especially under adverse conditions.
- >43 µS/cm/g—seed is not suitable for sowing.

9 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

It is important to have a germination test done as well, because a conductivity test cannot pick up all seed-borne chemical and pathogen scenarios.

2.6.5 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, including the amount and type of weed seed contamination, can be conducted if requested.

2.6.6 Disease testing and major pathogens identified in seed tests

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

Testing seed before sowing will identify the presence of disease and allow steps to be taken to reduce the risk of disease. If disease is detected, the seed may be treated with a fungicide before sowing or a clean seed source may be used (Table 2).

For a disease test, 1 kg of seed is required, except for Anthracnose (on lupin) which requires 2 kg. [10]

Table 2: *Major pathogens identified in seed tests on faba bean.*

Pathogen	Disease
Botrytis fabae	Chocolate spot
Ascochyta fabae	Ascochyta blight
Ditylenchus dipsaci	Stem nematode
BBSV	Broad bean stain virus

Laboratories that will test for some or all of the above diseases include:

DPIRD Diagnostic Laboratory Services (DDLS)

Seed Testing and Certification

Department of Primary Industries and Regional Development
Telephone (08) 9368 3721
Email: ddls-stac@agric.wa.gov.au

SARDI Field Crops Pathology
GPO Box 379, Adelaide, SA 5001
Telephone (08) 8303 9384
Facsimile (08) 8303 9393
Web: www.sardi.sa.gov.au/diagnostic_services/Crop_diagnostics

10 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

Planting

Key messages

- Inoculants carry live root-nodule bacteria (rhizobia), which can die from exposure to sunlight, high and low temperatures, and chemicals. The strain of rhizobia used to inoculate faba bean is WSM1455.
- Rhizobia only fix nitrogen (N_2) when inside a legume nodule.
- This nitrogen fixation process has a national benefit of ~$4 billion annually to Australian cropping.
- Stubble retention can increase water infiltration and slow moisture loss.
- Early sowing produces the highest potential yields, but requires greater attention to disease control, particularly for chocolate spot.

FAQ

3.1 Inoculation

Pulses have the ability to fix their own nitrogen (N_2) from the air via nodules on their roots if specific N_2-fixing bacteria (rhizobia) are available (Figure 1).

Faba beans tend to nodulate freely, but agronomists will often suggest inoculation as cheap insurance against poor nodulation, especially in acid soils. Inoculating legume seed or soil at sowing provides a large number of effective rhizobia around the emerging legume root to optimise nodulation and N_2 fixation.

When the legume germinates, the rhizobia enter the plant's roots, multiply rapidly and form a nodule. Effective nodule formation and function requires good growing conditions, the appropriate rhizobia and a host plant.

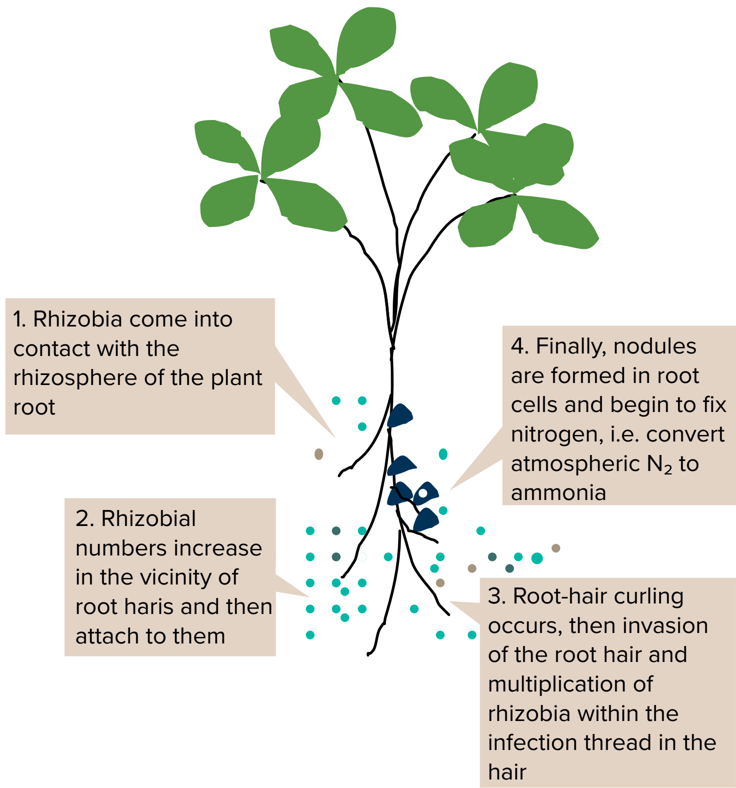

Figure 1: *Schematic representation of the process of nodulation.*

Source: D Herridge 2013

Inoculation with the correct rhizobial strain is essential for effective nodulation in some soil types and situations.

The strain of rhizobia used to inoculate faba bean, WSM1455, is common to field peas, vetches and lentils. Faba beans and lentils are in group F, which only responds to the use of WSM1455, while field peas and vetches are in group E.

Photo 1: *Well-nodulated faba bean roots.*

Source: D Herridge 2013

Rotation lengths of four to five years are recommended between successive faba bean crops as a disease management strategy (e.g. for Ascochyta blight). At this interval in some of the more 'hostile' situations (e.g. acid soils), it is unlikely that sufficient levels of Group F rhizobia will survive for effective nodulation, so inoculation is recommended.

The Group F rhizobia are regarded as 'aggressive' nodulators. This means nodulation will be successful in meeting the crop's N requirements provided:

- Inoculants are handled and stored in a manner that will ensure bacterial survival, i.e. they should be kept cool.
- Inoculated seed is planted into moisture within 12 hours of treatment—the sooner the better, as fungicide seed dressings and warm temperatures can affect the survival of the bacteria.

Group F rhizobia are extremely sensitive to the level of available nitrate-N in the soil.

While a high level of nitrate-N has no significant effect on the initial formation of nodules, and their number, it does markedly reduce both nodule size and activity.

Nodules remain inactive until the soil nitrate supply is exhausted; ineffective nodules remain white inside from the absence of leghaemoglobin. Effective N_2-fixing nodules, on the other hand, are rusty red or pink inside (Photo 2).

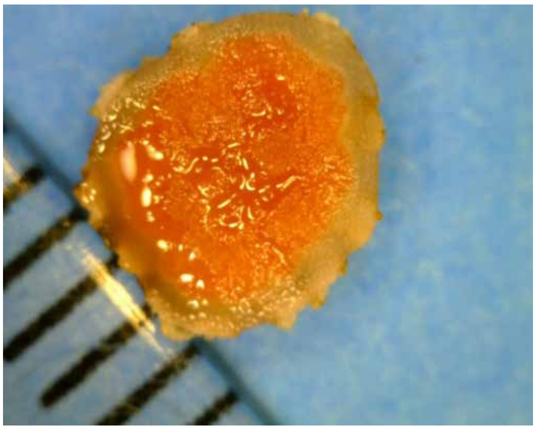

Photo 2: *Active nodules have a pink centre.*

Photo: G. Cumming, Pulse Australia

When the legume germinates, the rhizobia enter the plant's roots, multiply rapidly and form a nodule. Effective nodule formation and function requires good growing conditions, the appropriate rhizobia and a host plant (Photo 1). [1]

When purchasing inoculants:

- Choose Group F faba bean inoculum.
- Check the expiry date on packet.
- Note how it been has been stored.
  - » Packets should be stored at ~4°C.
  - » Do not freeze (below 0°C) or exceed 15°C.
- If applying a slurry, apply in the shade ad avoid exposure to high temperatures (>30°C), direct sunlight, and hot winds.
- Accurately meter adhesive slurry onto the seed. Too much water means sticky seeds and blockages in the seeder.
- Avoid high-speed mixing in augers.
- Sow inoculated seed immediately. Never delay more than 12 hours.
- Check air-seeders for excessively high temperatures in the air stream. Temperatures >50°C will kill the rhizobia. [2]

3.1.1 Inoculant types

A diverse range of inoculant products with different methods of application is available.

The inoculant type used will depend on product availability, relative cost, efficacy, ease of use and machinery availability. Granular products vary and may be dry or moist, uniform, variable, powdery, coarse or fine. [3]

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

2 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

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Table 1: *Rhizobial inoculants available for use in Australia.*

Manufacturer	Brand	Formulation	Application
Becker Underwood	Nodulaid™	Peat	Slurry on seed; slurry/liquid in furrow
	Nodulaid™	Liquid	On seed; in furrow
	Nodulator™	Clay granule	In furrow
	BioStacked®	Peat (rhizobia) plus liquid (*Bacillus subtilis*)	Slurry on seed; slurry/liquid in furrow
New-Edge Microbials	EasyRhiz™	Freeze-dried	Liquid on seed; liquid in furrow
	Nodule N™	Peat	Slurry on seed; slurry/liquid in furrow
Novozymes Biologicals Australia	N-Prove®	Peat	Slurry on seed; slurry/liquid in furrow
		Peat granule	In furrow
	TagTeam®	Peat (rhizobia) plus (*Penicillium bilaii*)	Slurry on seed; slurry/liquid in furrow
	TagTeam®	Peat granule (rhizobia) plus (*Penicillium bilaii*)	In furrow
ALOSCA Technologies	ALOSCA®	Clay granule	In furrow
Brushmaster	Inoculeze™	Peat	'Tea extract' on seed via an applicator

Source: D Herridge, 2013.

Photo 3: *Different forms of rhizobia. Left to right: EasyRhiz™ freeze dried, Nodulator™ granules, ALOSCA® granules, N-Prove® granules and Nodulaid™ peat inoculant.*

Photo: M. Denton, formerly Vic DPI

Photo 4 shows nodule development with peat and granular inoculants.

Photo 4: *Faba beans on acid soil inoculated with peat inoculant showing few nodules (left panel), compared with those inoculated with granular inoculant (right panel). Note that nodulation is still less than would occur on more neutral or alkaline soils*

Photo: W. Hawthorne, Pulse Australia)

Injection of inoculants mixed in water is becoming more common practice. It can be used where machines are set up to apply other liquids, such as liquid N, at seeding.

In-furrow water injected inoculants

Water injection of inoculant requires at least 40 L/ha of water, and is better with more water. The slurry–water suspension is sprayed under low pressure into the soil in the seed row during seeding. Benefits of the new inoculants over peat are that they mix more readily, and do not need to filter out peat. Compatibility of the inoculant with trace elements is not yet known, but caution is advised, because water pH is critical, and trace element types, forms and products behave differently between products and inoculant groups. [4]

Photo 5: *A seeding bar setup with Atom Jet narrow points, gang press-wheels and liquid injection for either inoculum or trace element application during sowing.*

Photo: W. Hawthorne, Pulse Australia

MORE INFORMATION

E Drew et al. (2014) Inoculating Legumes: A Practical Guide. Rev. edn. GRDC.

4 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

Photo 6: *Tanks mounted on the seeding bar for liquid injection of rhizobia or trace elements during seeding. Agitation is required. Note the tubes and manifold. Inoculum must be applied under low pressure only. Some machines have their tanks set up as a separate, trailed tanker.*

Photo: W. Hawthorne, Pulse Australia

Photo 7: *A disc seeder set up with Yetter trash-clearing wheels and tubing for liquid injection of inoculum or trace elements during sowing. Note also the closer, covering the seeding slot to act like a press-wheel from the side.*

Photo: W. Hawthorne, Pulse Australia

Photo 8: *In-furrow liquid injection. Note the droplets from the liquid injection, which can be used for inoculating pulses or applying liquid trace elements.*

Photo: W. Hawthorne, Pulse Australia

Granular inoculants

Granular inoculants are applied like fertiliser, as a solid into the seed furrow, near the seed or below it. 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 inoculant may also be better where dry sowing is practiced or when sowing into acidic soils, because the rhizobia survive better than on seed. A third, small seed box is required to apply granular inoculum (Photo 9). This is because rhizobial survival is jeopardised if the granular inoculum is mixed with fertiliser. If it is mixed with the seed, then distribution of both seed and inoculum is affected, causing poor and uneven establishment and/or patchy nodulation.

Granules contain fewer rhizobia per gram than peat-based inoculants, so they must be applied at higher rates. The size, form, uniformity, moisture and rate of application of granules differ between products. Depending on product or row-spacing sown, rates can vary from 2 to 10 kg/ha to deliver comparable levels of nodulation. [5]

5 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

Photo 9: *An 'after-market' third box fitted to a Flexicoil box to enable application of granular inoculum.*

Photo: W. Hawthorne, Pulse Australia

3.1.2 Inoculant and chemical compatibility

As rhizobia are living organisms, it is very important inoculants are kept away from toxic substances, such as fertilisers, fungicides, insecticides and herbicides, that will reduce their viability. Inoculated seed should not come into direct contact with fertiliser because the latter will kill the rhizobia through desiccation and exposure to acidity. Certain pesticides can also decrease rhizobial survival and nodulation. [6]

Caution should be used when treating pulse seed with a fungicide. Some insecticide and seed treatments can also cause problems. Check the inoculant and chemical labels for compatibility of the inoculant and fungicide or insecticide seed treatments, and the planting window (time) for either sequential or simultaneous application of seed treatments and seed-applied inoculants. [7]

Inoculant companies conduct compatibility tests with registered seed treatments to ensure the viability of inoculants is not compromised by pesticides and other seed treatments. Each inoculum formulation is tested with various seed treatments using different application methods. Note the compatibilities and planting windows are specific to the individual product, and should not be used for other inoculants, whether they be from a different company or of a different inoculum group.

Read the label of both the specific inoculum and the seed treatment being used. Some fungicide labels specify that their fungicides should not be mixed in a slurry mixture with particular rhizobial inoculants, as they may decrease rhizobium survival.

If in doubt, adding the fungicide to seed and then applying the rhizobium inoculant to the dried seed is suggested to promote better results. [8]

MORE INFORMATION

Novozymes (2016) Product Guide Australia.

6 E Drew et al. (2014) Inoculating Legumes: A Practical Guide. GRDC. Rev. edn, https://grdc.com.au/GRDC-Booklet-InoculatingLegumes

7 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

8 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

3.1.3 Assessing nodulation

Plants should be gently dug from the soil and the root system rinsed in water before scoring the level of nodulation.

Obvious signs of nodulation should be visible by 6 weeks after sowing (even in high-soil-nitrate situations).

The pattern of nodules on the root system is important. Nodules on the main taproot clustered near the seed are an indication nodulation occurred because of the inoculation process. These are referred to as 'crown nodules'.

If there are no crown nodules but nodules on the lateral roots, it is more likely that they have formed from native soil bacteria which are usually less effective at fixing N_2, even in faba beans.

Nodules on both the crown and lateral branches indicate inoculation was successful and that bacteria have spread in the soil. Faba bean rhizobia are not very aggressive and do not spread more than very short distances in the soil.

Inspect nodules for nitrogen-fixation activity by assessing their internal 'pink' (leghaemoglobin) colour. The best method is to slice a few nodules open with a razor blade or sharp knife and examine their colour.

Young nodules are usually white and have yet to develop. However, white nodules can also indicate the wrong bacteria in the nodule, and these will not fix N_2. Effective nodules, which actively fixing N_2, are a rusty red or pink inside. Effective red nodules can sometimes turn green when a plant is under water, diseased or otherwise stressed, or is deficient in nutrients. These nodules do not fix N_2, but if the stress is relieved without too much damage being done they can change back to red and begin to fix N_2 again. Black nodules are usually dead or dying. These are often seen as the crop matures, or after a crop has suffered severe waterlogging. [9]

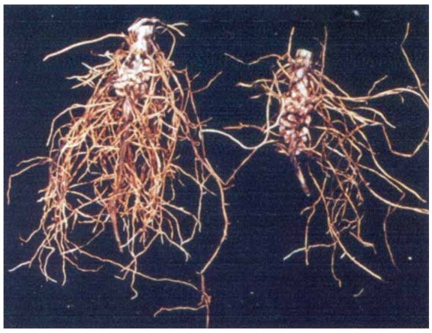
MORE INFORMATION

GRDC (2008) 'Seeding', Grain Legume Handbook.

E Drew et al. (2014) Inoculating Legumes: A Practical Guide. Rev. edn. GRDC.

9 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

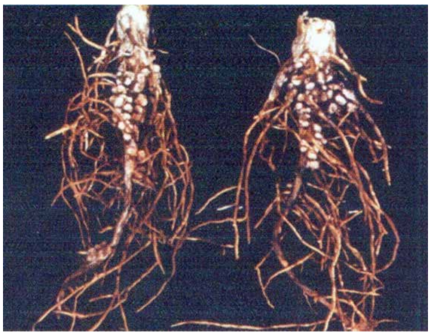
(a) Score 0: taproot, absent; lateral, absent.



(b). Score 1: taproot, few-medium; lateral, absent-few

(c) Score 2: taproot, medium; lateral, absent-low.

(d) Score 3: tap root, medium-high; lateral, low.



(e) Score 4: taproot, high; lateral, medium.

(f) Score 5: taproot, high; lateral, high.

Photo 10: *Visual key for nodulation scores.*

Source: TopCrop 'Growers guide to assessing nodulation in pulse crops'

Points to note:

- Where plant-available soil-N is low, the crop relies heavily on good nodulation for its N supply. A score of 4–5 is desirable.
- Where plant-available N is high, nodulation may be partly inhibited, and the crop will depend mainly on the soil for N supply.
- A high score indicates that the crop will yield well and conserve soil N for use by a following crop.
- A low score suggests that the crop will yield poorly and deplete soil N. [10]

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3.1.4 Storing inoculants

Moist peat provides protection and energy to an unopened pack in storage. For maximum survival, peat inoculant should be stored in a refrigerator at ~4°C until used. If refrigeration is not possible, store in a cool, dry place away from direct sunlight. Granules and other forms also need to be stored in a cool place out of direct sunlight. Do not store an opened inoculum packet, as it will deteriorate rapidly.

Discard the inoculant after the expiry date shown because the rhizobia population may have dropped to an unacceptable level. [11]

3.1.5 Inoculum survival

Rhizobia can dry out and lose viability when applied to seed and not kept in moist soil. Granular inoculant forms may not dry out as quickly.

With non-peat-based inoculants, such as freeze-dried rhizobia, it is recommended treated seed should be sown within 5 hours of inoculation.

Most commercial inoculants contain an adhesive solution or 'sticker' which delays drying and increases the survival rate of the rhizobia. If inoculated seed is sown into dry soil, the sticker helps the rhizobia survive until rain.

Inoculum viability rapidly diminishes over time in warm, dry soil. It is difficult to provide guidelines to survival times; however, it is best to sow as close to the appearance of a rain front as possible. The rhizobia will survive for longer in granules than when applied to seed. Hence, when dry-sowing pulses, granular inoculant is preferred over peat and liquid-injection methods.

Nodulation failure after dry sowing of inoculated seed is more likely if the soil has no naturalised rhizobia present.

Dry-dusting the peat inoculant into the seed box is not an effective means of either applying rhizobia on the seed or retaining it uniformly on seed. Under some conditions, rhizobial death is so rapid where dry-dusting is used that no rhizobia are alive by the time the seed reaches the soil.

3.1.6 Applying peat-based inoculants

Use a peat–slurry mix within 12 hours, and sow seed inoculated with peat slurry as soon as possible or store for up to three days in a cool place away from sunlight.

When mixing the slurry, do not use hot or chlorinated water. Add the appropriate amount of the inoculant group with a small amount of water to form a heavy paste, then add to the main solution and stir quickly.

Read the inoculant label before adding any approved insecticides, fungicides, herbicides, detergents or fertilisers into the slurry (see Seed treatments). Add the inoculant suspension (slurry) to the seed and mix thoroughly until all seeds are evenly covered. A small amount of fine lime can be added after mixing is complete to help dry the seed and prevent tackiness. If adding lime use only calcite lime; agricultural lime is too coarse. Do not use builders lime, hydrated lime or slaked lime: they will kill the rhizobia. [12]

Slurry can be applied to the seed using:

1. A cement mixer. This is practical for small lots only, unless a cement truck is used.
2. Through an auger (see Figure 2). Make sure the auger is turning as slowly as possible. Reduce the height of the auger to minimise the height of seed-fall. Perhaps add a slide, e.g. tin, to the outlet end of the auger to stop seed from falling and cracking. Meter the slurry in, according to the flow rate of the auger (about a 250g packet per 100 kg seed). If the auger outlet is out of reach, e.g.

MORE INFORMATION

GRDC (2008) 'Seeding', Grain Legume Handbook.

11 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

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under a field bin, then use some poly pipe to run the slurry into the auger. A clean drench pack fixed to a dropper makes a good funnel into the poly pipe.

3. Through a tubulator. The use of a tubulator reduces the risk of damaging the seed, but its mixing ability is not as effective as an auger. Apply the slurry in a similar fashion as with an auger.

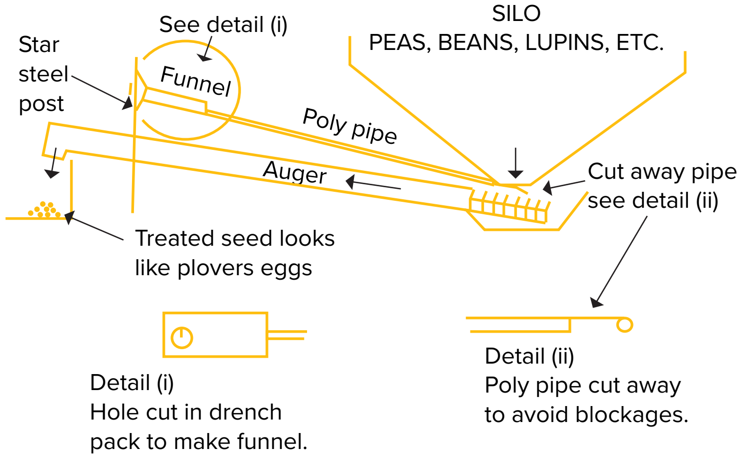

Figure 2: *Applying inoculum through an auger.*

Source: Grain Legume Handbook, 2008

3.2 Crop establishment

Successful establishment of faba beans in WA requires careful management of many factors including stubble management, seed quality, row spacing and sowing depth.

3.2.1 Stubble retention

The presence of stubble can increase water infiltration and slow moisture loss through evaporation. With standing stubble, lower wind speeds at the soil surface and cooler soil temperatures assist in reducing evaporation, resulting in increased soil-moisture storage for sowing and afterwards. Stubble retention ensures more moisture is captured and retained as stored soil moisture which benefits the pulse. Stubble retention also helps to retain some of the deeper moisture left from summer rains, provided weeds are controlled. This allows for earlier sowing opportunities.

Photo 11: *Faba beans sown into cereal stubble establish well and lose less soil moisture than those sown into bare soil.*

Photo: W. Hawthorne, Pulse Australia

By retaining stubble, combined with the ability to sow earlier, sowing into wider row spacing and achieving greater harvestable height with less lodging, growers have been able to produce a pulse crop in years that would otherwise have resulted in a failed crop.

Faba beans grown on burnt stubble have higher average disease levels (range 4.9–7.6) than those grown on slashed stubble (range 3.5–7.0). [13]

3.2.2 Time of sowing

Faba beans show a marked response to the time of sowing, with crops sown 'on time' having an excellent chance of maximising yields. Crops sown earlier or later than recommended will often give reduced yields.

Water Use Efficiency is commonly in the range 8–12 kg/mm grain for sowings made during the preferred sowing window. This drops to 4–6 kg/mm for very late or very early sowings.

Sowings made prior to the recommended sowing window tend to be more vegetative and suffer from:

- poor early pod set because of low light or low temperatures (10°C) at the commencement of flowering
- higher risk of chocolate spot at flowering and through podding
- crops pre-disposed to lodging
- increased frost risk at flowering and early podding
- high water use prior to effective flowering and earlier onset of moisture stress during flowering and podding
- increased risk of Ascochyta blight, chocolate spot and rust in susceptible varieties

Late-planted crops are more likely to suffer from:

- high temperatures and moisture stress during flowering and podding
- greater native budworm pressure
- fewer branching and flowering sites, unless the plant population is increased

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- shorter plants and lower podset, which make harvest more difficult

To achieve maximum yields, critical management factors such as weed control and seedbed preparation must be planned to allow crops to be sown as close as possible to the ideal sowing dates.

Faba bean seeds can germinate in soil as cold as even 5°C, but emergence will be slow. Seedlings are tolerant of frost but can still be affected. Seedling vigour will be greater if soil temperatures are at least 7°C.

Table 2: *Sowing times for faba and broad bean varieties at different locations* [14]

Month	April				May				June				July	
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2
WA – low rainfall														
WA - medium rainfall														
WA - high rainfall – WA														

Marginal area or low disease risk area
Preferred sowing time
For high disease-risk areas or more susceptible varieties
Sowing-time needs vary with the flowering date and maturity rating of each variety.
Yield loss: 250 kg/ha for each week's delay

Faba bean sowing dates are often a compromise between delaying sowing to reduce disease without severely reducing yield potential. Early sowing, even dry sowing, is a priority in some drier areas or where sowing is completed early to optimise operations and enable optimum sowing times for cereals.

Early sowing produces the highest potential yields in faba beans, but requires greater attention to disease control, particularly for chocolate spot. Late sowing produces short, low-yielding crops with less disease. The time of sowing is therefore a compromise. Added to this, some varieties, e.g. Fiesta VF⯑, Farah⯑ respond less to early sowing because they do not set early pods under cold and shaded conditions.

In low-rainfall areas faba beans must be sown early. Hot winds in spring cause the beans to wilt, stop flowering and ripen prematurely. Compacted soils that do not allow root penetration exaggerate this effect.

Sowing also needs to be earlier:

- in wetter areas
- in areas where soils have lower fertility, or are acidic
- where excessively tall growth of beans is unlikely

Ultimately the use of varieties with resistance to chocolate spot will enable earlier sowing in most areas. In the interim, wider row spacing (skip row or wider) is being used in early sowings to delay canopy closure and so lessen disease risk. [15]

3.3 Seeding rates

Seeding rates (kg/ha) for faba beans vary with the size of the seed being sown (Table 3).

Growers of faba beans should target 30 plants/m^2.

Not all seeds are equal—some grow better than others. Before deciding on a seeding rate take a representative sample, have it sized and then germination- and vigour-tested (see Section 2, Pre-planting).

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Seeding rates can have a significant effect on crop yields. Be aware of the very large differences in seed size between varieties and the impact that variable seasons can have on grain size of even the same variety.

When determining a seeding rate, consider plant populations and not just kilograms of seed per hectare: the kilogram rate should be adjusted to achieve a target population of plants based on seed size and germination percentage.

The seeding rate for the target plant density can be calculated using germination percentage, 100-seed weight and establishment percentage:

$$\text{Seeding rate (kg/ha)} = \frac{\text{(100 seed weight (g)} \times \text{target plant population per m}^2 \times 1000)}{\text{(germination\%} \times \text{estimated establishment\%)}}$$

Example:
100-seed weight = 60 g
Target plant density = 25 plants/m^2 (i.e. 250,000 plants/ha)
Germination % = 90
Estimated establishment % = 95% (90–95% is a reasonable estimate, unless sowing into adverse conditions)

Seeding rate (kg/ha) = (60 × 25 × 1000) ÷ (90 × 95) = 175 kg/ha

To determine the seed weight, weigh 100 seeds (g). A seeds per kg reading from a laboratory test can be easily converted to 100-seed weight, as follows:

100-seed weight = (1000 ÷ no. of seeds per kg) × 100

Table 3: *Seeding rate (kg/ha) required for targeted plants/m^2 for a range of faba bean varieties and sizes at 85% germination and 95% establishment* [16]

Example variety	Average size range (g/100 seeds)	Seed weight used (g/100)	Plants required per square metre*			
			10	18	25	32
FiordⒹ	35–55	45	56	100	139	178
FarahⒹ, Fiesta VFⒹ	55–75	65	80	145	201	258
PBA RanaⒹ	80–90	85	105	189	263	337

* = targeted seeds/m^2

3.3.1 Row spacing

There is a trend towards wider row spacing with pulses, especially faba beans. Wider-row and 'skip'-row pulses (30–54 cm) must be part of an overall system, and it should not be considered in isolation. Stubble retention, preferably standing stubble, is considered essential for wide rows, where retaining soil moisture and ensuring adequate weed control are required (Photo 12). Yield comparisons in research trials can vary depending on the system and location, and there is no one solution that fits all situations.

Reasons for choosing wider rows with faba beans vary with location and operator, but key drivers are the combination of:

- yield and yield consistency
- better stubble clearance and other sowing practicalities
- drought tolerance
- minimised disease risk and easier management of diseases
- desire to sow pulses early
- weed control through minimised soil disturbance
- herbicide application options between the rows using hooded sprayers

16 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

If row spacing is doubled, the seeding rate per row must be doubled if the same plant density is to be maintained. This is significant when using seeders with one seed meter per row, but relatively unimportant in air seeders where one meter supplies all. [17]

MORE INFORMATION

Pulse Australia (2015) Wide row pulses and stubble retention. Australian Pulse Bulletin.

W Hawthorne, (2010) Wide row pulses and stubble systems. Southern Pulse Bulletin.

S Kleeman and G Gill (2008) Row spacing, water use, and yield of wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) and faba bean (*Vicia faba*). 14th Australian Agronomy Conference.

Photo 12: *Wide ('skip') rows in faba beans allow easier sowing into heavy cereal stubbles, assist in weed control, promote better pod set, and delay canopy closure, which assists in disease control and fungicide application.*

Photo: W. Hawthorne, Pulse Australia

3.3.2 Sowing depth

Faba beans have a hypogeal pattern of emergence (i.e. they leave their cotyledons below the soil surface) and therefore are able to emerge from deeper in the soil than plants with an epigeal emergence pattern (Figure 3), such as lupins. Faba beans are also large-seeded and produce a relatively strong seedling, which further enable seedlings to emerge from deeper in the soil (Table 4).

17 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

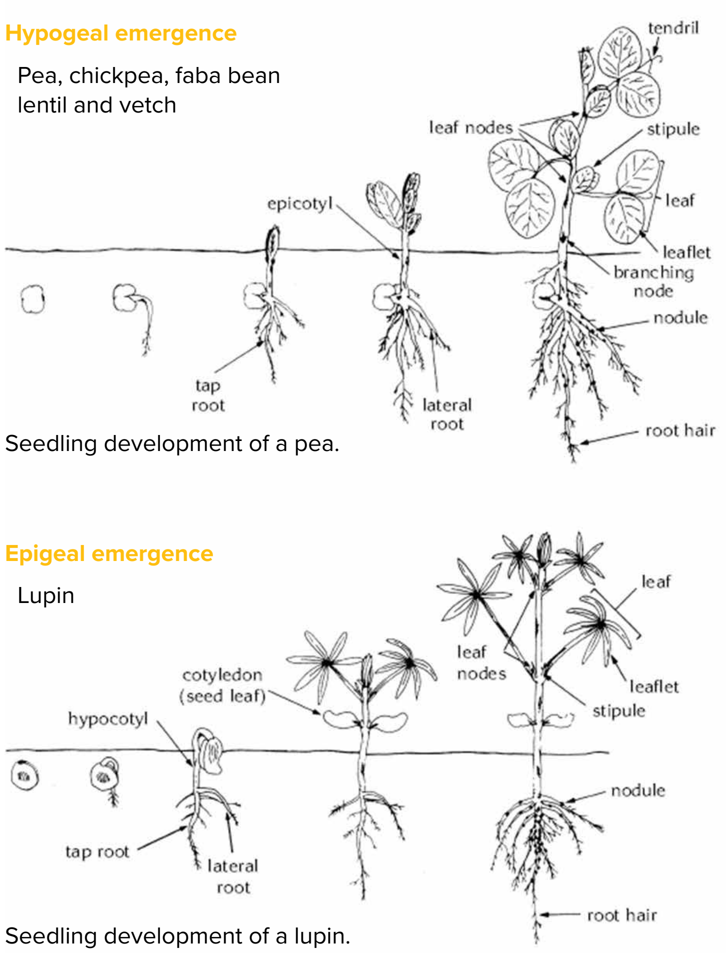

Figure 3: *Epigeal versus hypogeal emergence patterns.*

Source: Grain Legume Handbook, 2008

Table 4: *Sowing depth ranges (cm) for pulses*

Crop	General recommended sowing depth range
Chickpeas	3–5 cm
Faba beans	5–8 cm
Lentils	2–6 cm
Lupins	1–3 cm
Peas	3–5 cm
Vetch	3–5 cm

Note that if applying a pre-emergent herbicide, the greater depth should be used.

Photo 13: *Faba beans are much more tolerant of deeper sowing than are lupins, because of their hypogeal emergence. The lupins shown were sown too deep (greater than 5 cm). Note the stunted first true leaf and lack of early vigour.*

Photo: Grain Legume Handbook, 2008

Faba beans can be sown at depth to 15 cm if necessary. Deep-sowing or moisture-seeking techniques can be used to ensure timely planting when the soil surface is still dry. The large seed size makes faba beans very suitable for this type of planting system. [18]

3.3.3 Rolling

Leaving a flat, firm soil surface free of stumps, stones and clumps is essential when growing most pulse crops, including faba beans. A flat soil surface at harvest becomes even more essential when crops are short at maturity, or are tall but have lodged.

Rolling also improves seed–soil contact in sandy, non-wetting soils, although press-wheels will normally achieve this.

Rolling of paddocks sown to pulses in the past has generally occurred before crop emergence. However, some growers have taken to post-emergent rolling of their pulses. This is particularly common with field peas but faba beans can be rolled after emergence if the plants themselves are not taking the weight of the roller.

3.4 Pulses and herbicide damage

Pulses can be affected by application of some post-emergent broadleaf herbicides even when applied at label rates. Crops may have reduced plant biomass or N_2 fixation and lower yields.

18 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

Pulses grown in lower-rainfall regions with >250 mm annual rainfall and with sandy, calcareous soils are at most risk of herbicide damage. Crops with a significant reduction in N_2 fixation can mean the difference between making or losing money from a pulse crop, particularly in low-rainfall situations. [19]

When planning weed control programs in crops and fallow prior to faba beans, be cautious about the use of herbicides with damaging residues. Many of the Group B herbicides have long plant-back periods, up to 24 months for faba beans, which are prolonged on dry soils with pH ($CaCl_2$) above 6.5. [20] See Section 6. Weed control.

3.5 Seeding equipment

Success with pulses may depend on the type of sowing equipment used. The large size of pulses can make sowing with conventional seeders very frustrating.

If the seeder is not suitable for sowing a particular pulse (usually the larger-seeded types) in standard form there are several options available.

The machine may be adapted by minor modifications such as:

- modifying the metering mechanism with manufacturer-supplied optional parts
- modifying seed tubes to reduce blockages, particularly on older machines
- modifying or replacing dividing heads on air seeders

Sow a percentage of faba beans (i.e 25%) at a shallower rate through seed tubes and the remainder through deep banding tubes. This may help any blockages in the seed/fertiliser hose.

Agronomist's view

Most pulse-seeding problems are related to seed metering and the transfer from seed meter to soil. These problems are caused by the large size of some pulses and the high seeding rates generally used.

Faba beans can be sown with a standard air seeder or conventional combine, but care is needed because seeds tend to bridge over the outlets, causing very uneven sowing. This difficulty can be eliminated by filling the box to only one-third or one-half capacity or by fitting an agitator.

Faba beans can also cause problems in some combines, but air seeders with adequate metering rollers can sow them successfully if the airflow is adequate.

3.5.1 Air seeders

Air seeders that use peg-roller metering systems (Napier, Shearer) will handle grain up to the size of smaller faba beans without problems, because of the banked metering arrangement. The optional rubber star roller will be necessary for larger seeds.

Air seeders using metering-belt systems (Fusion, Alfarm, Chamberlain–John Deere, New Holland) can meter large seed at high rates with few problems.

Air seeders with large or very coarse, single-fluted rollers cannot meter faba beans >18 mm without modifications to the metering roller. Consult a machinery dealer about possible modifications.

On some air seeders, the dividing heads may have to be modified because there is too little room in the secondary distributor heads to allow seeds to flow smoothly. Figure 23 shows a standard secondary distributor head (on the left) and a conversion

19 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

20 P Matthews, H Marcellos (2003) Agfact P4.2.7, NSW Agriculture, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

to suit Connor–Shea air seeders. The conversion head increased the bore from 23 mm to 41 mm. Four larger hoses replace the original eight, and row spacings are increased from 150 mm to 300 mm. This conversion allows large seeds to be sown easily.

Significant levels of seed damage can be caused in air seeders by excessive air pressure, so growers need to take care to use only enough air to ensure reliable operation.

MORE INFORMATION

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3.5.2 Combine seeders

Combines with fluted roller feeds have few problems feeding seed of <15 mm down to the metering chamber.

Combines with peg-roller and seed-wheel feeds will sow grains up to the size of faba beans without problems, providing adequate clearances are used around the rollers. Smaller faba beans such as Fiord⑴ can be metered with the more aggressive seed-wheel system, but peg rollers are best replaced with rubber stars for larger faba beans.

Combines with internal force-feed seed meters perform well on small seeds but cannot sow seed >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.

Plant growth and physiology

Key messages

- Faba bean flowers are white with some purple or black markings, and are both self-pollinated and cross-pollinated.
- A rigid plant, the faba bean is 0.5–1.8 m tall with stout, hollow but erect stems of a square cross-section.
- Faba beans will survive despite periods of waterlogging, especially in cool winter conditions.
- Faba bean seeds contain about 25% protein, 10% fat and 55% carbohydrate.

4.1 Faba bean growth stages

Uniform growth-stage descriptions were developed for the faba bean plant based on visually observable vegetative and reproductive events.

Germination is hypogeal, with the cotyledons remaining below the soil surface. This enables it to emerge from sowings as deep as 25 cm. 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 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 last node counted must have its leaves unfolded (Figure 1).

In faba beans, alternate primary branches ('tillers') usually originate from the base just above ground level (usually 1–5 primary branches on the main stem, depending on variety and growing conditions).

The reproductive stages begin when the plant begins to flower at any node.

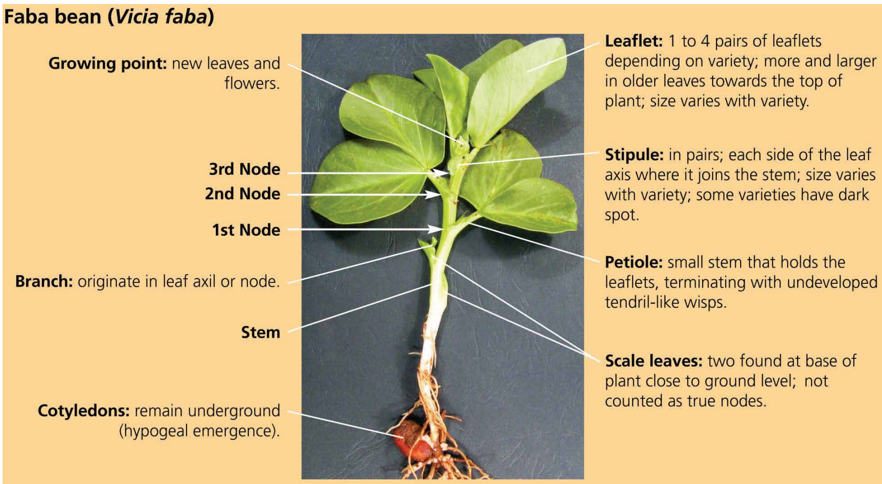

Figure 1: *Faba bean early growth stages.*

Source: Holding and Bowcher (2004) Weeds in Winter Pulses, CRC for Australian Weed Management

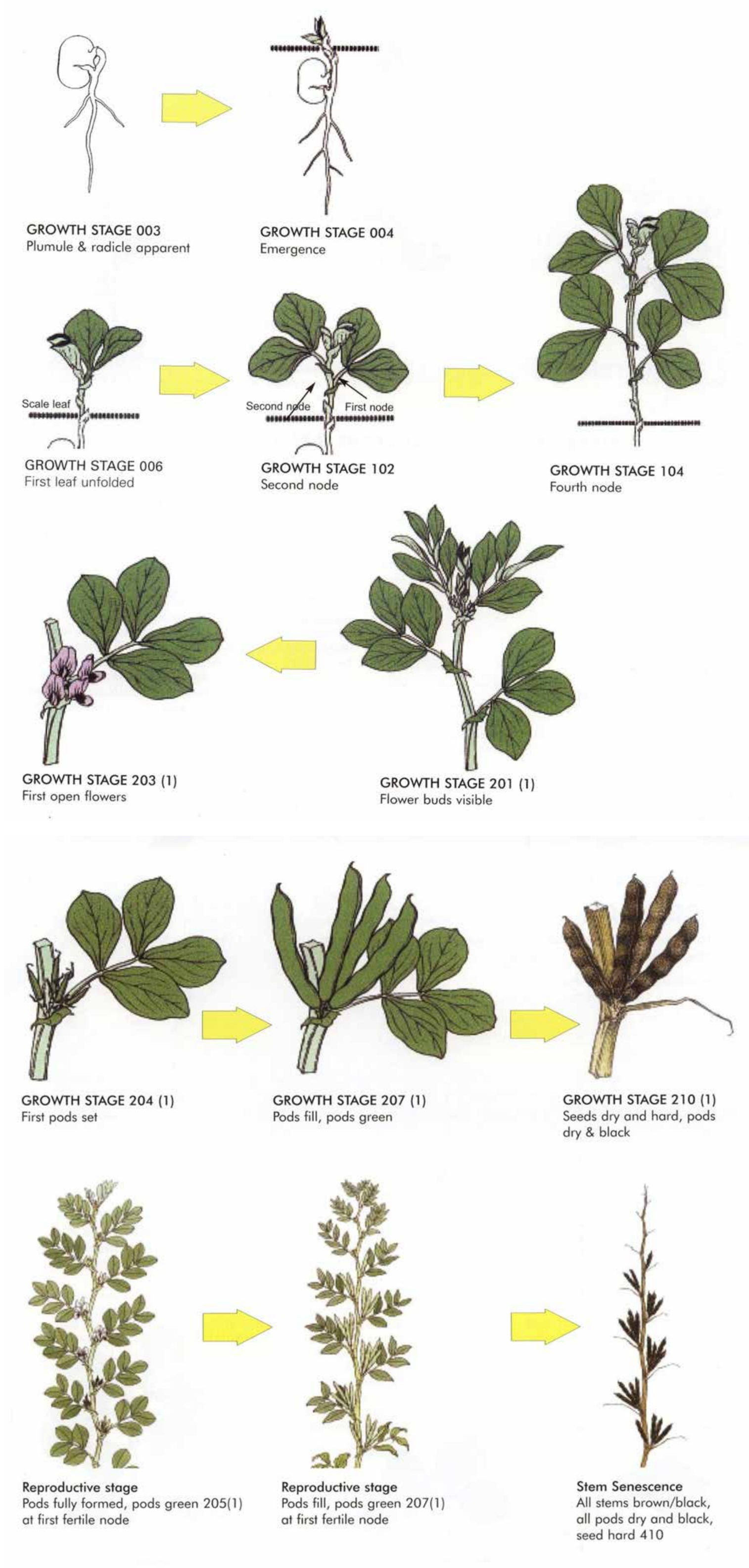

Figure 2: *Stages in the development of the faba bean (Vicia faba).*

Source: PGRO, UK

Table 1: *Growth stages of a faba bean plant.*

Development phase	Growth stage (GS)	Description
00 Germination and Emergence	GS 000 Dry seed	
	GS 001 Imbibed seed	
	GS 002 Radicle apparent	
	GS 003 Plumule and radicle apparent	
	GS 004 Emergence	
	GS 005 First leaf unfolding	
	GS 006 First leaf unfolded	
10 Vegetative	GS 101 First node	First leaf fully unfolded with one pair leaflets
	GS 10(X) X node	X, leaf fully unfolded with more than one pair of leaflet
	GS1(N) N, Last recorded node	N, any number of nodes on the main stem with fully unfolded leaves according to cultivar
20 Reproductive	GS 201 Flower buds visible	First buds visible and still green
	GS 203 First open flower	First open flowers on fist raceme
	GS 204 Pod set	First pods visible at first fertile node
	GS 205 Green pods fully formed	Small immature seeds within
	GS 207 Pod fill	Seeds maximum size and fill pod cavity
	GS 209	Seeds rubbery, pods still pliable turning black
	GS 210 Dry seed	Pods dry and black, seed dry and hard
30 Senescence	GS 301 10% pods dry and black	
	GS 305 50% pods dry and black	
	GS 308 80% pods dry and black, some upper pods green	
	GS 309 90% pods dry and black, desiccation stage	
	GS 310 All pods dry and black, seed hard	
40 Stem senescence	GS 401 10% stem brown/black or most stem green	
	GS 405 50% stem brown/black or 50% stem green	
	GS 410 All stems brown/black, all pods dry and black, seed hard	

Source: PGRO, UK.

Faba bean varieties generally exhibit either indeterminate or semi-determinate growth habits. The terminal bud of an indeterminate plant is always vegetative and keeps growing. Vegetative growth continues even as the plant switches to reproductive mode and flowering begins. For a semi-determinate growth habit, vegetative growth continues initially after the plant switches to reproductive mode and flowering begins, but can terminate before moisture becomes limiting. Australian faba bean varieties are semi-determinate (Photo 1).

Photo 1: *An Australian semi-determinate faba bean type that is typical of our current varieties.*

Photo: W. Hawthorne, Pulse Australia

Photo 2: *A breeding line that is determinate. No new growth appears above the pods.*

Photo: W. Hawthorne, Pulse Australia

Flower terminals develop from the auxiliary bud at the base of each node, with flowering commencing at ~6th–10th node, depending on the variety, location and time of sowing. Faba bean flowers are white with some purple or black markings. Flowers are borne on a peduncle that arises from nodes. Flowers are both self-pollinated and cross-pollinated. [1]

For populations, vegetative stages can be averaged if desired. Reproductive stages should not be averaged.

A reproductive stage should remain unchanged until the date when 50% of the plants in the sample demonstrate the desired trait of the next reproductive (R) stage. The timing of a reproductive stage for a given plant is set by the first occurrence of the specific trait on the plant, without regard to position on the plant. [2]

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

2 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

4.2 Growth and development

4.2.1 Emergence

Under optimum moisture and temperature conditions, faba bean seeds imbibe water relatively quickly and germinate within a few days, provided temperatures are >0°C. Unlike lupins, faba bean seedling cotyledons (embryonic leaves) remain underground inside the seed coat while providing energy to the rapidly growing roots and shoots.

Emergence occurs seven to 30 days after sowing, depending on soil moisture, temperature conditions and depth of sowing. Growth of the shoot (plumule) produces an erect shoot and the first leaves are scales. The first true leaves have a single pair of leaflets (i.e. two leaflets), and from the 5th–8th node, leaves have two or three pairs of leaflets. The development of multiple pairs of leaflets per leaf generally corresponds with the development of the first flower bud.

When placed in a moist environment, the seed goes through three stages of water uptake during germination as it imbibes water, as follows.

Phase 1 is water movement into the grain, imbibition, which occurs because the moisture content in the soil is greater than that in the seed. The seed swells. Water enters primarily at the hilum end of the grain where it was originally attached to the funiculus and nutrient-conducting tissues of the plant. There is also some minor movement of water through the seed coat. Water uptake into the embryo (germ) proceeds very rapidly, depending on the soil moisture content, to the point that normal cellular processes (metabolism, cell division, etc.) can occur. Seed moisture needs to reach ~35% dry weight before germination can occur. Too much water can impede germination by restricting diffusion of oxygen to the seed. All seeds, whether viable or non-viable, dormant or non-dormant, go through this phase 1 process.

Phase 2 is when there is minimal uptake of water, and the phase extends through to the first visible signs of germination. The major metabolic events required to prepare the seed for germination occur during phase 2 only in viable and non-dormant seeds. These changes are conserved if the seed is dried, and the seed can remain dry for a considerable period without significant reduction in viability or germination potential. When these seeds are re-wetted, they again rapidly imbibe and show accelerated germination as the phase 2 duration is markedly shortened.

Phase 3 is associated with visible germination and subsequent growth (Photo 3). As part of this growth, there is rapid uptake of water again and new metabolic activity, including the start of mobilisation of stored food reserves in the endosperm. Visible germination starts with the rupture of the seed coat over the germ and the protrusion of the shoot and radicle. As this process advances, the seedling becomes increasingly vulnerable to damage through drying, and there is a reducing capacity to regenerate following re-wetting.

Photo 3: *Germinating bean seed.*

Until the establishment of green leaves, the seedling is dependent on the stored food reserves in the endosperm. During the early stages of germination, the embryo produces gibberellic acid, which triggers the synthesis of enzymes that ultimately lead to the production of sugars and amino acids required by the growing seedling. [3]

Implications of this information are that:

- Seeds sown into marginal moisture and have imbibed some moisture may have either dried down or not taken up sufficient moisture to germinate. These 'primed' seeds will germinate quickly when the soil is again wetted up, as part of the germination process has commenced.
- Seed with a cracked seed coat can allow direct access of water and microorganisms into the stored starch and protein reserves in the endosperm.
- Seed with a cracked seed coat may imbibe moisture too quickly and impede oxygen diffusion into the seed.
- If there has been pre-harvest sprouting, it may have limited effects on germination percentage when tested at harvest, but will cause a decline in germination percentage, germination vigour and seed viability during storage. [4]

4.2.2 Leaves

Leaves in faba beans are alternate along the branch. Each leaf is 10–25 cm long, pinnate and consists of 2–7 leaflets each up to 8 cm long and of a distinct glaucous grey–green colour. Leaflets are not serrated. Unlike most other members of the *Vicia* genus, the faba beans is without tendrils or with rudimentary tendrils.

Leaflets fold and become limp in dry, hot conditions to minimise transpiration. Canopy development in faba beans is quite rapid, especially during early sown and warmer winter conditions.

The entire surface of the leaflets is free of fine hairs (trichomes). [5]

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3 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

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4.2.3 Roots

Faba beans have a robust taproot with profusely branched secondary roots that increase in size near the soil surface as the season develops. The root systems are strong, but do not always penetrate to depth.

Faba bean roots can leave moisture at depth late in the season, and this can result in a reduced ability to withstand dry conditions. Root growth is most rapid before flowering but will continue until maturity under favourable conditions. Faba beans are susceptible to hard pans, and prefer deep, well-structured soils so that roots can penetrate deeply. Subsoil constraints, such as soil chloride in excess of ~800 mg/kg soil in the top 60 cm, will restrict root growth and water availability.

As well as their role in water and nutrient uptake, faba bean roots develop symbiotic nodules with the rhizobial bacteria *Rhizobium leguminosarum* bv. *Viciae*, a species capable of fixing atmospheric nitrogen (N_2) (Photo 4). The plant provides carbohydrates for the bacteria in return for N_2 fixed inside the nodules.

These nodules are visible within about a month of plant emergence, and eventually form slightly flattened, fan-like lobes. Almost all nodules are confined to the top 30 cm of soil and 90% are within 15 cm of the surface. When cut open, nodules actively fixing N_2 have a pinkish centre. Nitrogen fixation is highly sensitive to waterlogging; hence, faba beans need well-aerated soils.

Photo 4: *Nodulated roots.*

Source: W. Hawthorne, Pulse Australia

Waterlogging and drainage

Faba beans are considered tolerant of waterlogging. They will survive despite periods of waterlogging, especially in the cool conditions of winter. However, waterlogging will reduce yields.

Soil nitrate and temperature effects on nodulation

Nitrate in the soil can delay nodulation, decrease nodule number and decrease nodule activity. Nodulation can be markedly reduced by low temperature, and it is likely to be slow in the field when the soil temperature is low (10°C) as may occur after a late sowing. The known yield advantage of early planting of faba beans may in part be due to better nodulation under warm (15°C) soil conditions.

Root mass and penetration

Faba-bean roots do not penetrate to the same soil depths as those of wheat or barley. Studies have shown water use by wheat and barley over the growing season was unaffected by row spacing; however, both cereals were more effective than faba beans at extracting soil water. In contrast to the cereals, faba beans used 50 mm less water, which was related to its inability to extract water below 85 cm depth and its failure to 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 (Figure 3). [6]

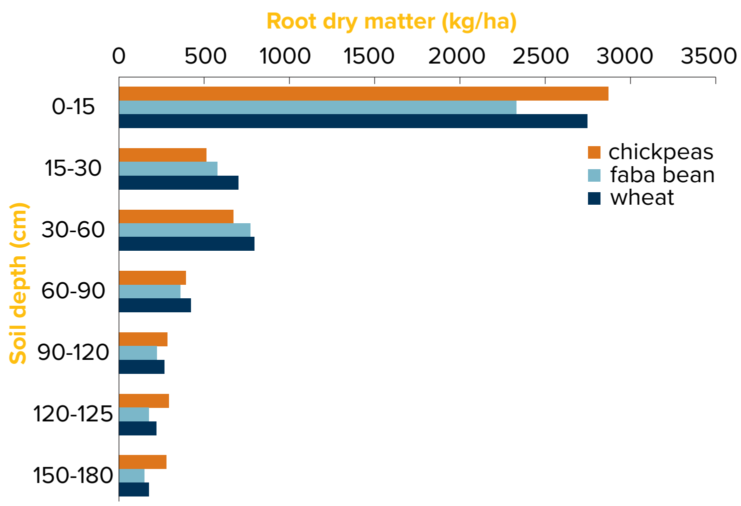

Figure 3: *Root biomass (kg/ha) at each soil depth of chickpea, faba bean, and wheat.*

Source: Turpin et al. 2002

4.2.4 Stem and branches

Vicia faba is an annual with rigid, erect plants, ideally 0.5–1.8 m tall, with stout, hollow but erect stems of a square cross-section.

Primary branches, starting from ground level, grow from buds at the lowest nodes or plumular shoot, as well as from the lateral branches of the seedling (Photo 5). These branches are thick, strong and woody, and determine the general appearance of the plant. Height achieved by the main stem and branches depends on soil moisture or rainfall conditions, length of growing season and variety.

Unlike lupins and some other pulses, there are no secondary or tertiary branches that develop from the main stem or branches. [7]

6 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

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Photo 5: *Maturing, well-podded faba bean plants showing their basal branching habit and multiple-podding nodes.*

Photo: W. Hawthorne, Pulse Australia

4.2.5 Flowering and fruit development

If every flower on every faba bean plant produced a pod and each of those pods produced three seeds, the yield potential of the crop would be ~38–43 t/ha (Patrick and Stoddard 2010). However, 4 t/ha is a more realistic figure. The explanation is in the amount of sunlight hitting the leaves adjacent to open flowers for three consecutive days. Those leaves photosynthesise and produce sugars that feed the flowers. If there is no or very little photosynthesis, then there are insufficient assimilates to sustain the flowers. Necessity for sunlight to improve podset has implications for time of sowing, sowing rate and for row spacing in faba beans.

Flowering commences at the appropriate node on the main stem and lower branches and proceeds acropetally (from the base to the apex of the plant) at intervals averaging at least five to seven days between successive nodes along each branch. The node of the first flower, and the interval between successive nodes, vary depending on the month, season, variety and sowing time. Duration between nodes is particularly slow during vegetative and early reproductive stages (≥7 days) in winter, but shorter than this interval during spring.

Photo 6: *Flowering faba bean.*

Photo: Drew Penberthy, Penagcon

Faba bean flowers are large, borne on short pedicels in clusters of 1–5 on each axillary raceme, usually from the node where flowering commences (Photo 6). There can be up to 15 flowering nodes in well-grown faba beans in Australia; 1–4 pods develop from each flower cluster. Growth is largely indeterminate. Flowers are 1.0–2.5 cm long, with five petals, the standard petal (white), the wing petals (white with a black spot, not deep purple or blue) and the keel petals (white) (Photo 7).

Photo 7: *Faba bean flowers are not completely white, because of the tannins that occur in their seeds. Only tannin-free faba beans that lack anthocyanin, will produce white flowers.*

Photo: W. Hawthorne, Pulse Australia

At any location, seasonal variations in temperature can bring about a significant shift in flowering times for the same time of sowing (i.e. +10 days). In general, warmer temperatures hasten development, as reflected in thermal-time calculations.

Progress toward flowering follows a conventional thermal-time model. For commercial faba bean varieties, ~830–1000 degree-days (>0°C) are required for the onset of flowering, but this varies with location, time of sowing and variety. Optimum temperature of flowering is 22–23°C.

Flowers may abscise from the crop because of:

- lack of pollination
- proximal flowers on the same raceme being fertilised
- vegetative–reproductive competition for assimilate
- stresses such as drought

There can be an early period of ineffective flowering, during which podset does not occur. In warmer environments, this period is minimal, but in colder temperate environments, it can be as long as 30 days.

If there is a critical mean or average daily temperature for faba beans to flower, in most current varieties it would be <10°C.

Once true flowers are produced in faba beans, a period of cool weather or lack of sunlight for 3 days can cause flower or pod abortion to varying degrees.

If moisture and temperature conditions are favourable, additional crop growth, node production, flowering and crop height occur until flowering ceases. Hot conditions (maximum temperatures >30°C) or lack of moisture cause flowering, and hence additional crop growth, to cease.

Pollination

Pollination takes place after the flower bud opens. Faba beans are allogamous, or have a mixed mating system with both self- and cross-pollination. Faba bean pollen is very heavy and sticky and is not released into the air. Virtually all cross-pollination is via insect transfer of the pollen. The rate of cross-pollination in a faba bean crop is typically 30%, but this varies with environmental conditions, the presence of insect vectors and variety. The main insect pollinators are honeybees.

If low numbers of bees are present, introducing commercial pollinating bees through the crop in a grid of at least two hives/ha can increase yield by 30–100% and has been useful in South Australia. [8]

8 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

Photo 8: *Bee hives need to be strategically placed within crops in SA to aid pollination.*

Photo: W. Hawthorne, Pulse Australia

Pod development

Faba bean plants generally produce many flowers; however, a large proportion (~80–90%) do not develop into pods, depending on the variety, sowing date and other environmental conditions (Figures 10–12). Some pods that set do not progress to fill seeds either.

Photo 9: *Flower raceme indicates flowers that did not set pods.*

Photo: W. Hawthorne, Pulse Australia

Photo 10: *Faba bean pod and dead flowers that, when removed, may show small pods.*

Photo: W. Hawthorne, Pulse Australia

Photo 11: *Faba bean branches showing small pods, pods that have formed but not developed, and flower raceme left after flower abscission without setting pods.*

Photo: W. Hawthorne, Pulse Australia

The pods of faba beans are green and leathery, maturing to be blackish-brown, with a dense downy internal surface. Modern cultivars developed for human food use have pods 15–25 cm long and 2–3 cm thick. Each pod contains 3–8 seeds; round to oval, usually flattened and up to 20–25 mm long, 15 mm broad and 5–10 mm thick.

Under favourable temperature and soil-moisture conditions, the time taken from fertilisation of the ovule (egg) to the first appearance of a pod (podset) is about six days. The seed then fills over the next three to four weeks. The developing pod stands above its subtending leaf. It may become too heavy (e.g. in broad bean) and then hang below the flowering node for harvest. After podset, the pod wall grows rapidly for the first 10–15 days, while seed growth mainly occurs later.

Once flowers begin to develop and fertilisation has occurred, the pods remain erect and beneath the leaf canopy. Pods only bend and point downward when seeds are near maturity in some bean varieties. The pod can contain 3–8 ovules, of which most usually develop into seeds. The bulk of the yield is found on the lower flowering nodes of the main stem and basal branches.

Fewer pods per node are set at lower nodes for an early-sown crop. At a low seeding rate, more pods are set per node at lower nodes, whereas at higher sowing rates pods are more evenly distributed along the stem (Photo 13). This means that matching the variety with the time of sowing and sowing rate is particularly important with faba beans. Using a high seeding rate with early-sown crops produces dense, vigorously growing crops early in the season that shade the flowers, reducing podset and therefore the yield potential.

Photo 12: *Distribution of pods depends on seeding rate.*

Photo: Drew Penberthy, Penagcon

Lack of sunlight is a major factor in determining the level of podset in WA. The amount of radiation hitting the flower from when it opens and for the following three days is the main contributing factor.

There are significant differences between varieties for time between producing first flower and first podset, and this contributes to the variation in podset between varieties. [9]

Some growers have associated poor podset with early sowing. However, poor light in dense canopies, and hence low photosynthesis, is likely to be the major cause, often in conjunction with low levels of pollinator activity and possible chocolate spot on flowers.

In many well-grown faba bean crops, podset does not occur until temperatures rise in August–September, when there is also more sunlight, and less wind and rain (for pollinator activity). More consistent podset and seed-filling then commences. Disease incidence in flowers (i.e. chocolate spot) is implicated in poor podset in some situations, and thus many faba bean growers consider fungicide protection of early flowers important. When temperatures rise and environmental conditions improve, pods can develop quickly, within three to six days. Even after flowers develop into pods, periods of low temperature and poor conditions may result in abortion of seeds or whole pods before filling commences. [10]

Seed development

Faba bean pods vary greatly in size between varieties because of varying seed sizes. Seed-filling and subsequent seed size are highly dependent on variety, the number of seeds set and weather conditions.

Seeds are characteristically oval and flat, with a ridged, dimpled or smooth seed coat. Seed colour varies between varieties from white (tannin-free) to light tan or green (commercial varieties), brown (aged beans), and even purple or black (specific lines).

9 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

10 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

Kernel colour is yellow. Seed numbers vary from one to eight per pod, and not every ovule in a pod necessarily develops.

The weight of individual seeds is more uniform along a stem for an early-sown than for a late-sown crop, which has more small seeds towards the plant top. [11]

4.3 Crop development

Crop duration is highly correlated with temperature: crops will take different times from sowing to maturity under different temperature regimes. The concept of thermal time is the method used to represent a crop's need to accumulate a minimum time for development through each essential growth stage (e.g. vegetative or reproductive growth). Consequently, crops growing under low air temperatures generally need more time to develop than crops growing at warmer temperatures.

Progress to flowering in faba beans is significantly influenced by temperature and can be described by the accumulation of thermal time (max T° – min T°)/2. The base temperature for calculating thermal time for faba bean is 0°C.

Thermal time is also referred to as heat units, degree-days or growing degree-days. Once a certain number of degree-days are reached (accumulated), flowering commences, but the actual number of thermal units required varies with the location, photoperiod and variety. Similarly, the end of flowering is controlled by thermal unit accumulation.

When sufficient heat units have been accumulated, the plant will enter its reproductive phase and start flowering. It is at this point that the stress tolerance of faba beans is significantly reduced. Low light or low average daily temperatures (<10°C) can cause flower abortion. Sub-zero temperatures can cause flower, pod and seed abortion, and severe frost can cause vegetative distortion, total defoliation and death. Temperatures >30°C can also cause flower loss and water stress.

Faba beans are most sensitive to water logging at flowering, with a similar response to low light or low temperatures with flower and pod abortion and leaf senescence. Sowing date and canopy closure are other factors that can impact on podset and yield.

The phenology of most crops can be described using nine phases:

1. Sowing to germination.
2. Germination to emergence.
3. A period of vegetative growth after emergence, called the basic vegetative phase (BVP), during which the plant is unresponsive to photoperiod.
4. A photoperiod-induced phase (PIP), which ends at floral initiation.
5. A flower development phase (FDP), which ends at 50% flowering.
6. A lag phase prior to commencement of grain-filling. This period is relatively short in faba beans.
7. A linear phase of grain-filling.
8. A period between the end of grain-filling and physiological maturity.
9. A harvest-ripe period prior to grain harvest.

These stages of development are generally modelled as functions of temperature (phases i–iii, and v–viii) and photoperiod (phase iv).

Faba beans are a medium-duration crop, usually beginning flowering within 29 to 96 days of sowing, depending on photoperiod and temperature. Faba beans are either day-neutral or long-day requiring, depending on variety. European germplasm is generally more photoperiod-sensitive. A day length of >12 hours might be required for them to flower under southern Australian conditions, while Mediterranean types flower under much shorter days.

11 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

Photo-thermal response of flowering in faba beans over the range of environments normally experienced by the crop may be described by the equation:

$1/f = a + bt + cp$

where f is the number of days from sowing to first flower, t is the mean temperature and p is the photoperiod. The values of the constants a, b and c vary between genotypes and provide the basis for screening genotypes for sensitivity to temperature and photoperiod. [12]

Photo 13: *Faba bean with excellent podset, but note the need for fungicide protection of flowers (and leaves) in a disease-risk situation.*

Photo: W. Hawthorne, Pulse Australia

4.3.1 Erectness

Faba beans are prone to lodging, 'necking', or both. They are different processes; either way, the end result is a crop that is no longer erect and becomes more difficult to harvest.

Lodging occurs when the stems bend and the crop is less erect as it becomes taller late in the season. Taller (e.g. early-sown) and dense crops are more prone to lodging than shorter, thinner crops. Strong winds and rain can also cause lodging. There are varietal differences in erectness, and disease (Ascochyta blight in particular) in the stem can also make a crop more prone to lodging. Chocolate spot becomes more severe in lodged crops, and penetration of foliar fungicide into the canopy becomes more difficult.

Necking occurs when the stem bends over sharply, virtually snapping at about pod height, so the upper part of the plant either dies or becomes less able to assist in grainfill. It occurs under strong winds or conditions causing moisture stress. Sometimes plants recover somewhat from necking, and the growing points turn to grow upright again. These plants then appear to have stems that are bent into an S-shape, and are often considered to be lodged. [13]

12 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

13 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

4.3.2 Maturity

Soon after the development of pods and seed-filling, the senescence of subtending leaves begins. If there is plenty of soil moisture and maximum temperatures are favourable for growth, flowering and podding will continue on the upper nodes. However, as soil moisture is depleted or if temperatures increase, flowering ceases and eventually the whole plant matures.

Under mild moisture stress, faba beans are incapable of accumulating solutes (sugar, proteins and other compounds) in their cells. Stomatal conductance and low levels of photosynthesis are therefore not maintained.

In Western Australia, faba bean crops can reach maturity 180–220 days after sowing, depending on the sowing date, variety, and a range of environmental factors including temperature. Faba beans are ready to harvest when >90% of the stems and pods lose their green colour and become black (Photo 15). At this point, seeds are usually hard but do not rattle when the plant is shaken.

Photo 14: *Mature faba beans are black, and in this photo have been desiccated (front and right) for earlier maturity and harvest compared with those allowed to mature naturally (centre).*

Photo: W. Hawthorne, Pulse Australia

Pulses can be desiccated or windrowed pre-harvest to enable earlier harvest and to dry out green weeds. Timing of desiccation is based on crop stage, and is similar to, or later than that for windrowing. See Section 11.

Nutrition and fertiliser

Key messages

- Nutrient balance is vital for profitable yield.
- The value of legumes in agricultural systems is measured by how well they grow and fix N_2.
- Soil pH has an effect on the availability of most nutrients.
- Faba beans have a high P requirement.

Most Western Australian cropping soils are ancient and were formed from granitic parent rock. Weathering over geological time has leached minerals and clay from the topsoils leaving them sandy and chemically infertile. Low buffering capacity makes the soils prone to nutrient leaching and rapid acidification.

Many WA soil profiles are duplex, consisting of a thin sandy or loamy topsoil overlaying a thicker clay layer. The sandy topsoils have weak structure and are prone to compaction and a low water and nutrient holding capacity. The clay subsoil can store large amounts of water but its poor structure and small pore size distribution makes it difficult for crop roots to access.

The positive aspect of low fertility soils is that crop nutrient supply and timing is almost entirely in the hands of the farmer. This is increasingly the situation for all cropping soils, not just in WA, as nutrients are depleted by crops.

5.1 Crop removal rates

A balance of soil nutrients is essential for profitable yields. Fertiliser is commonly needed to add the essential nutrients phosphorus (P), potassium (K), sulfur (S) and zinc (Zn). Lack of other micronutrients may also limit production in some situations.

Knowing the nutrient demand of crops is essential in determining nutrient requirements. Soil testing and nutrient audits assist in matching nutrient supply to crop demand. [1]

Balancing inputs

The nutrients removed by 1 t of grain by the various pulses is shown in Table 1. Actual values may vary by 30%, or sometimes more, due to the differences in soil fertility, varieties and seasons. For example, the P per tonne removed by faba bean grain can vary from a low 2.8 kg on low-fertility soils to 5.4 kg on high-fertility soils.

From Table 1, it can be seen that a 3 t/ha crop of faba beans will remove (on average) 12 kg/ha of P. This, then, is the minimum amount of P that needs to be replaced. Larger quantities may be needed to build up soil fertility or overcome soil fixation of P.

1 P Matthews, D McCaffery, L Jenkins (2013) Winter Crop Variety Sowing Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/aboutus/news/all/2013/2013-wcvsg

Table 1: *Nutrient removed by 1 t of grain.*

Grain	N	P	K	S	Ca	Mg	Cu	Zn	Mn
			(kg)				(g)		
Pulses									
Chickpea (Desi)	33	3.2	9	2.0	1.6	1.4	7	34	34
Chickpea (Kabuli)	36	3.4	9	2.0	1.0	1.2	8	33	22
Faba bean	41	4.0	10	1.5	1.3	1.2	10	28	30
Lentil	40	3.9	8	1.8	0.7	0.9	7	28	14
Lupin	53	3.0	8	2.3	2.2	1.6	5	35	18
Field pea	38	3.4	9	1.8	0.9	1.3	5	35	14
Cereals									
Wheat	23	3.0	4	1.5	0.4	1.2	5	20	40
Barley	20	2.7	5	1.5	0.3	1.1	3	14	11
Oats	17	3.0	5	1.6	0.5	1.1	3	17	40

Source: Grain Legume Handbook, 2008

5.2 Nutrition

Too little or too much of a nutrient, or incorrect proportions of nutrients, can cause nutritional problems. Visual symptoms do not develop until a major effect on yield, growth or development has occurred; therefore, damage can be done before there is visual evidence.

Healthy plants are more able to ward off disease, pests and environmental stresses, leading to higher yields and better grain quality. A plant-tissue analysis can be important in detecting non-visible or subclinical symptoms, and in fine-tuning nutrient requirements. This is particularly helpful where growers are aiming to capitalise on available moisture.

Tissue tests also help to identify the cause of plant symptoms that are expressed by plants. Technology is enabling quicker analysis and reporting of results to enable foliar- or soil-applied remedies to be used in a timely manner for a quick crop response. [2]

Identifying nutrient deficiencies

Many nutrient deficiencies may look similar:

- 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 etc.), 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.
- Look at individual plants for more detailed symptoms such as stunting or 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 from those when one nutrient alone is deficient. Micronutrients are often used by plants to process other nutrients, or work together with other nutrients, so a deficiency of one may look

2 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

MORE INFORMATION

R S Jessop and J Mahoney (1982) Effects of lime on the growth and nodulation of four grain legumes. Australian Journal of Soil Research 20(3) 265–268.

GRDC (2013) Micronutrients and trace elements. Fact sheet.

like a deficiency of another. For instance, molybdenum (Mo) is required by pulses to complete the N_2-fixation process. [3]

Nutrient types

Plant nutrients are categorised as either macronutrients or micronutrients (also called trace elements).

Macronutrients are those elements needed in relatively large amounts. They include N, P and K, which are the primary macronutrients, with calcium (Ca), magnesium (Mg) and S considered secondary. Higher expected yields of crops for grain or forage will place greater demand on the availability of major nutrients such as P, K and S. Nitrogen, P and at times S are the main nutrients commonly lacking in Australian soils. Others can be lacking under certain conditions. Each pulse type is different, has different requirements for nutrients, and may display different symptoms.

Micronutrients are those elements that plants need in small amounts. They include iron (Fe), boron (B), manganese (Mn), Zn, copper (Cu), chlorine (Cl) and Mo.

Both macronutrients and micronutrients are taken up by roots and they require certain soil conditions for uptake to occur:

- Soil must be sufficiently moist to allow roots to take up and transport the nutrients. Plants that are moisture-stressed from too little or too much (saturation) moisture can often exhibit deficiencies even though a soil test may show these nutrients to be adequate.
- Soil pH affects the availability of most nutrients and must be within a particular range for nutrients to be released from soil particles. On acid soils, (Al) and Mn levels can increase and may restrict plant growth, usually by restricting the rhizobia and thus the plant's ability to nodulate.
- Soil temperature must be within a certain range for nutrient uptake to occur. Cold conditions can induce deficiencies of Zn or P.

The optimum range of temperature, pH and moisture can vary for different pulse species. Thus, nutrients may be physically present in the soil, but not available to those particular plants. Knowledge of a soil's nutrient status (soil test), pH, texture, history and moisture status can be useful for predicting which nutrients may become deficient. Tissue tests can help to confirm the contents of individual nutrients in the plant. [4]

5.2.1 Detecting nutrient deficiencies

Soil tests are specific for both the soil type and the plant being grown. The most useful soil tests are for P, K, organic matter, soil pH and salt levels. A test for S has now been developed. The pulse crops can have different requirements for K; hence, they have different soil-test K-critical levels.

Plant-tissue testing can also be used to diagnose a deficiency or monitor the general health of the pulse crop. Plant-tissue testing is most useful for monitoring crop health, because the yield potential can be markedly reduced by the time noticeable symptoms appear in a crop.

Several companies perform plant-tissue analysis and derive accurate analytical concentrations; however, it can be difficult to interpret the results and determine a course of action. As with soil tests, different plants have different critical concentrations for a nutrient, and in some cases varieties can vary in their critical concentrations.

Table 3 lists the plant analysis criteria for faba beans. These should be used as a guide only, and plant-tissue tests should be used for the purpose for which they have been developed. Most tests diagnose the nutrient status of the plants only at the time

3 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

4 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

they are sampled, and cannot reliably indicate the effect of a particular deficiency on grain yield. [5]

Table 2: *Critical nutrient levels for faba beans at flowering.*

Nutrient	Plant part	Critical range
Nitrogen (%)	YOL	4.0
Phosphorus (%)	YOL	0.4
Potassium (%)	YML	1.0
Calcium (%)	YML	0.6
Magnesium (%)	YML	0.2
Sulfur (%)	Whole shoot	0.2
Boron (mg/kg)	YOL	10
Copper (mg/ka)	YML	3.0–4.0
Manganese (mg/kg)	YML	<40
Zinc (mg/kg)	YOL	20–25

YOL, youngest open leaf blade; YML, youngest mature leaf. Any nutrient level below the critical range will be deficient; any level above will be adequate

5.2.2 Diagnosing nutrient disorders

Table 4 summarises the symptoms of nutrient deficiencies in faba bean leaves of various ages.

Table 3: *Key to nutrient deficiencies in faba beans.*

Symptom	Old to middle leaves						Middle to new leaves					New leaves to terminal shoots					
Deficiency:	**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						
Interveinal					x						x						
On margins			x		x												
Necrosis (tissue death)																	
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 (yellow) or chlorotic (dead) 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

5 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Symptom	Old to middle leaves						Middle to new leaves					New leaves to terminal shoots					
Deficiency:	**N**	**P**	**S**	**K**	**Mg**	**Zn**	**N**	**Mg**	**Mn**	**Zn**	**B**	**Mn**	**Fe**	**Zn**	**Cu**	**Ca**	**B**
Wilting		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
Source: Snowball and Robson 1991

5.2.3 Nutrient toxicity

Soil pH has an effect on the availability of most nutrients. Occasionally, some nutrients are so available they inhibit plant growth. For example on some acid soils, Al and Mn levels may restrict plant growth, usually by inhibiting the rhizobia and consequently, the plant's ability to nodulate (Table 5, Photo 1).

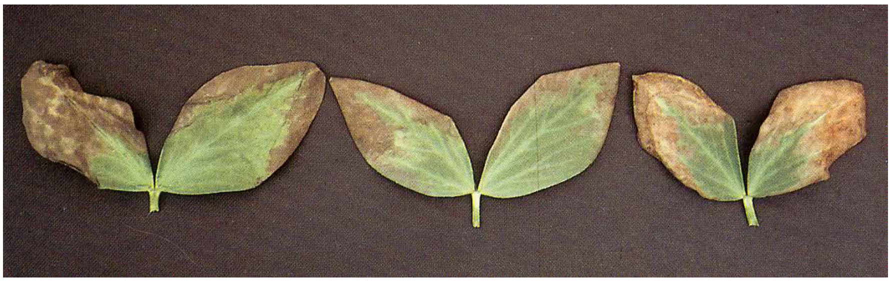

Photo 1: *Similarity of visual toxicity symptoms of manganese (left), boron (centre) and phosphorus (right) in old and middle-aged leaves of faba bean.*

Photo: A. Robson

5.2.4 Boron toxicity

Boron toxicity can occur on more alkaline soil types. The most characteristic symptom of boron toxicity in pulses is chlorosis (yellowing), and if severe, some necrosis (death) of leaf tips or margins (Photo 2). Older leaves are usually more affected. There appears to be little difference in reaction between current varieties of faba beans. [6]

5.2.5 Manganese toxicity

Manganese toxicity can occur in well-nodulated faba beans grown on soils of low pH.

Symptoms

Symptoms appear on new leaves first and can then develop in middle-aged and older leaves, the opposite to other toxicities such as Mn or P. Small purple spots appear from the margins on young leaves, and in slightly older leaves take on a reddish colouration (Photo 3).

6 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Photo 2: *Manganese toxicity in young leaves (left) and in middle-aged leaves (right) of faba bean.*

Photos: A. Robson

5.2.6 Aluminium toxicity

Like Manganese toxicity, aluminium toxicity can also occur in faba beans that are grown in low pH soils.

Visual symptoms

There are no visual symptoms of Al toxicity in faba beans other than delayed germination and plants appearing miniature and dark green. Roots are extremely stunted, with many laterals appearing dead. Symptoms may be confused with P deficiency. [7]

FAQ

5.3 Fertiliser

5.3.1 Overview

Fertiliser recommendations should take into account:

- soil type
- rotation (fallow length and impact on arbuscular mycorrhizae fungi (AMF) levels)
- yield potential of the crop
- plant configuration (row spacing, type of opener and risk of seed burn)
- soil analysis results
- effectiveness of inoculation techniques

Faba beans have a high P requirement. Phosphorus should be applied at rates of at least 12 and up to 22 kg/ha.

Soil P levels influence the rate of nodule growth. The higher the P level the greater the nodule growth.

MAP or DAP fertilisers can be used because fertilisers containing N in small amounts (5–15 kg N/ha) are not harmful to nodulation and can be beneficial by extending the early root growth to establish a stronger plant.

Faba beans appear more susceptible to K deficiency than other pulses such as field peas, and especially lupins.

Molybdenum (Mo) and cobalt (Co) are required for effective nodulation and should be applied as needed.

Excessive applied N will restrict nodulation and reduce N_2 fixation. High background levels of soil N can have similar effects or delay nodulation until N levels are depleted.

7 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Inoculated seed and acidic fertilisers should not be sown down the same tube. The acidity of some fertilisers will kill large numbers of rhizobia. Neutralised and alkaline fertilisers can be used.

Acid fertilisers include:

- superphosphates (single, double, triple)
- fertilisers with Cu and/or Zn included
- MAP (also known as 11:23:0 and Starter 12)

Alkaline fertilisers include:

- DAP (also known as 18:20:0)
- starter NP
- lime [8]

5.3.2 Pulses and fertiliser toxicity

Practically all fertilisers are capable of causing damage to germinating seeds if they are in close proximity to each other and in a concentrated band. [9]

Drilling 10 kg/ha of P with the seed at 18-cm row spacing through 10-cm points rarely causes problems. However, changes in sowing techniques to narrow sowing points or disc-seeders with minimal soil disturbance, and wider row spacing, have increased rates of fertiliser (all of which concentrate the fertiliser near the seed in the seeding furrow) and increase the risk of toxicity.

The effects are also increased in highly acidic soils, sandy soils and where moisture conditions at sowing are marginal. Drilling concentrated fertilisers to reduce the product rate per hectare does not reduce the risk.

The use of starter N (e.g. DAP) banded with the seed when sowing pulse crops may reduce establishment and nodulation if higher rates are used. On sandy soils, up to 10 kg/ha of N at 18-cm row spacing can be safely used. On clay soils, do not exceed 20 kg/ha of N at 18-cm row spacing. [10]

5.3.3 Nitrogen

Fertilisation with N is unnecessary for faba beans, because the crop can meet its N needs through biological N_2 fixation in nodules formed on the roots, unless a nodulation failure has occurred.

Soil nitrate levels greatly affect legume nodulation and N_2 fixation. At low nitrate levels of <50 kg N/ha in the top 1.2 m of soil, the legume's reliance on N_2 fixation is generally high. As soil nitrate levels increase, legume nodulation and N_2 fixation become increasingly suppressed.

Deficiency symptoms

First sign of N deficiency in faba beans is a general paleness of the whole plant, even before a reduction in plant growth. There may be a cupping of the middle-aged to new leaves. With time, a mottled chlorosis of old leaves slowly develops with little sign of necrosis (Photo 4).

Check for nodulation and for whether nodules are fixing N_2 (nodule colour), to confirm suspected N deficiency from visual plant symptoms. [11]

8 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

9 GRDC (2011) Fertiliser Toxicity Fact sheet. https://grdc.com.au/Resources/Factsheets/2011/05/Fertiliser-Toxicity

10 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

11 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Photo 3: *Nitrogen deficiency: plants show signs of stunting, yellowing and poor growth relative to well-nodulated plants. Check nodulation and internal nodule colour to confirm nodulation failure and deficiency.*

Photo: W. Hawthorne, Pulse Australia

Some situations where N fertiliser may warrant consideration include:

- The grower is unwilling to adopt recommended inoculation procedures.
- Late or low-fertility situations, where rapid early growth is critical in achieving adequate height and sufficient biomass to support a reasonable grain yield (Table 6).

Faba bean grain contains about 40 kg N/t.

Table 4: *Nitrogen balance.*

Total plant dry matter (t/ha)	Total shoot dry matter yield (t/ha)	Grain yield (t/ha) 40% HI	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	50
7.00	5.00	2.0	160	66
8.75	6.25	2.5	200	83
10.50	7.50	3.0	240	100

HI, Grain harvest index—grain yield as a percentage of total shoot dry matter production (averages ~40%

5.3.4 Phosphorus

Deficiency symptoms

Symptoms of P deficiency take time to develop because of initial seed reserves of P. When symptoms start to appear, large differences in growth are apparent and the plant has smaller leaves compared with P-adequate plants. Visual symptoms appear first on the oldest pair of leaves as a mildly mottled chlorosis over much of the leaf.

MORE INFORMATION

[L Barton, C Scanlon and F Hoyle (2016) Where does the nitrogen go? Soil sources and sinks in Western Australia cropping soils. GRDC Research Update.]

[GRDC (2012) Crop nutrition phosphorus management. Fact sheet.]

These symptoms could be confused with N or S deficiency, but middle-aged and new leaves remain a healthy green, so 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 5).

Faba beans are very responsive to P fertiliser, but Zn status must be adequate to achieve a P response. [12]

Photo 4: *Symptoms of phosphorus deficiency in old leaves of faba bean. Note the spotting within darker green areas of an otherwise mildly chlorotic leaf.*

Photo: A. Robson

5.3.5 Potassium

Deficiency symptoms

Older leaflets show symptoms first, and initially growth is stunted compared with other parts of the paddock, e.g. in old stubble rows. Older leaves show a slight curling and then a distinct greying of leaf margins, eventually dying.

12 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Photo 5: *Potassium deficiency in faba bean (left and middle), alongside a plant with adequate K taken from the same paddock but from within old stubble rows left by the harvester when taking off previous cereal crop. Note the necrosis of leaf margins and purple blotching.*

Photo: W. Hawthorne, Pulse Australia

Photo 6: *Potassium deficiency in faba beans. Note loss of lower leaves and general poorer height and vigour compared with K-adequate plants.*

Photo: W. Hawthorne, Pulse Australia

Responses to K are unlikely on most stronger soils but should be based on soil analysis.

Fertiliser responses are likely where soil test levels using the ammonium acetate test fall below:

- 0.25 cmol(+)/kg of exchangeable K on black earths and grey clays
- 0.40 cmol(+)/kg of exchangeable K on red earths and sandy soils

Applying 20–40 kg/ha K banded 5 cm to the side of, and below the seed line, is recommended where soil test levels are critically low. [13]

5.3.6 Sulfur

Deficiency symptoms

Youngest leaves turn yellow, and plants are slender and small (Photo 9).

Photo 7: *Sulfur deficiency in faba beans shows up as chlorosis of leaf edges (left photo) and can progress to necrosis within those chlorotic areas (right photo).*

Photos: A. Robson

5.3.7 Zinc

Faba beans are very responsive to Zn fertiliser, but P status must be adequate to achieve a Zn response.

Deficiency symptoms

Plants are small; the areas between veins turn yellow, becoming yellower on the lowest leaves. Maturity can be delayed (see Photos 10 and 11).

Faba beans have a relatively high demand for Zn, but have evolved highly efficient mechanisms for extracting Zn from the soil.

Foliar application of Zn is relatively common, often fitting in with herbicide or early fungicide applications.

There is a lack of Australian and overseas research on Zn responses in faba bean. Zn fertiliser recommendations are conservatively based on a general recommendation used for all crops, based on DTPA analysis of soil samples 0–10 cm:

- <0.8 mg/kg on alkaline soils
- <0.3 mg/kg on acid soils

Arbuscular mycorrhizal fungi (AMF) can be extremely important to Zn nutrition in faba beans, and responses can be expected in situations where AMF levels have become depleted after long fallows (8–10 months).

Pre-plant treatments

Severe Zn deficiency can be corrected for 5–8 years with a soil application of zinc sulfate monohydrate of 15–20 kg/ha, worked into the soil 3–4 months before sowing.

13 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Zinc is not mobile in the soil and needs to be evenly distributed over the soil surface, and then thoroughly cultivated into the topsoil.

In the first year after application, the soil-applied zinc sulfate monohydrate may be not fully effective and a foliar Zn spray may also be required.

Foliar zinc sprays can correct a mild zinc deficiency if applied within the first 6-8 weeks of emergence.

Zinc seed treatments may be a cost-effective option where soil P levels are adequate but Zn levels are likely to be deficient.

A range of phosphate-based fertilisers contain, or can be blended with, a Zn additive.

Photo 8: *Zinc-deficient faba beans (far left and centre right) are paler and poorer in growth than those with adequate Zn applied (centre left).*

Photo: Grain Legume Handbook, 2008

Photo 9: *Zinc-deficient middle-aged leaves of faba bean (right).*

Photo: A. Robson

5.3.8 Iron

Iron (Fe) deficiency can be confused with Mn and Mg deficiency. Iron is strongly immobile in plants.

Deficiency symptoms

Yellowing between leaf veins can progress to completely yellow plants (Photo 12). Contrast in colour between old and new leaves is much stronger with Fe deficiency than with Mn deficiency.

Photo 10: *Bean varieties have different tolerances to Iron deficiency. Aquadulce (between the pegs) is more tolerant, but not immune compared to many other faba beans (e.g. left).*

Photo: Grain Legume Handbook, 2008

Occurrence

Iron deficiency is observed occasionally on alkaline (high pH) soils. It is usually associated with a waterlogging event following heavy rainfall, and is attributed to interference with Fe absorption and translocation to the foliage.

Symptoms include a general yellowing of young leaves, which can develop in severe cases to distortion, necrosis and shedding of terminal leaflets (pinnae).

A mixture of 1 kg/ha of iron sulfate + 2.5 kg/ha of crystalline sulfate of ammonia (not prilled) + 200 mL non-ionic wetter/100 L water has been successfully used to correct Fe deficiency.

The addition of sulfate of ammonia will improve absorption of Fe, with a significantly better overall response.

Cultivars exhibit marked differences in sensitivity to iron chlorosis, and major problems with Fe deficiency have largely been overcome through the efforts of the plant breeders. Most current varieties are considered tolerant to all but extreme situations.

Iron deficiency symptoms tend to be transient, with the crop making a rapid recovery once the soil begins to dry out. [14]

MORE INFORMATION

For detailed descriptions and images of nutrient deficiencies, see Faba beans: The Ute Guide', available from the GRDC bookshop on the GRDC website.

14 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

5.3.9 Manganese

Deficiency symptoms

Deficiency appears in new leaves, which first show mild chlorosis, followed by small dead spots or purple spotting at each side of the mid-rib and lateral veins. The leaves can turn yellow and die.

Some plants may have only a few brown spots on unopened new growth, whereas in other plants symptoms may extend to middle-aged leaves and range from blackened tops of leaves and new growth to purple necrosis over much of the leaf (Photo 13).

Photo 11: *Manganese-deficient faba bean new leaves as they are opening (right).*

Photo: A. Robson

5.3.10 Copper

Deficiency symptoms

Copper (Cu) deficiency does not appear until flowering; hence, there is little effect on vegetative growth. The first symptom of Cu deficiency is an apparent wilting and rolling of the leaflet ends of fully opened leaves. Wilting symptoms are followed by a partial opening of new leaflets, which in some cases appear puckered and kinked over towards the leaf ends. If the deficiency is severe, wilting of fully formed leaves develops into a withertip, as often seen in Cu-deficient wheat. The tips of each leaflet become pale green with a dried-up appearance, and then become twisted and necrotic (Photo 14).

Flowering is not delayed in faba bean as it is in field peas, and flowers appear quite normal, but few pods and seeds form. [15]

15 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Photo 12: *Copper deficiency in faba beans -- new leaves (left) and fully opened leaves (right), both showing withertip.*

Photo: A. Robson

5.3.11 Molybdenum

Molybdenum (Mo) is an important trace element in faba bean growth. It is the least abundant of the trace elements in soils, and very little is present in forms available to plants. Sandy soils, and those which are inherently infertile in their natural state, e.g. soils low in P, are typically low in Mo. It can be deficient when the pH in the paddock is low.

Mo is important in N metabolism, and the synthesis of protein. Two important processes are:-

- the reduction of nitrate (NO3-) to nitrite (NO2-), the first step in the synthesis of amino acids and protein; and
- in root nodules in legumes, Rhizobium bacteria require Mo to fix atmospheric or molecular nitrogen (N_2). [16]

Deficiency symptoms

Leaves are pale green and mottled between veins, with brown scorched areas developing rapidly between the veins.

Molybdenum-deficient plants may contain high nitrate-N levels resulting from the inhibition of nitrate reduction to ammonia. The presence of high nitrate levels in a chlorotic, apparently N-deficient plant is thus evidence for Mo deficiency.

5.3.12 Boron

As with calcium, B has a dramatic effect on the root system of faba beans.

Deficiency symptoms

Roots become brown with lateral extremities showing shortening and thickening. The first leaf symptoms are a reduction in growth, with the development of a waxy look and a darkening of colour. This is followed by a folding back of these leaves in an umbrella fashion, leaving the leaflet folded over and twisted. Stem internode length is shortened. As the deficiency progresses, middle-aged leaves develop a mottled chlorosis that forms between the veins (Photo 15).

16 Incitec Pivot Fertilisers (2016) Molybdenum. http://www.incitecpivotfertilisers.com.au/News/Nutrient%20Facts/Molybdenum

Photo 13: *Boron-adequate left on left, with B-deficient leaves (older to youngest, left to right) of faba bean.*

Photo: A. Robson

As B becomes deficient, the vegetative growing point of the affected plant becomes stunted or deformed, or disappears altogether. When this occurs, apical dominance of the growing point ceases to exert control over lateral shoot development. Thus, a proliferation of side shoots can occur resulting in a 'witches broom' condition. Deformed flowers are a common symptom of B deficiency. Many plants may respond by reducing flowering and pollinating improperly, as well as developing thickened, curled, wilted and chlorotic new growth. [17]

5.4 Arbuscular mycorrhizae fungi

The symbiotic relationships between some soil fungi and plant roots are known as arbuscular mycorrhizae (AM) or arbuscular mycorrhizal fungus (AMF). These can help plants to take up nutrients such as P and Zn from the soil and from fertiliser. AMF colonises and builds up on the faba bean root system. The fungi produce hyphae that colonise the root and then grow out into the soil (much further than root hairs do). Phosphorus and Zn are taken up by the hyphae and transported back for use by the plant.

Crops vary in their AM dependency and crops such as faba beans, chickpeas, safflower and linseed have a high AM dependency and promote AM build-up. Winter cereals and field peas are less AM-dependent, but do allow AM to build up. Canola and lupins, and paddocks under extended fallow, do not host AM, so AM levels are reduced under these crops in rotation.

Products containing AMF are available as seed treatments, often in association with other seed enhancers, which in combination can give the most potent means to ensure a highly successful AMF spore inoculation.

MORE INFORMATION

Seed Enhancer™VAM from Ferti-Tech Australia,

5.5 Nutrition effects on following crop

5.5.1 Nitrogen

Legume growth is the major driver of legume N_2 fixation, the bulk of which occurs during pod-filling. Faba beans fix similar amounts of N to field peas (110kg/ha N compared to 105kg/ha N) while lupins fix 130kg/ha N (Table 5).

17 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Table 5: *Estimates of the amounts of N_2 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 N_2 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; D Herridge 2013.

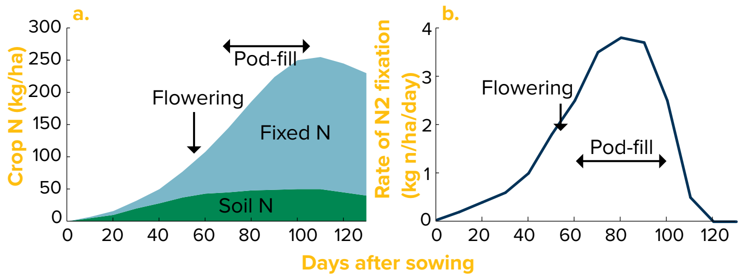

Figure 1: *Typical patterns of nitrogen accumulation and N2 fixation by annual crop legumes. In (a), total crop N is shown to have two sources, soil N and fixed N, and the bulk of N accretion occurs after flowering. In (b), rates of N2 fixation are shown to peak at 4 kg/ha N per day during mid-podfill, then decline as the crop matures.*

Source: D Herridge 2013

Benefits of nitrogen fixation

Crop legumes are usually grown in rotation with cereals, and the benefits to the system are measured in terms of increased soil-total and plant-available (nitrate) N, and grain N, and yield of the subsequent cereal crop, all relative to a cereal–cereal sequence.

The N available to the cereal is a combination of the N mineralised as part of the decomposition of legume residues and soil humus, and from applied fertiliser N. A fourth source of N is the mineral N not used by the legume during its growth, but spared. The residue N that is not released as mineral N remains in the soil as organic matter (Figure 3).

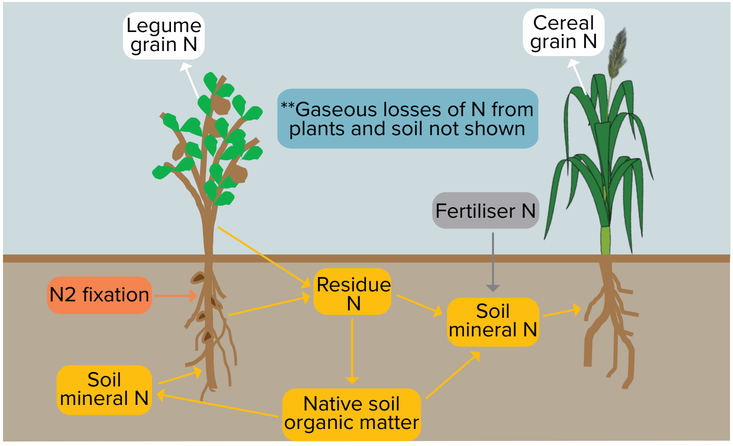

Figure 2: *Nitrogen cycling through a grain legume to the following cereal crop. Gaseous losses of N are not shown, nor are potential leaching losses. All of the flows of N are facilitated by the action of the soil biota.*

Source: D Herridge 2013

MORE INFORMATION

[GRDC (2014) Nitrogen fixation of crop legumes: basic principles and practical management. Fact sheet.]

Researchers believe that in lupin-growing areas of WA, N fixed by lupins supplies the plants own requirements in addition to enough N for a 1.0t/ha cereal crop.

Cereals grown after crop legumes commonly yield 0.5–1.5 t/ha grain more than cereals grown after cereals that had not had fertiliser N applied. To generate equivalent yields in the cereal–cereal sequence, research has also shown that 40–100 kg/ha fertiliser N needs to be applied. [18]

18 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course Module 4–General Agronomy.

Weed control

Key messages

- Competition from weeds reduces grain yield and quality, and costs Australian agriculture more than $2.5 billion a year.
- Good management of crop rotations can substantially reduce the cost of controlling weeds with chemicals.
- Timely cultivation is a valuable method for killing weeds and preparing seedbeds.
- Herbicide resistance is one of the biggest agronomic threats to the sustainability of our cropping systems.
- Choose paddocks that are relatively free, or carry a low burden, of grass and broadleaf weeds.
- Substantially reduce the weed seedbank in the soil before the crop emerges, as there are limited weed-control options post-emergence.

Weed control is important, because weeds can:

- rob the soil of valuable stored moisture
- rob the soil of nutrients
- cause problems at sowing time, restricting access for planting rigs (especially vine-type weeds such as melons, tarvine or bindweed, which wrap around tines)
- cause problems at harvest
- increase moisture levels of the grain sample (green weeds)
- contaminate the sample
- prevent some crops being grown where in-crop herbicide options are limited, i.e. in broadleaf crops
- be toxic to stock
- carry disease
- host insects

MORE INFORMATION

R Bowman (2013) Harvest weed seed key to overcoming resistance, GRDC Media Centre. Includes video.

AHRI (2013) Harvest Weed Seed Control

GRDC (2010) Managing the weed seedbank. Fact sheet.

GRDC and CropLife Australia (2008) Herbicide resistance: mode of action groups.

6.1 Specific weed issues for faba beans

Problem weeds or issues in faba beans that require special attention or are difficult to fully control include:

- Faba beans are reasonably poor competitors against weeds initially, because of their slow germination, low plant populations and the extended period before ground is covered by the canopy closing.
- 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.
- Wild radish—there are no safe post-emergent treatments available.
- Crop-topping cannot always be conducted in a timely manner so as to be safe for the beans and at the optimum stage for preventing ryegrass seedset. Late germination of weeds (e.g. ryegrass, brome grass) can safely be prevented from setting seed by crop-topping in many earlier-maturing pulses.
- Snails
- Hoary cress, soursob, medics and tares. [1]

1 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

6.2 Integrated weed management

Good weed-control management is vital to successful and profitable crop production. Yield losses caused by weeds can vary enormously from almost negligible to a complete loss. Before sowing crops, thoroughly investigate which weed species are likely to germinate in a paddock and determine the availability of suitable herbicide options.

Weeds lower crop yields by competing for soil moisture, nutrients, space and light. They can also carry diseases and viruses that can infect crops. This competition reduces grain yield and quality, and can impede harvesting. Some weeds can restrict cropping options because herbicides for controlling them are sometimes limited.

Weed control is a numbers game, and growers should aim to reduce weed numbers and keep them low with an ongoing management program. A weed-management program should make the most of rotations and the opportunity to use selective herbicides from a different herbicide group in each crop in the rotation in order to reduce weed presence in the following crop. Care should be taken in planning a cropping rotation to avoid herbicide resistance, or in growing a crop that may become a 'weed' itself or lead to weeds that cannot be controlled with selective herbicides in the subsequent crop.

An IWM system that combines all available methods is the key to the successful control of weeds (Table 1). [2]

6.2.1 In-crop weed control

There are pre-emergent and early post-emergent herbicides available for grass-weed control in faba beans. However, with broadleaf weeds, post-emergent options are very limited. Weeds should be removed from crops early, and certainly no later than 6 weeks after sowing if yield losses are to be minimised. Yield responses will depend on weed species, weed and crop density and seasonal conditions. The stage of growth of the weed and of the crop are vital factors to consider when planning the use of post-emergent herbicides.

Read herbicide labels carefully for details on the best conditions for spraying.

Herbicide resistance

Herbicide resistance continues to develop and become more widespread. It is now one of the biggest agronomic threats to the sustainability of our cropping systems. However, this problem can be managed through good crop rotations, rotating herbicide groups, and by combining both chemical and non-chemical methods of weed control. [3]

2 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

3 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

MORE INFORMATION

Australian Glyphosate Sustainability Working Group.

Weed Smart.

GRDC. Integrated weed management. YouTube videos.

Download the GRDC Herbicide Injury app from your app store or visit http://uteguides.net.au/

Table 1: *Weed control options for integrated weed management.*

	Herbicidal	Non-herbicidal
Crop phase	• Crop-top in pulse/legume crops • Use knockdown herbicides, e.g. double-knock strategy, before sowing • Use selective herbicides before and/or after sowing, ensuring escapes do not set seed • Utilise moderate-resistance-risk herbicides • Delay sowing (as late as spring in some cases) with weeds controlled in the interim • Brown-manure crops	• Rotate crops • Rotate varieties • Grow a dense competitive crop • Cultivate • Green-manure crops • Delay sowing • Cut crops for hay or silage • Burn stubble or windrows • Collect weed seeds at harvest and remove or burn • Destroy weed seeds harvested (use Harrington seed destructor)
Pasture phase	• Use spray topping • Use winter cleaning • Use selective herbicides, ensuring escapes do not set seed	• Use good pasture competition • Make hay or silage • Cultivate fallow • Graze

6.3 Herbicide damage in pulse crops

The risk of crop damage from herbicide application should be balanced against the potential yield loss from weed competition. In heavy weed infestations, some herbicide crop damage can be tolerated, because removing competing weeds means that yields will compensate for crop damage.

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 the herbicide washes into the seed row. Incorporation by sowing (IBS) may be more appropriate in dry conditions; or use a split application to minimise risk. Post-sowing pre-emergent (PSPE) herbicides should be applied to moist soil regardless of the sowing time.

Herbicides move more readily in soils with low organic matter, and with more sand, silt or gravel. Herbicide movement is much less in soils with higher organic matter and higher clay contents. Damage from leaching is also greater where herbicides are applied to dry, cloddy soils than to soils that have been rolled and are moist on top from recent rain.

The relative leaching potentials presented in Table 2 show that metribuzin leaches at almost three times the rate of simazine, and seven times the rate of diuron.

Table 2: *Relative leaching of some soil-active herbicides.*

Chemical	Example of product	Leaching index
Pendimethalin	Stomp®	1
Trifluralin	Treflan®	1
Diuron	Diuron 900DF	2
Prometryn	Prometryn 900DF	3–4
Simazine	Simazine 900 WDG	5
Metolachlor	Dual®	6
Metribuzin	Sencor®	14

1 is the least leaching

The relative tolerance of the crop type and variety will also affect the degree of crop damage from these herbicides. For example, lupins are more tolerant of simazine than are the other pulses. For more specific details on soil-active herbicides and the risk of crop damage in the cropping situation, seek advice from an experienced agronomist. [4]

Some soil-active herbicides (e.g. Terbyne® or simazine) can damage faba beans where wetter conditions favour greater activity and leaching.

Traces of sulfonylurea herbicides (such as chlorsulfuron, metsulfuron or triasulfuron) and carfentrazone (Affinity Force®) in spray equipment can cause severe damage to faba beans. [5]

6.3.1 Spray drift

When applying pesticides, the aim is to maximise the amount reaching the target and to minimise the amount reaching off-target areas. This results in:

- maximum pesticide effectiveness
- reduced damage and/or contamination of off-target crops and areas

In areas where various agricultural enterprises co-exist, conflicts can arise, particularly from the use of pesticides.

Pulse crops can be severely damaged by some hormone herbicide sprays, such as 2,4-D ester, drifting into the crop. This can happen when these sprays are applied nearby in very windy or still conditions, especially where there is an inversion layer of air on a cool morning.

When using these herbicides, spray when there is some wind to mix the spray with the crop. Do not use excessively high spray pressure, as this will produce very fine droplets that are more likely to drift onto a neighbouring pulse crop.

All pesticides are capable of drift. There is a moral and legal responsibility to prevent pesticides from drifting and contaminating or damaging neighbours' crops and sensitive areas (Photo 1). [6]

4 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

5 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

6 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

Photo 1: *Glyphosate spray drift from the road verge on the left. Note the barrier effect of the tall weeds on the fence line.*

Photo: G. Bardell, Nufarm

Damage to faba beans from various herbicides is depicted in Photos 2–13.

Photo 2: *Crops grown on lighter soils are more prone to damage from simazine (Group C).*

Photo: A. Mayfield, Grain Legume Handbook, 2008

MORE INFORMATION

Pulse Australia (2015) Residual herbicides and weed control.

GRDC (2002) Field crop herbicide injury: The Ute Guide

Photo 3: *High rates of simazine can damage faba beans, causing the lower leaves turn black and die back from the edge.*

Photo: A. Mayfield, Grain Legume Handbook, 2008

Photo 4: *Faba beans are susceptible to Tordon® or Lontrel® residue in soil. Note the stem distortion and severe leaf curl.*

Photo: A. Mayfield, Grain Legume Handbook, 2008

Photo 5: *Trifluralin (Group D) injury causing stunted growth (left). This herbicide can also cause multiple growing points to develop.*

Photo: C. Preston, University of Adelaide

Photo 6: *Damage (left) from Dual Gold® (metachlor, Group K).*

Photo: C. Preston, University of Adelaide

Photo 7: *Chemical leaf spotting from oils in a Group A herbicide applied after emergence. Note that spots are numerous, small, irregular in shape, and differ on top and bottom sides of leaf. It can be confused with chocolate spot and Aschocyta blight.*

Photo: R. Kimber, SARDI

Photo 8: *Leaf spotting caused by an MCPB herbicide (Group I) can be confused with Ascochyta and chocolate spot infections in beans.*

Photo: A. Mayfield, Grain Legume Handbook, 2008

Photo 9: *Symptoms of Brodal® (diflufenican, Group F) damage: white–pale yellow leaves with yellow blotches.*

Photo: A. Mayfield, Grain Legume Handbook, 2008

Photo 10: *Spray drift from 2,4-D (Group I) caused narrow leaves with crinkled edges.*

Photo: A. Mayfield, Grain Legume Handbook, 2008

Photo 11: *Damage from drift of Lontrel® (Group I).*

Photo: T. Bray, formerly Pulse Australia

Photo 12: *Leaf spotting from spray droplets of Affinity® (carfentrazone, Group G).*

Photo: C. Preston, University of Adelaide

Photo 13: *Leaf spotting from spray droplets of paraquat (Group L).*

Photo: C Preston, University of Adelaide

6.3.2 Tolerance of faba bean varieties to herbicides

Faba bean varieties do differ in their herbicide tolerance, depending on season, soil type and rate of application.

PBA Rana⁽ᵇ⁾ performs similarly to current varieties of faba beans at label-recommended rates of registered herbicides. This is based on visual observations from National Variety Trials (NVT) and Pulse Breeding Australia (PBA) breeding trials conducted on a range of soil types.

Herbicide-tolerance trials in South Australia (on alkaline sandy loams) showed Nura(D exhibited greater sensitivity to imazethapyr (e.g. Spinnaker®). However, all varieties exhibit some yield loss to imazethapyr (Table 3).

Raptor® (imazamox) has a narrow safety margin in all faba bean varieties. It can be applied only under APVMA permit No. 14726. Field experience shows damage is more severe under moisture stress and conditions of slow growth. It should be considered a salvage option rather than a routine application.

Diuron has been safe in Farah(D and Nura(D over seven or eight trials, and is registered for use in faba beans, IBS or PSPE. [7]

Table 3: *Herbicide effect on yields of varieties, from variety trials.*

Variety	Years	Diuron® (diuron)	Simazine		(metribuzin)	Spinnaker® (imazathapyr)	Raptor®A (imazamox)	Terbyne® (terbuthylazine)
		2000–10	2000–10	2001–08	2003–10	2000–10	2003–10	2009–10
Farah(D	2002–08	Safe (7)	Narrow (1/7)	6–18% (3/7)	Safe (6)	28–39% (2/3)	Narrow (3/6)	–
Fiesta	2000–07	Narrow (1/8)	18% (1/8)	21% (1/7)	S (5)	11–32% (2/8)	Narrow (4/5)	–
Fiord(D	2000–02	Narrow (1/3)	Narrow (2/3)	Narrow (1/2)	–	18–30% (2/3)	–	–
Nura(D	2003–10	Safe (8)	Narrow (1/8)	Narrow (1/6)	Safe (8)	10–53% (4/8)	Narrow (8/8)	Safe (2)
Rate		1.0 L/ha	1.5 L/ha	1.5 L/ha	280 g/ha	85 g/ha	45 g/ha	1.0 kg/ha
Application		PSPE	PSPE	6 weeks	PSPE	PSPE	3–4 leaf	PSPE

Safe: no significant yield reductions at recommended rates or higher in 2+ trials (no. of trials in parentheses).

Narrow: narrow margin, significant yield reductions at higher than recommended rate in 1+ trials (X of Y trials in parentheses), but not at recommended rate.

X%: percentage yield reduction (warning), significant yield reduction at recommended rate in 1 trial only.

X–Y%: percentage range yield reductions (warning), significant yield reductions at recommended rate in 2+ trials.

A Denotes use under APVMA permit. This use is not endorsed by this data and no responsibility will be taken for its interpretation.

MORE INFORMATION

NSWDPI. Broadleaf weed trial in faba beans.

Pulse Australia variety management packages (VMPs).

National Variety Trials.

6.3.3 APVMA

The national body in charge of administering these processes is the Australian Pesticides and Veterinary Medicines Authority (APVMA), and it is based in Canberra.

Details of product registrations and permits are available via the APVMA's website.

6.3.4 Always read the label

Apart from questions about the legality of such an action, the use of products for purposes or in manners not on the label involves potential risks. These risks include reduced efficacy, exceeded MRLs and litigation.

Be aware that herbicide-use guidelines on the label are there to protect product quality and Australian trade by keeping residues below specified MRLs. Residue limits in any crop are at risk of being exceeded or breached where herbicides:

- are applied at rates higher than the maximum specified;
- are applied more frequently than the maximum number of times specified per crop;
- are applied within the specified withholding period (i.e. within the shortest time before harvest that a product can be applied); or
- are not registered for the crop in question [8]

7 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

8 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

FAQ

6.4 Weed management planning

Faba beans can be relatively slow to emerge but have rapid early growth even during the colder winter months. Consequently, they are initially poor competitors with weeds. Even moderate weed infestations can cause large yield losses and harvest problems.

Faba beans are reasonable competitors against ryegrass and other weeds early on, but because faba beans are sown at a relatively low plant population, weeds can grow without necessarily inhibiting early development of the beans. If weeds are present in the crop later in the season, they can affect yield and become a nuisance by setting seed, often necessitating desiccation to enable harvest.

Yield loss caused by weeds has not been recorded in faba bean research trials. The impact of weed seed-set and carryover to subsequent years may be more significant than yield loss, especially where weeds such as ryegrass or late broadleaved weeds are present and not controlled.

Faba beans can mature too late in some extended seasons, so crop-topping may have to be delayed or done before physiological maturity, risking yield and quality losses.

The weed-control strategy for growing a successful faba bean crop depends on substantially reducing the viable weed seedbank in the soil before the crop emerges, because there are limited weed-control options post-emergence.

Selecting paddocks that are relatively free, or carry a low burden, of grass and broadleaf weeds is very important.

Broadleaf weeds need to be heavily targeted in the preceding crop and/or fallow and paddocks with a severe broadleaf or grass weed problem should be avoided.

Pre-emergent herbicide options

The absence of cost-effective and safe post-emergent herbicides effectively limits broadleaf weed control options in faba beans to a small number of pre-emergent herbicides. The efficacy of most of these chemicals is very dependent on rainfall soon after application; inconsistent or partial weed control can result under drier conditions. [9]

The pre-emergent herbicides will not adequately control large weed populations by themselves, and so they need to be used in conjunction with paddock selection, crop rotation and pre-seeding weed control. [10]

Outlook® (dimethenamid) has been registered to control herbicide-resistant ryegrass in some pulses. But it is *not registered* for use in faba beans because it is deemed too damaging.

Trifluralin (i.e. TriflurX®), pendimethalin (i.e. Stomp®), triallate (i.e. Avadex®), cyanazine (i.e. Bladex®), simazine, terbuthylazine (i.e. Terbyne®) and some diuron brands (e.g. Diurex ®) are registered for use on faba beans.

Trifluralin is used to control barley grass and for suppression of wild oats and brome grass. Pendimethalin is used for suppression of wild oats.

Stubble can tie up these two products. Best results have been achieved when stubble is at ≤50% ground cover, preferably left standing, and when higher water volumes (>80 L/ha) and coarse droplets are used.

Triallate provides control of wild oats and assists in the control of resistant ryegrass when used in a mixture. It can be applied immediately prior to or up 3 weeks before sowing. In a mixture, it does help to control ryegrass that has some resistance to trifluralin.

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9 GRDC (2015) Pre-emergent herbicides. Fact sheet, https://grdc.com.au/GRDC-FS-PreEmergentHerbicide

10 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

MORE INFORMATION

GRDC (2015) Pre-emergent herbicides. Fact sheet.

Specific guidelines for Group A herbicides. CropLife Australia.

Cyanazine may be applied from 14 days before sowing to the time of sowing and is often recommended in combination with trifluralin or pendimethalin.

Simazine is often mixed with trifluralin or other products to provide a broader spectrum of control of both broadleaf and grass-weed, including annual ryegrass, capeweed, fumitory, mustards, and geranium and suppression of wild oats.

Typically, a follow-up, post-emergent grass-weed herbicide is still required to provide the level of grass-weed control. [11]

Simazine

Simazine is the most widely used herbicide for broadleaf weed control, and can provide relatively cheap control of cruciferous weeds. Efficacy is highly dependent on receiving 20–30 mm rainfall within two to three weeks of application, and consequently weed-control efficacy varies under drier conditions.

Simazine has an adequate level of crop safety provided the following guidelines are adhered to.

- Simazine needs to be applied to moist soil as close to planting as possible.
- Weed control will be more reliable if the seedbed is level and free of clods. When clods break down after rainfall they expose untreated soil and disrupt the herbicide 'blanket'. Heavily ridged seedbeds often exhibit 'striping' and poor weed control on the 'hills'.
- Stubble does not present major problems, other than in heavy header trails or when it becomes heavily 'bunched' from tillage operations.
- Avoid shallow planting if simazine is to be used, because crop tolerance is based on the physical separation of the chemical from the faba bean roots. A planting depth of 7 cm is normally adequate on clay soils.
- Crop damage is often evident in compacted wheel tracks as a result of shallower planting depth and/or the concentration of chemically treated soil in the wheel-track depressions after rain.
- The planting furrow or trench needs to be closed and levelled at planting to reduce damage to plants. This will minimise the risk of simazine-treated soil being washed in and concentrated near the seedling.
- Good subsoil moisture at planting will also help to minimise the risk of crop damage. Roots will grow down into moisture, rather than developing into a shallow root system in the topsoil, where simazine activity is greatest.
- If grass weeds are present at application, consider tank-mixing glyphosate or Spray.Seed® with simazine.
- Avoid using simazine on coarse-textured, sandy loam soils; even low rates can leach down to the roots and cause significant crop damage.
- When applying simazine, avoid overlapping and double spraying on headlands. [12]

6.4.1 Post-emergent herbicides

Only one broadleaf herbicide, imazamox (e.g. Raptor® WG), is currently registered for post-emergence use, and only to a very limited extent. It can be used after emergence for broadleaf weed control, but can cause transient yellowing, height reduction and delayed flowering, any of which can reduce yield. (These effects are stated on the product label.) It is effective on cruciferous and many other weeds, e.g. barley grass.

Imazamox can result in significant crop damage in our environment, particularly with dry conditions after application.

11 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

12 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

It is used mainly in salvage situations (i.e. as a last resort), and even then should be applied only under good growing conditions.

With the shift into row-crop faba beans, some growers are successfully using glyphosate and other products as a directed spray into the inter-row area. This keeps a large proportion of the herbicide off the faba bean foliage, and minimises problems associated with crop damage.

Control of grass weeds after emergence is often inconsistent, with variable levels of control gained depending on the rate used and the level of resistance to the fop or dim herbicide being used.

Group A herbicides can occasionally cause leaf spotting in faba beans. This is usually associated with either frost or high temperatures occurring soon after spray application. It is not the Group A itself but the oil it is mixed with that causes the damage. The oil acts as a magnifying glass on the leaf and burns the leaf surface (Photo 14).

Photo 14: *Herbicide-mix injury from a Group A grass selective herbicide.*

Photo: R. Kimber, SARDI

Traces of sulfonylurea herbicides in boom sprays can cause significant damage to faba bean crops. The risk of residue damage is greater in the presence of grass-selective herbicides.

See product labels for specific recommendations on decontamination. [13]

6.5 Other weed-control strategies

Directed sprays in the crop

With the shift to cropping faba beans on wide rows, there is greater scope for the use of 'directed sprays' of glyphosate and other chemicals, either alone or in tank mixes with simazine. This 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.

Growers in cotton growing areas of Australia are having good results using glyphosate in shielded sprayers. Although faba beans do have a degree of tolerance

13 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management.

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 bean yield. Issues that need to be considered include:

- the selection and operation of spray shields (speed, nozzle type, etc.)
- the height of the crop (small faba bean plants are more susceptible)

Crop-topping and desiccation

With correct timing, desiccation can improve overall weed control as well as increase profitability in pulse crops.

The major differences between crop-topping and desiccation are:

- Herbicides used for crop-topping and desiccation are not always the same.
- Timing is not the same: desiccation occurs after crop maturity, while crop-topping is done earlier, to reduce the seedset of weeds before the crop matures.
- Herbicides are registered for desiccation as 'harvest aids', and the rates used are higher than those used for crop-topping.
- Both desiccation and crop-topping will cause reduced grain quality and yield if applied at the wrong maturity stage of the crop.

For more information, see Section 11 Crop desiccation.

MORE INFORMATION

For assistance with pest identification, visit My Crop at https://www.agric.wa.gov.au/mycrop

Insect control

Key messages

- The main insect pest of faba beans in WA, the native budworm, appears late in the season.
- Control thresholds should be followed when considering management options.

The main insect pest of faba beans in Western Australia is the larvae of native budworm (*Helicoverpa punctigera*) which occurs late in the season and can cause yield loss and damage to grain quality (Photo 1). [1]

Photo 1: *Helicoverpa sp. larva damaging a maturing pod.*

Photo: M. Miles, DAF Qld

7.1 Insect control thresholds

The following factors should be monitored and considered when using thresholds and making decisions about spraying:

- Environmental conditions and the health of the crop.
- Extent and severity of the infestation and how quickly the population increases.

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

- Prevalence of natural control agents such as parasitic wasps, predatory shield bugs and ladybirds.
- Type and location of pest damage, and whether it will affect yield indirectly or directly.
- Stage in the life cycle of the pest and the potential for damage.
- Crop stage and ability of the crop to compensate for damage.
- Amount of damage which has already occurred and the additional damage that will occur if the crop is not sprayed.
- Value of the crop compared to the cost of the spraying and the likely yield or quality benefit gained from control. (High-value crops cannot sustain too much damage as a small loss in yield or quality can mean a large financial loss.) [2]

The impact of insects can be far greater on grain quality in pulses than on yield damage. This must be accounted for when calculating thresholds because in pulses visual quality has a large impact on price.

Faba beans are susceptible to attack from establishment pests such as redlegged earth mites, lucerne fleas, cutworms, and aphids; however their large leaves and early plant vigour make faba beans less susceptible than some other pulses.

While snail populations do not build up as readily under faba beans as they do under field peas, they can still be a problem. Snails climb onto standing faba bean plants, and even onto standing cereal stubble in a stubble-retention system. They can enter the grain sample at harvest with or without having climbed onto the faba bean plant. [3]

7.2 *Helicoverpa* species

7.2.1 Native budworm

Native budworm (*Helicoverpa punctigera*) is widely distributed throughout mainland Australia and during winter breeds in semi-arid parts of WA.

Native budworm occurs mostly in southern Australia in September, October and early November.

To manage the *Helicoverpa* spp. effectively, it is important to be able to sample and identify the different larval instars. An instar is a stage in the growth of the larva, marked by the shedding of the exoskeleton. Proportions, colours and other features may change between instars. Familiarity with these different life stages is critical because knowledge about them is used to determine the likelihood of damage occurring, and to optimise timing of control.

7.2.2 Life cycle and development

Adult moths (Photo 2) are active at night, but during the day may be disturbed when sampling or walking through the crop. Moths vary in colour from grey-green to pale cream and have a wing span of 3–4.5 cm.

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

3 Pulse Australia (2016) Faba bean production: southern and western region, http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/southern-guide

Photo 2: *Native budworm moths, showing male (right) and female (left). Note the buff colouring.*

Photo: SARDI

The female moths lay round eggs (0.5 mm in diameter) singly on the host plant. The eggs are white but turn brown just before hatching (Photo 3). In the spring, eggs hatch within seven to 10 days (depending on temperature) and larvae feed for four to six weeks. The larvae can grow to 5 cm in length. [4]

Photo 3: *Left to right: fresh white eggs, brown ring and black larval head visible in the eggs close to hatching.*

Photo: DAF Qld

Larvae develop through five to six instars. Categorising larval size can be done in terms of instar, or more commonly, a size category (Figure 1): very small (1st instar), small (2nd instar), medium (3rd and 4th instars) and large (5th and 6th instars).

4 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

Actual larval size	Larval length (mm)	Size category
	1-3	very small
	4-7	small
	8-23	medium
	24-30+	large

Figure 1: *Size categories of larvae of Helicoverpa species.*

Once fully developed, larvae leave the plant and tunnel down to as much as 10 cm into the soil where they form a chamber in which they pupate (Figure 2).

Pupae will normally develop to produce a moth in two to three weeks. The moth emerges, feeds, mates and is then ready to begin the next cycle by laying eggs. As with all insect development, the duration of pupation is determined by temperature, taking around two weeks in summer and up to six weeks in spring and autumn.

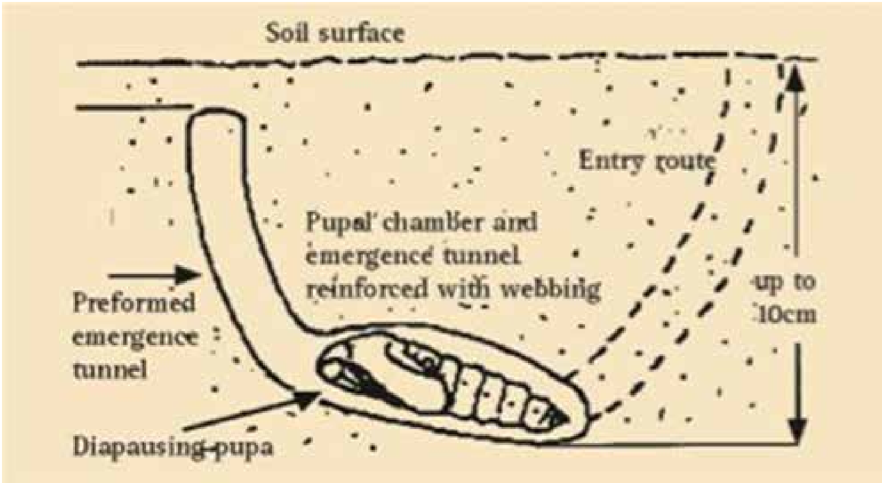

Figure 2: *Helicoverpa pupa in pupal channel, with the entry and exit tunnels that are excavated before the larva pupates.*

Source: DPIF 2005

Ninety per cent of all feeding (and therefore damage) by *Helicoverpa* spp. is done by larvae from the third instar (small–medium larvae that are 8–13 mm long) onwards. Large *Helicoverpa* larvae (>24 mm) are the most damaging, since larvae consume about 80% of their overall diet in the fifth and sixth instars. This highlights the importance of controlling the larvae while they are still very small to small (<7 mm).

Full-grown, sixth instar larvae are up to 40 mm long with considerable variation in markings and colours, and which range through green, yellowy-pink and reddish brown to almost black (Photo 4). [5]

5 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

Photo 4: *Helicoverpa larvae occur in a range of colours.*

7.2.3 Budworm management

The following management strategy is recommended for effective budworm control in faba beans.

1. Start sampling for budworm spp. when the crop starts flowering. Be aware of the limitations of both the beat sheet and sweep net in detecting low densities and smaller larvae.
2. Use a visual sample to detect small larvae in the terminal leaves, buds and flowers before they reach medium size.
3. Aim to treat the crop before larvae reach medium size and become capable of damaging pods.
4. Consider including a low rate of nucleopolyhedrovirus (NPV), a naturally occurring virus where available.

Photo 5: *Helicoverpa larva killed by NPV*

Photo: M. Miles, DAF Qld

Sampling

Egg counts are an unreliable indicator of Native budworm larval densities, and therefore of potential crop damage. Eggs are difficult to find and count, and egg survival through to larvae is generally very low because eggs fall off plants in the wind or rain, or are eaten by predators. Therefore, counting eggs is not recommended.

Similarly, counting very small larvae is not recommended, as it does not give reliable information, either. Larvae < 3 mm are difficult to find in the crop; and mortality in other crops is known to be high. Given the high level of beneficial insect activity in faba beans, we can assume that many eggs and very small larvae will be eaten by predators (such as predatory bugs, ladybeetles, red and blue beetles, and lacewings).

Visible egg lays and moth activity in the crop indicate Helicoverpa spp. pressure on the crop, and are signs that they need to be monitored for in coming days and weeks.

Exactly which larval stages have the capacity to cause damage in faba beans has not been researched. At this point it is assumed Native budworm behave similarly in faba beans to how it behaves in other pulses.

It is typically the medium–large larvae (≥8 mm) that cause the most loss in pulses. This is why it is important to implement control, if required, before larvae reach this stage.

The natural mortality of larger larvae is lower than for earlier stages, although there are a number of natural enemies (e.g. parasitoids, predatory bugs) that will attack medium–large larvae.

Damage

Budworm larvae feed on leaves, buds and flowers, and on the developing grain in pods. It is not known if they have a preference, but preliminary examination of their distribution on faba bean plants during flowering and podding has shown few larvae on leaves compared with the number on the reproductive structures (Photo 7).

Whilst the poor rate of conversion of flowers to pods in faba beans is acknowledged, there seems to be a general acceptance that the plant produces an excess of flowers and that protecting these is not necessary. Observations during trial work by DAF Queensland has shown that damage to flowers can be significant enough to result in non-viable flowers. The larvae feed directly on the pollen sacs or on the ovary of the flower (Photo 6).

Photo 6: *Budworm caterpillar damage to flowers: to the pollen sacs (left) and the ovary (right).*

Photos: M. Miles, DAF Qld

Budworm caterpillars are very damaging to faba bean pods, making many more exploratory holes and partially consuming more grain than in other pulses.

The holes make the pods vulnerable to infection by fungi and bacteria, which may in turn increase the likelihood of weathered and discoloured grain (Photo 7).

Photo 7: *Helicoverpa damage to faba bean pods. Multiple entry points in a pod and partially consumed grain are typical.*

Photos: M. Miles, DAF Qld

Table 1: *Economic thresholds (ET) for native budworm on faba beans*

Crop	P Grain price per tonne	C Control costs including chemical + application	K Loss for each grub in 10 sweeps (kg/ha/grub)	ET Grubs in 10 sweeps	ET Grubs in 5 lots of 10 sweeps	ET Grubs (>15mm) per m2
Faba bean	280	10	90	0.4	2	-

Note: Growers using this table to calculate spray thresholds should substitute their own control costs and the current on-farm grain price expected.

Where:

ET = Economic threshold (numbers of grubs in 10 sweeps)
C = Control cost (includes price of chemical + application) ($ per ha)
K = Kilogram per hectare (ha) eaten for every one caterpillar netted in 10 sweeps or per square metre
P = Price of grain per kg (price per tonne ÷ 1000)

Source: DAFWA

MORE INFORMATION

DAFWA Management and economic thresholds for native budworm

Yield and quality thresholds

Considerations when making control decisions based on budworm larval densities are:

- environmental conditions and the health of the crop
- how quickly the crop is finishing, and how long it will be susceptible to damage
- how likely wet weather is—it may exacerbate the *Helicoverpa* damage through weathering
- the prevalence of natural control agents such as parasitic wasps, predatory shield bugs, ladybirds and diseases

- the type and location of pest damage, and whether it affects yield indirectly or directly
- the stage in the life cycle of the pest, and therefore its potential to cause damage
- the crop stage and its ability to compensate for damage
- the value of the crop—high-value crops cannot sustain too much damage as a small loss in yield or quality could mean a large financial loss—versus the cost of the spraying and the likely yield or quality benefit gained from control [6]

Losses attributed to native budworm come from direct weight loss through seeds being wholly or partly eaten.

Grain quality may also be downgraded through unacceptable levels of chewed grain or fungal infections introduced via caterpillar entry into pods, especially in faba bean and albus lupin pods.

The percentage of broken, chewed and defective seed found in grain samples affects the final price of pulse crops marketed for human consumption. This applies particularly to the large-seeded crops such as faba bean, kabuli chickpea and field pea. [7]

Control

Within the range of options available for pest control in faba beans, there is considerable variability in the impact they will have on beneficial insects (predators, parasitoids, bees) in the crop. It is worth being familiar with the relative impact of the softer, moderate and highly disruptive options.

Always read the label

Apart from questions about the legality of such an action, the use of products for purposes or in manners not on the label involves risks. These risks include reduced efficacy, exceeded MRLs and litigation.

Be aware that pesticide-use guidelines on the label are there to protect product quality and Australian trade by keeping pesticide residues below specified MRLs. Residue limits in any crop are at risk of being exceeded or breached where pesticides:

- are applied at rates higher than the maximum specified
- are applied more frequently than the maximum number of times specified per crop
- are applied within the specified withholding period (i.e. within the shortest time before harvest that a product can be applied)
- are not registered for the crop in question

7.3 Aphids

Identification

Although several aphid species may infest faba beans, the cowpea aphid (*Aphis craccivora*) is the most commonly observed because it forms clearly visible dark colonies (Figure 3).

Characteristics of adult aphids:

- The pea aphid is up to 4 mm long, and may be yellow, green, or pink in colour. They have black knees and dark joints on their antennal segments. These aphids feed primarily on field pea, faba bean, and lucerne.
- The green peach aphid (GPA) tends to be shiny or waxy, and ranges from yellow, through to green and pink. They can be similar in colour to young unfurled field

6 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

7 DAFWA (2017) Costs of native budworm https://www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm?page=0%2C1

pea leaves. GPA has a wide host range including canola, lupins and other pulse crops, and can also be found on weeds including wild radish, doublegee and blackberry nightshade.

- The bluegreen aphid (BGA) is up to 3 mm long, and matt bluish-green. Large numbers of winged BGA fly from pastures to crops later in the growing season.
- The cowpea aphid (CPA) has a black body and black and white legs. It often colonises lupin and faba bean plants. [8]

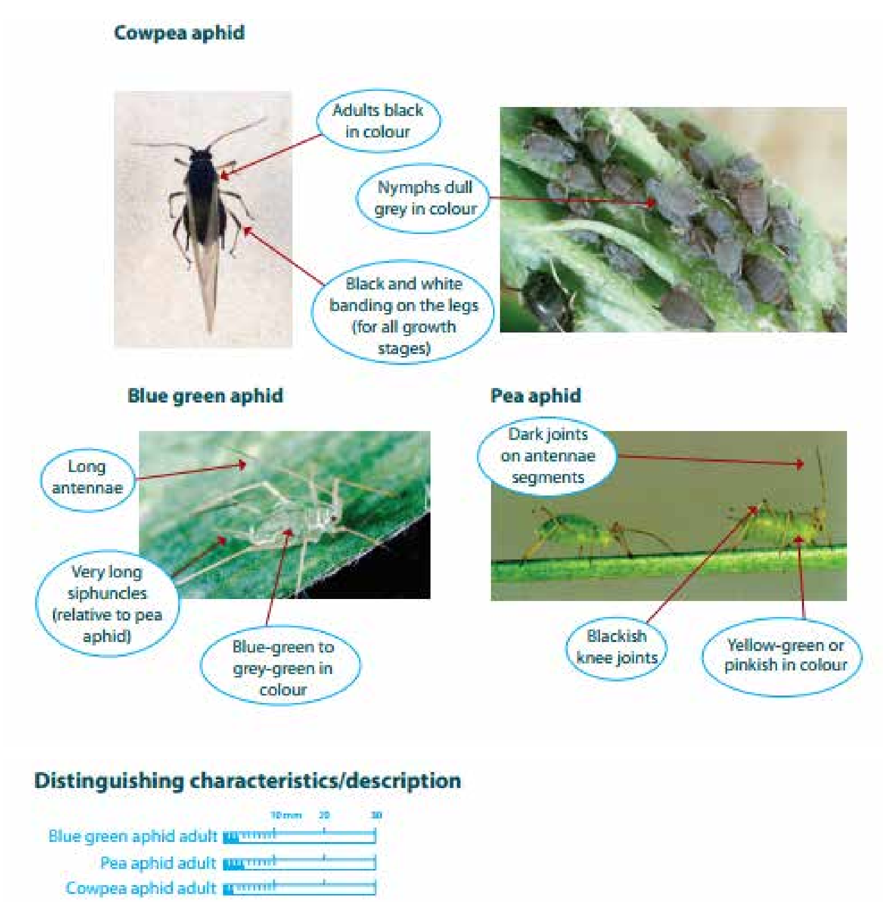

Figure 3: *Characteristics of the blue-green, pea and cowpea aphids.*

Cowpea aphid *(Aphis craccivora)* is the only black-coloured aphid. The nymphs of brown smudge bugs and cowpea aphids superficially look alike, but the cowpea aphid is unlikely to be confused with other aphids of pulses, as it is the only black aphid (Photo 8). Adults are small (up to 2.5 mm long) and are shiny black, whereas the nymphs are slate grey.

The cowpea aphid is the major Bean leafroll virus (BLRV) vector, as well as the most efficient Subterranean clover stunt virus (SCSV) vector and a vector of Cucumber mosaic virus (CMV).

MORE INFORMATION

GRDC (2015) Crop Aphids Back Pocket Guide.

GRDC (2015) Resistance Management Strategy for the Green Peach Aphid in Australia Grains. Fact Sheet.

J Bellati, P Mangano, P Umina and K Henry (2012) I Spy: Insects of Southern Australian Broadacre Farming Systems Identification Manual and Education Resource. PIRSA, DAFWA and Cesar.

8 DAFWA (2015) Diagnosing aphid damage in field peas Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-aphid-damage-field-peas

Photo 8: *Cowpea aphid (Aphis craccivora). Note the different aphid ages—young to old. The older aphids are shiny black. All life stages have black-and-white-banded legs. The white cast is a skin, which is shed as the aphid grows.*

Photo: Grain Legume Handbook, 2008

Adult life cycle

In Australia, most pest aphid species produce only females, which may be winged (alates) or wingless (apterae), and give birth to live young.

Spring often triggers a rapid increase in aphid numbers as increasing temperatures and flowering crops provide favourable breeding conditions. Most aphids form dense colonies before winged aphids are produced. These move onto surrounding plants further into the crop, creating hot spots. Rain, and the activity of natural enemies can impact significantly on aphid survival and population growth.

Many aphids are plant host-specific, and require this host for survival. Aphid populations usually decline over summer, as most species are adapted to cooler environments because they were introduced from the northern hemisphere. The availability of suitable host plants (e.g. specific weed families on roadsides and verges) allows populations to survive and increase.

Winged aphids move into crops in autumn, and aphid numbers will usually start to build up along crop edges. Where mild autumn conditions persist, aphid populations can build quickly, but they generally decline as temperatures drop in winter. The formation of winged aphids and aphid movement generally increase when host plants are dying or when overcrowding occurs because of high populations.

In some seasons, aphids form large colonies and heavy infestations may produce large amounts of a sticky secretion known as honeydew. The reaction of faba bean leaves to honeydew and/or the fungi that grow on the honeydew can be seen when there are heavy aphid infestations (Photo 9).

Photo 9: *Spotting on lower leaves associated with dense aphid infestations and the production of honeydew and associated fungi.*

Photo: M. Miles, DAF Qld

Direct-feeding damage

Aphids damage plants by direct feeding, although they generally cause minimal damage unless they are in extremely high numbers. Direct-feeding damage is typically seen in hot spots, often along the margins of a paddock where the aphids have first colonised the crop. Cowpea aphids will colonise the plant terminal and gradually spread lower on the plant if densities are high (Photo 10).

Photo 10: *A moderate infestation of cowpea aphid in the terminal of a vegetative faba bean plant. Some distortion of the leaves is evident as a result.*

Photo: M. Miles, DAF Qld

The impact of direct aphid feeding is not well understood, although in most instances the crop grows out of the symptoms. The main concern with aphids is their capacity to act as vectors that carry and transfer virus diseases during feeding or sucking.

Aphids as vectors of viruses

Two virus-disease symptoms are seen: virus mosaic (dark and light green areas on leaves), usually accompanied by leaf roughness or distortion; and virus yellowing, accompanied usually by leaf stiffness or rolling, stunting, and root blackening.

Two of the major viruses are BLRV and BYMV. Both survive summer on green legume plants (such as lucerne), and can infect plants only through aphid vectors. Chemical control may prevent infection with BLRV, as the aphid needs a relatively long period to feed on the plant and transmit the virus. Chemical control will not have any effect on the rapidly transmitted BYMV. There are no current guidelines for the application of aphicides on faba beans to control virus. Early sowing, while maximising yield, will increase the exposure of crops to aphid flights, potentially resulting in more virus infection.

Cultural controls are the first options to be implemented. These include:

- Sow even plant stands into standing stubble.
- Control weeds that host aphids, including around the perimeter of the crop and in neighbouring paddocks. Keep in mind that aphids may migrate long distances into crops, and local weed control may not always prevent aphid infestation. However, local weed control will contribute to minimising the persistence of virus reservoirs.
- Avoid sowing faba beans in paddocks adjacent to legume pastures.
- Avoid practices that lead to crop stress (e.g. late sowing into cold soils, excessive herbicide application, poor nutrition) that reduce crop vigour.

- Block faba bean paddocks together and limit aphid entry points into paddocks.

How aphids transmit viruses

Persistent transmission

Persistent transmission means that when an insect vector feeds on an infected plant, the virus has to pass through the body of its vector and lodge in its salivary glands before it can be transmitted to a healthy plant, a process that takes >1 day (Figure 4). Once the insect is infectious, it remains so for the rest of its life.

Very few aphid species are vectors of this kind of virus in pulses. These species of aphids tend to colonise their hosts. The pea aphids and green peach aphids are important as vectors of luteoviruses in pulses. Because acquisition of the virus is slow, insecticides that kill aphids work well (except in the case of insecticide-resistant green peach aphid) in suppressing the spread of these viruses (Figure 5), which include:

- BLRV
- BWYV
- SCRLV
- SCSV

Non-persistent transmission

Non-persistent transmission means that the insect vector can land on a virus-infected plant, make a brief probe, acquire the virus on its mouthparts within seconds, and then transmit it immediately when probing on a healthy plant (Figure 5). The aphid loses the virus after it probes a healthy plant once or twice. After this, the insect does not infect further plants. The whole process is so fast that insecticides do not act quickly enough to prevent transmission, and can exacerbate the situation by making the aphids hyperactive, so that they flit between more plants than usual.

Many aphid species are vectors of this type of virus; they include ones such as oat and turnip aphids that do not colonise legumes but just land and probe pulse crops while searching for their preferred hosts. Such viruses include:

- AMV
- BYMV
- CMV
- PSbMV [9]

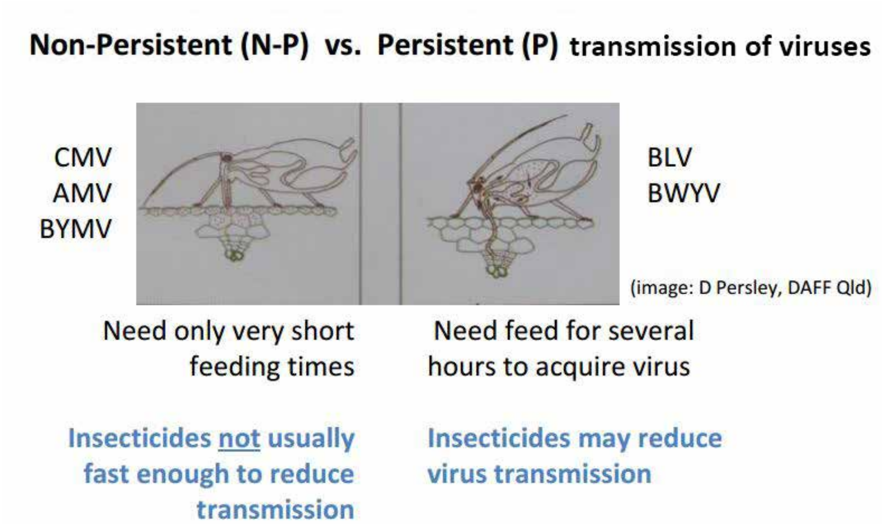

Figure 4: *Persistent v. non-persistent transmission of viruses.*

9 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

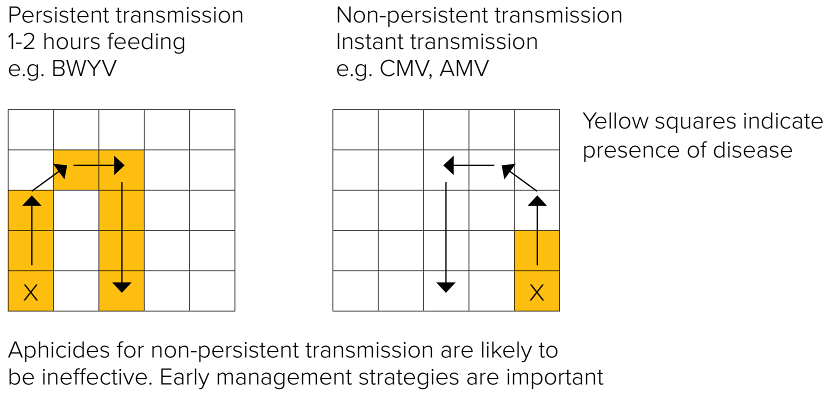

Figure 5: *Differences in the progression of infection within a field of persistent and non-persistent viruses transmitted by aphids.*

Source: Bellati et al. 2012

7.4 Other insect pests

7.4.1 Cutworms

The common name cutworm is derived from the larval habit of severing the stems of young seedlings at or near ground level, causing the collapse of the plant.

Identification

Larvae are up to 50 mm long, hairless, with dark heads and usually darkish coloured bodies, often with longitudinal lines and/or dark spots. If picked up larvae curl into a C-shape and remain still. Moths are a dull brown-black colour (Photo 11). Cutworms may be confused with armyworms and *Helicoverpa* larvae.

Damage

Cutworm larvae can sever stems of young seedlings at or near ground level, thereby causing collapse of the plant (Photo 12). Sometimes the young plant is partially dragged into the soil where the larvae feed on it. Larvae may also climb plants and browse on or cut off leaves. Crop areas attacked by cutworms tend to be patchy, and the destruction of seedlings in one area may cause cutworms to migrate to adjacent fields. The risk period is summer and spring, and there is one generation per crop.

Monitoring and thresholds

Inspect emerging seedlings twice a week, and plants up to the budding stage once a week. Check 1 m of row at a number of locations. Check along the plant row, at the base of seedlings under the soil surface and stubble. The placement of a hessian bag on the soil surface may draw cutworms to the surface. Check for their presence in the morning. Treat seedlings when there is a rapidly increasing area or proportion of crop damage. Treat older plants if 90% of field checks reveal that cutworms are present, or if defoliation exceeds 75%.

Management

- Controlling weeds prior to planting will reduce the risk of cutworm infestations. Moths will lay on weeds, and large larvae move from the weeds to establishing crops when weeds are sprayed, cultivated or deteriorate with age.
- A late-afternoon spray, close to the time when feeding commences, gives the best results.
- Spot spraying of infested patches may suffice.
- Cutworms are killed by a number of natural enemies such as parasitoids, predators and diseases, and it may be possible to capitalise on these.

Photo 11: *Bogong moth.*

Photo: L. Gibson and K. Walker, Museum Victoria

Photo 12: *Cutworm larvae, which will grow to about 40 mm in length before pupating.*

Photo: P. Room

7.4.2 Thrips

Several species of thrips will damage faba bean crops, but little is known of their economic impact. Leaf-feeding damage can occur in seedlings, because thrips cause distortion of the emerging and expanding leaves. Unless the thrip pressure is extreme, and the crop emergence compromised by limited moisture or cold, plants will grow out of the damage, which is therefore considered to be cosmetic rather than damaging.

MORE INFORMATION

DAFWA (2016) Diagnosing cutworm in canola and pulses.

More commonly, thrips are observed in flowers. They feed on the pollen in flowers and it is thought that they affect the development of small pods. However, the link between thrips and pod damage is not well established. Thrip numbers almost always exceed the nominal threshold of four to six per flower. [10]

Onion thrips (*Thrips tabaci*), plague thrips (*T. imaginis*), tomato thrips (*Frankliniella schultzei*, Photo 13) and western flower thrips (*Frankliniella occidentalis*) are all likely to be present in faba beans.

Thrips damage

Damaged leaves and older pods are marked with silvery-brown blotches. Unless excessive, e.g. on seedlings where growth has slowed because of cool, wet or dry conditions, plants will grow through this damage.

Monitoring and thresholds

Seedling thrip infestation can be monitored by gently pulling up seedlings to examine for the presence of thrips; a hand lens may be used. In budding and flowering plants, beat the growing points and flowers onto a surface to dislodge any thrips.

Photo 13: *Adult tomato thrips (Frankliniella schultzei).*

Photo: L. Wilson

7.4.3 Snails

Numbers of slugs and snails have increased in broadacre cropping in Western Australia with the use of minimum tillage and stubble retention. These systems increase the organic content of paddocks and the soil moisture content leading to higher survival levels of slugs and snails.

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

Slug and snail pests in Australia have come from other countries, mainly the Mediterranean region. They damage plant seeds (mainly legumes), recently germinated seeds, seedlings and leaves and can be a contaminant of grain at harvest. [11]

Even in a less susceptible crop like faba beans, snails climb onto standing plants and onto standing cereal stubble in a stubble-retention system. Therefore, they can enter the grain sample at harvest with or without having climbed onto the crop plant.

White snails

There are two species of white snail of interest to faba beans growers: the vineyard or common white snail (*Cernuella virgata*), and white Italian snail (*Theba pisana*) (Photos 14 and 15).

The species look similar: both have white, coiled shells up to 20 mm in diameter; the shells may have brown bands around the spiral. The common white snail has an open umbilicus, whereas that of the white Italian snail is partly closed. [12]

Photo 14: *Vineyard or common white snail.*

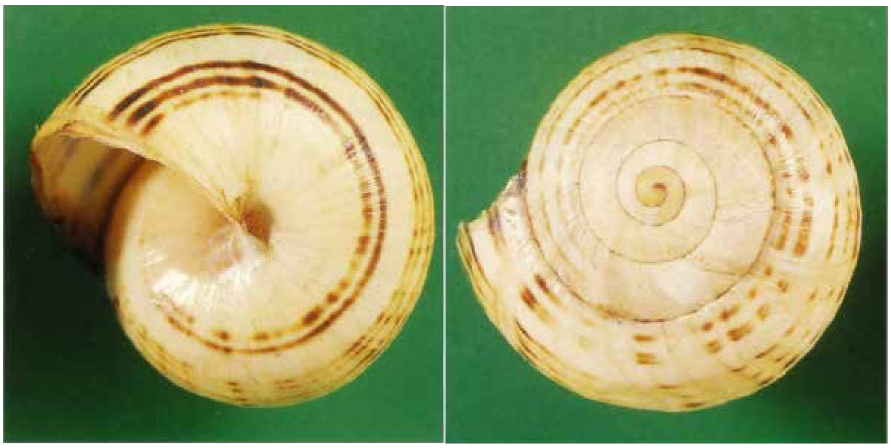

Photo 15: *White Italian snail.*

Photos: SARDI

MORE INFORMATION

DAFWA (2016) Identification and control of pest slugs and snails for broadacre crops in Western Australia.

DPIPWE (2010) Common white snail (*Cernuella virgata*). Fact sheet.

11 DAFWA (2017) Identification and control of pest slugs and snails for broadacre crops in Western Australia https://www.agric.wa.gov.au/grains/identification-and-control-pest-slugs-and-snails-broadacre-crops-western-australia

12 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

Pointed or conical snails

There are two pointed snails that cause damage in faba beans: the pointed snail (*Cochlicella acuta*) (Photo 16) and the small pointed snail, either *Cochlicella barbara* or *Prietocello barbara* (Photo 17). Both snails are fawn, grey or brown in colour.

Photo 16: *Pointed snail. The ratio of its shell length to its base diameter is always greater than two.*

Photo: SARDI

MORE INFORMATION

SARDI (2014) Small pointed snail. Pest notes.

Photo 17: *Small pointed snail. The ratio of its shell length to its base diameter is always two or less.*

Photo: SARDI

Damage

Damage caused by snails is mainly at crop establishment and at harvest. Both common white and white Italian snails may feed on young crops and damage substantial areas which then need re-sowing. In late spring, the snails climb plants, and are in the upper part of the crop when it is harvested, thereby contaminating the grain. Contaminated grain may be downgraded, or even rejected. In addition, live snails in grain pose a threat to exports.

Conical snails feed mostly on decaying plant material but can damage seedlings. The small pointed snail feeds on growing plants and can contaminate grain.

Life cycle

White snails are dormant in summer. They feed and grow through the winter and spring, and then climb fence posts and plant stems in late spring, where they go into summer dormancy. Snails live for 1–2 years, and move only short distances. They are spread in hay, grain, machinery and vehicles.

Pointed snails have a similar life cycle to the white snails. They may live under stones as well as up on posts and plants (whereas small conical snails live on the ground in the leaf litter).

Monitoring

Monitoring and baiting early, before egg laying, are critical for snail control.

To sample snail numbers, mark out a 32 cm x 32 cm quadrat on the ground and count all live snails within it. If round-shelled and conical-shelled snails are present, record the numbers of each type. To determine sizes, place the snails in a sieve box and shake gently to separate into two groups: larger and smaller than 7 mm. Round snails and small conical snails <7 mm are unlikely to be controlled by bait.

MORE INFORMATION

SARDI (2003) Bash 'em, burn 'em, bait 'em: Integrated snail management in crops and pastures. South Australian Research and Development Institute.

DAFWA (2014) Snails–economic considerations for management.

Control

Snail control starts in the summer, before sowing. The best control is achieved by stubble management on hot days or burning, followed by baiting in autumn before egg are laid. Rolling, harrowing or dragging a cable over stubble on hot days reduces snail numbers by knocking snails to the ground, where they die in the heat (when the air temperature is over 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. (Wind or water erosion becomes a risk when stubble is burnt.)

Bait in autumn when snails have commenced activity following rain. 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.

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.

Control measures for conical snails are the same as those used on white snails, but are generally less effective as these snails shelter in cracks in the ground or under stones.

Dragging harrows or a cable before burning it improves the control by exposing more snails to burning. [13]

7.4.4 Slugs

The main slug pests of faba beans are the reticulated slug (*Deroceras reticulatum*) and the black-keeled slug (*Milax gagates*). Usually grey in colour, the adult slugs range from about 2–4 cm long (Photo 18). Slug attacks on emerging crops can cause economic losses, even when slug numbers are relatively low. Slugs will eat all parts of a crop plant; however seedlings are the most vulnerable, and this is when economic losses can occur. [14]

Faba beans are probably one of the more slug-tolerant winter crops, and generally grow out of slug damage without any adverse impact.

The black-keeled slug has also been found in canola and wheat paddocks. This slug is uniform black to grey, and 4–5 cm long and is an issue in south-eastern WA.

Photo 18: *Top: Reticulated slug (Deroceras reticulatum). Bottom: black-keeled slug (Milax gagates).*

Photo: Peter Mangano, DAFWA

13 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

14 GRDC (2014) Slugging slugs. Media Centre. 5 June 2014. GRDC, https://grdc.com.au/Media-Centre/Hot-Topics/Slugging-slugs

Life cycle

Slugs are hermaphrodites (individuals are both male and female). Each individual can lay about 100 eggs.

Moisture is essential for slug survival, and some species may move into the soil to depths of 20 cm or more in dry periods and reappear when conditions improve. [15]

Photo 19: *Slug damage in a faba bean seedling. Beans tolerate slug damage better than many other crops do, particularly compared with lupins and canola.*

Photo: W. Hawthorne, Pulse Australia

Damage

Plants are eaten to ground level, or irregular patches or strips are chewed from the leaves. Leaves can look shredded (Photo 19). There can be poor legume emergence from slugs feeding in furrows.

Slugs are usually found on heavy soils and wet areas in high rainfall areas and can be a problem in canola or pulse paddocks with high levels of stubble retention or rock piles, which provide protection over the summer.

Monitoring and thresholds

Monitoring has recently been shown to be an unreliable way to assess slug densities. This is principally because slug distribution across a field is highly variable, and they are only active under a narrow range of conditions. Slugs can be found on the heavier clay soils, but can spread to lighter and gravel soil types which makes it difficult to target by soil type.

In WA the recommended threshold for control in pulses is 1-2 snails or slugs per square metre. [16]

Management

Baits are more effective in controlling slugs and snails when there is no green material (i.e. weeds or emerging crops) to provide an alternative food source. Spread pellets when slugs are active after rain and to apply at recommended rates.

Baits alone may not provide sufficient control so it is necessary to carry out additional management practices.

MORE INFORMATION

GRDC (2013) Slug identification and management. Fact sheet.

A Snug Blog is maintained by SARDI slug researcher Michael Nash, and via Facebook.

My Pest Guide

15 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

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

MORE INFORMATION

GRDC (2013) Slug identification and management. Fact sheet.

A Snug Blog is maintained by SARDI slug researcher Michael Nash, and via Facebook.

DAFWA (2015) Diagnosing redlegged earth mite.

GRDC (2016) RLEM resistance management strategies. Ground Cover Radio. No. 122. 4 May 2016. Audio file.

GRDC (2012) Crop mites: The back pocket guide. GRDC.

Control of summer weeds ('green-bridge') results in fewer slugs being present in crops and also increases the effectiveness of baits by removing food competition.

Burning and tillage will reduce reticulated slugs but black keeled slugs are unaffected. [17]

7.5 Mites

Mites are among the most diverse and successful of all the invertebrate groups. Because they are tiny they often go unnoticed; however, they are one of the most important pests of Australian grain crops. Some species have become more problematic over the last decade as farming practices have changed, and others are proving difficult to control due to tolerance and chemical resistance. [18]

7.5.1 Redlegged earth mite

The mite grows to about 1 mm in length. Adults have a velvety black body and eight red legs (Photo 20). Newly hatched mites are 0.2 mm long, and have pinkish-orange with six legs. Nymphs develop into mature adults in approximately four to six weeks.

In autumn, over-summering eggs hatch when there is significant rainfall and the mean daily temperatures fall below approximately 21°C.

Redlegged earth mites can have three generations a season.

Photo 20: *Redlegged earth mite close up.*

Photo: Grain Legume Handbook, 2008

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

18 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

Life cycle

Earth mites are active in the cool, wet part of the year, usually between April and November. During this winter–spring period, RLEM may pass through three generations, with each generation surviving six to eight weeks. Prolonged plant growth during long, wet springs favours the production of over-summering eggs.

Autumn rains trigger hatching in three to nine days. Mites take 20–25 days to mature and start laying eggs (Figure 6). False breaks in the season can cause large losses in mite numbers. [19]

Monitoring

Inspect susceptible crops for mites and their damage from autumn to spring, particularly in the first few weeks after sowing. Mites feed on the leaves in the morning or on overcast days, and in the warmer part of the day RLEM tend to gather at the base of plants, sheltering in leaf sheaths and under debris. They will crawl into cracks in the ground to avoid heat and cold. When disturbed during feeding they will drop to the ground and seek shelter.

Control

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.

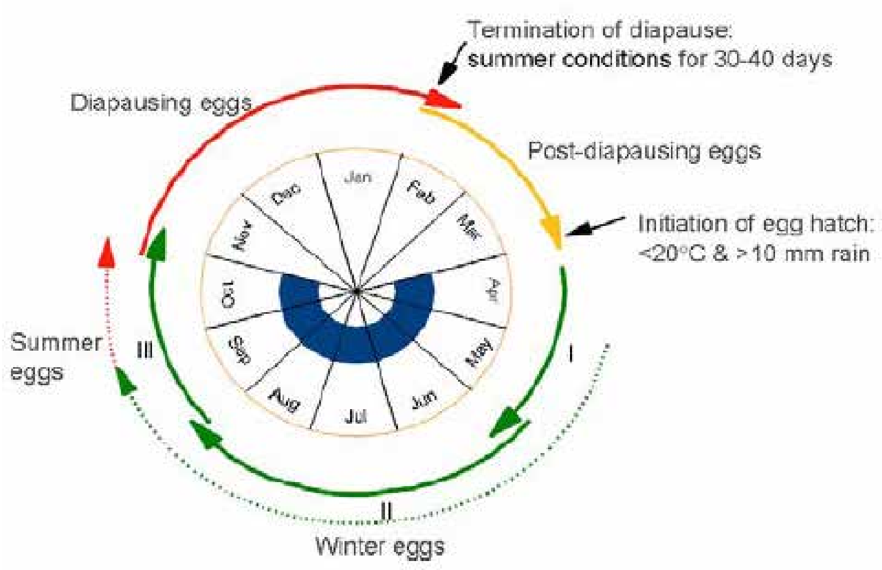

Figure 6: *Life cycle of redlegged earth mite.*

Source: Umina 2006

Chemical control

Chemicals are the most commonly used control for earth mites. Chemicals are registered for control of active RLEM, but none currently registered are effective against RLEM eggs.

DAFWA reports RLEM that are resistant to commonly applied insecticides including synthetic pyrethroids (Group 2A), the organophosphates (Group 1B) omethoate and chlorpyrifos were first found in Western Australia. Resistant RLEM populations are likely to be present in paddocks that have a history of repeated insecticide applications.

19 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

DAFWA advises growers with SP resistant RLEM to control these mites by using insecticides from the OP group (Group 1B), for example, dimethoate or omethoate.

RLEM with omethoate tolerance or chlorpyrifos can not be controlled by using registered rates of these insecticides. As populations have been found with omethoate tolerance and SP resistance is showing that reliance on insecticides for the control of RLEM is starting to break down.

In all cases residual populations of resistant or tolerant RLEM were found on weeds along fencelines and re-infested paddocks. [20]

Autumn sprays

Control first-generation 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.

Timing of chemical application:

- Pesticides with persistent residual activity can be used as bare-earth treatments to protect seedlings.
- Foliage sprays applied after the crop has emerged and are generally an effective control.
- Systemic pesticides applied as seed dressings act by maintaining the pesticide at toxic levels within the seedling. If mite numbers are high, plants may suffer significant damage before the pesticide has much effect.

Spring sprays

A correctly timed spring spray can reduce populations of RLEM the following autumn. Use climatic variables, and tools such as Timerite® to determine the optimum date for spraying. Spring RLEM sprays will generally not be effective against other pest mites.

Do not keep using the 'spring spray' technique year in, year out. To avoid pesticide resistance evolving, rotate spring-spray products with different modes of action.

Other controls

Cultural control measures include:

- Rotating crops or pastures with non-host crops, e.g. cereals
- Cultivating, which can reduce RLEM populations
- Clean fallowing and controlling weeds around crop and pasture perimeters
- Controlling weeds, especially thistles and capeweed, to remove breeding sites for RLEM. [21]

7.5.2 Lucerne flea

Broadleaf seedlings—including canola, faba beans, lupins, field peas, clovers and lucerne—are most susceptible to the lucerne flea (*Sminthurus viridis*). This pest, which is actually a springtail, requires cool, moist conditions to hatch, and will produce up to five generations in most years.

Life cycle

Long, wet springs favour flea build-ups, which often cause more serious outbreaks in the following autumn. Over-summering eggs are laid in the soil and hatch soon after soaking autumn rains. The eggs take about two weeks to hatch and the immature stages a further three weeks before the flea reaches sexual maturity.

A second generation may be completed before winter temperatures retard development and reduce the numbers. In spring a second burst of activity occurs

20 DAFWA (2017) Prevent redlegged earth mite resistance https://www.agric.wa.gov.au/mites-spiders/prevent-redlegged-earth-mite-resistance

21 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

when rising temperatures allow both pests to breed faster and increase their numbers. This period of activity stops in late spring when dry conditions lead to the production of over-summering eggs.

The final generation of females each season lay eggs that over-summer in the soil. The female will excrete a substance that contains ingested soil particles to form a protective mass that protects and camouflages the eggs (Photo 21). [22]

Photo 21: *Lucerne flea with eggs.*

Photo: Grain Legume Handbook, 2008

Monitoring

Monitoring from autumn through spring is the key to reducing the damage caused by lucerne fleas. Crops are most susceptible to damage immediately following seedling emergence.

Lucerne fleas are 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 characteristic lucerne-flea damage, such as windowing of leaves, and check the soil surface where insects may be sheltering.

It is important to assess the complex of pests present before deciding on the most appropriate control strategy.

It is also important to note the growth stage of the lucerne flea population. Spray immature lucerne fleas before they have a chance to reproduce to reduce the size of subsequent generations.

Damage includes chewed leaves.

Chemical control

If warranted, treat the infested area approximately three weeks after lucerne fleas have been observed on a newly emerged crop. This will allow for any remaining over-summering eggs to hatch, but will occur be before the lucerne fleas reach maturity and begin to lay winter eggs.

Biological and cultural control

Several predatory mites (e.g. snout mites), various ground beetles and spiders prey on lucerne fleas. Clean fallows and the control of weeds, especially capeweed, within crops and around pasture perimeters helps reduce lucerne flea numbers.

Grasses and cereals are less favourable to the lucerne flea and as such can be useful for crop borders. [23]

22 GRDC (2014) Beating the lucerne flea. Media Centre. 5 June 2014, https://grdc.com.au/Media-Centre/Hot-Topics/Beating-the-lucerne-flea

23 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 7—Insect Management.

7.6 Monitoring faba bean for insect pests

There are a number of sampling methods that can be used in faba beans, and the use of one or more of these methods when checking crops depends on the crop stage, and which pests are expected.

It is likely that more than one method may be necessary to effectively estimate pest density. For example, when sampling for *Helicoverpa* spp. a beat sheet or sweep net will not dislodge small larvae in terminals and flowers, so a visual inspection of a number of plants is also required.

Photo 22: *The beat sheet can be used between the rows (as is done in chickpeas, left) or in larger crops, draped over the adjacent row to maximize the capture of insects dislodged when sampling (right)*

Photos: GRDC, DAF Qld

How to use a beat sheet to sample faba beans

Check crops at least once a week with a beat sheet, from flowering through to harvest.

To avoid possible edge effects, start sampling at least 50 m into the field.

Each inspection, take 5–10 samples across the field. The number of samples should be influenced by what you find. Consistently high or low numbers of insects will require fewer samples be taken because the overall picture is clear. Where pests are patchy and numbers are variable, more samples will be needed to be confident in averaging the counts to get an estimate of pest numbers.

An estimate of pest density is usually the average of all individual samples taken (e.g. 5 + 1 + 4 + 3 + 2 + 5 + 5 = 25; 25 ÷ 7 = 3.6 per sampling unit).

In addition to larval counts, visual observation of crop growth stage, progress of flowering and podding, and the presence of natural enemies of insect pests (beneficials) all provide useful information for making decisions.

When using a beat sheet, it is worth converting pest density estimates into standard units, generally the number per m^2. This conversion adjusts for the amount of crop (linear metres of row) at different row configurations.

To convert pest density to m^2, use the following formula:

Number / m^2 = Average number of pest ÷ row spacing (in metres)

MORE INFORMATION

Watch a video on using a beat sheet in canola or chickpeas on the Beatsheet YouTube channel.

How to use a sweep net to sample faba beans

A standard beat sheet is made from plastic or tarpaulin with heavy dowel on each end to weigh it down. It is typically 1.3 m wide by 1.5 m long.

Lay the sheet on the ground under the plants. Using a 1-m-long stick (dowel, heavy conduit), shake the row vigorously 10 times to dislodge larvae from the plants. Size and count larvae that drop onto the sheet. The beat sheet is wider than the stick so that there is an extra 0.15 m on each side to catch insects thrown out sideways.

Where crops are sown on narrow row spacings, and it is not possible to get a beat sheet between the rows, a sweep net can be used to sample faba beans.

Hold the sweep-net handle in both hands and sweep it across the front of your body in a 180° arc. Take a step with each sweep. Keep the head of the net upright so the bottom of the hoop travels through the canopy. Use sufficient force in the sweep to pass the hoop through the canopy and dislodge larvae.

Take 10 sweeps and then stop and check the net for insects.

Nematode management

Key messages

- Root-lesion nematodes (RLNs) are found over 5.74 million ha or 65% of the cropping area of Western Australia.
- In WA, P. neglectus is the main species of RLN, with P.quasitereoides the next most prevalent.
- All RLN species cause root damage and yield losses, particularly in cereals. Root-lesion nematodes have a wide range of hosts, including cereals and grassy weeds, pulses, pasture, and forage legumes and oilseeds.
- The life cycle of RLN begins after the opening rains in autumn in WA.
- RLNs are worm-like organisms less than 1 mm in length, and cannot be seen with the naked eye.
- Rotations of resistant crop species can effectively keep RLNs to a minimum.
- Faba beans are resistant to Pratylenchus neglectus.
- Weeds can host parasitic nematodes, so control of host weed species and crop volunteers is important.

8.1 Background

Root-lesion nematode (RLN) is a microscopic, worm-like organism <1 mm in length that feeds in root tissues (Photo 1).

They are migratory endoparasites, meaning they enter roots to feed and lay eggs but may live for some time in soil, feeding on the exterior of the roots or travelling between roots and plants. [1]

In Western Australia (WA), *P. neglectus* is the main species of RLN, with *P. quasitereoides* (originally described as *P.teres)* [2] the next most prevalent, and *P. thornei* rarely occurring. [3]

Faba bean is resistant to *P. neglectus* but susceptible to *P. penetrans*. [4] There are variable reports about the response of faba beans to *P. thornei*, but in terms of usefulness as a break crop for *Pt*, the crop is generally rated as 'susceptible'.

Intensive cropping of susceptible species, particularly wheat, will lead to an increase in RLN levels. Crop rotation with resistant crop species is the key to reducing RLN and the damage caused by this pest.

1 GRDC (2015) Tips and tactics: root-lesion nematodes, Western Region, www.grdc.com.au/TT-RootLesionNematodes
2 GRDC (2015) Tips and tactics: root-lesion nematodes, Western Region, www.grdc.com.au/TT-RootLesionNematodes
3 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course.
4 GRDC (2015) Tips and tactics: root-lesion nematodes, Western Region, www.grdc.com.au/TT-RootLesionNematodes

Photo 1: *Microscope image of a root-lesion nematode. Notice the syringe-like stylet at the head end; it is used for extracting nutrients from the plant root. The nematode is <1 mm long.*

Photo: Sean Kelly, Department of Agriculture and Food, Western Australia

8.1.1 The life cycle of RLN

Root-lesion nematodes are migratory plant-parasitic nematodes, and will migrate freely between roots and soil if the soil is moist. In WA, the life cycle of RLN begins after the opening rains in autumn.

Juvenile and adult nematodes rehydrate, become active and invade plant roots, where they feed and multiply as they move through the root (Figure 1). Individual eggs are laid within the root, from which juvenile nematodes hatch and grow to adults, which in turn lay more eggs. They develop from egg to adult in 40–45 days (~6 weeks) depending on soil temperature and the host (Figure 1). There may be 3–5 life cycles within the plant host each season.

As plants and soil dry out in late spring, RLN enter a dehydrated state called anhydrobiosis and can survive high soil temperatures and desiccation over summer. As the nematodes feed and multiply, lesions and/or sections of brown discoloration are formed on the plant root. Other symptoms include a reduction in the number and size of lateral roots and root hairs. [5]

5 GRDC (2015) Tips and tactics: root-lesion nematodes, Western Region, www.grdc.com.au/TT-RootLesionNematodes

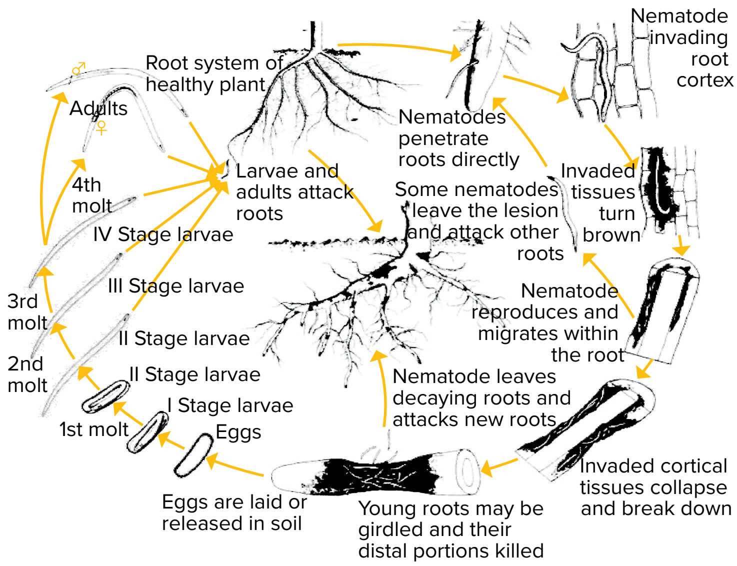

Figure 1: *Life cycle of root-lesion nematode.*

Source: GRDC (2009) Plant parasitic nematodes. Fact sheet

8.2 Symptoms and detection

Root-lesion nematodes cannot be seen with the naked eye in the soil or in plants. The most reliable way to confirm the presence of RLN is to test farm soil. Nematodes are extracted from the soil for identification and determination of their population size. Look out for telltale signs of nematode infection in the roots and symptoms in the plant shoots, and if seen, submit soil and root samples for nematode assessment.

Aboveground symptoms of RLN attack on all crops can include:

- poor establishment
- stunting
- yellowing of lower leaves
- poor tillering

Symptoms can be confused with nutrient deficiency and may be exacerbated by a lack of nutrients. Infected plants may wilt prematurely in dry periods and at the end of the season.

When roots are damaged by RLNs, the plants become less efficient at taking up water and nutrients and tolerating stresses such as drought or nutrient deficiencies. Affected plants may partly recover if the rate of new root growth exceeds the rate at which RLNs damage the roots. However, recovery will depend on the extent of root damage, the growing conditions, and whether sufficient fertiliser is applied.

An examination of washed plant roots may provide some information, but symptoms can be difficult to see and roots may be difficult to remove from heavy clay soils.

The root cortex (or outer root layer) may be damaged and may disintegrate. Diagnosis is best confirmed with laboratory testing of soil and/or plants for the presence and population densities of RLNs. [6]

MORE INFORMATION

DAFWA (2014) How to diagnose root lesion nematode. Video.

S Collins et al. (2013) *Pratylenchus teres*: WA's home grown root lesion nematode (RLN) and its unique impacts on broadacre crops. GRDC.

GRDC (2010) Plant parasitic nematodes, Southern and Western Region. Fact sheet.

S Collins et al. (2014) Root lesion nematode has a picnic in 2013, DAFWA.

6 GRDC (2009) Root lesion nematode dominates in the north. Northern Region. Fact sheet, http://www.grdc.com.au/uploads/documents/GRDC_NematodesFS_North_4pp.pdf

8.3 Varietal resistance or tolerance

Resistance: nematode multiplication

- Resistant crops do not allow RLNs to reproduce and increase in number in their roots.
- Susceptible crops allow RLNs to reproduce so that their numbers increase. Moderately susceptible crops allow increases in nematode populations, but at a slower rate.

Tolerance: crop response

- Tolerant varieties or crops yield well when sown in fields containing large populations of nematodes.
- Intolerant varieties or crops yield poorly when sown in fields containing large populations of nematodes (Table 1).

Table 1: *Resistance and tolerance of pulses to Pratylenchus spp.*

	Pratylenchus neglectus		***Pratylenchus thornei***	
	Resistance	**Tolerance**	**Resistance**	**Tolerance**
Chickpeas	S–MR	MI–T	VS–R	MI–T
Faba beans	R	-	MR	MI
Field peas	R	-	R	T
Lentils	R	T	R	MT
Vetch:				
Blanchefleur	MR	T	S	I–MI
Languedoc	MR	T	MS	I–MI
Morava	MR	T	MS	I–MI

S, susceptible; R, resistant; I, intolerant; T, tolerant; M, moderately; V, very. Chickpea varieties have a range of resistances and tolerances to Pratylenchus species.

8.4 RLN damage

Numbers of RLN build up steadily under susceptible crops, causing a decrease in yields over several years. Yield losses >50% can occur in some wheat varieties, and up to 20% in some chickpea varieties. The amount of damage caused will depend on:

- the numbers of nematodes in the soil at sowing
- the tolerance of the variety of the crop being grown
- the environmental conditions

Damage from RLN results in brown root lesions, but these can be difficult to see or can be caused by other organisms. Root systems are often compromised by reduced branching, reduced quantities of root hairs and an inability to penetrate deeply into the soil profile. RLNs create an inefficient root system that reduces the ability of the plant to access nutrition and soil water. [7]

7 GRDC (2013) Managing root lesion nematodes: how important are crop and variety choice? GRDC update papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

8.5 Management of nematodes

Rotations and variety choice are key to the successful reduction of RLN populations in the soil. Only non-host crops or resistant varieties will minimise the build-up of RLNs. Tolerant crops will suffer less damage, but if these varieties are susceptible, RLN numbers can still increase. Faba beans can assist with managing *P. neglectus* due to its resistance.

Weeds can play an important role in the increase or persistence of nematodes in cropping soils. Thus, poor control of susceptible weeds compromises the use of crop rotations for RLN management. [8]

As different species of RLN can be hosted on different crops, it is important to identify which species are present. Testing services are available around Australia, and growers are advised to contact their local department of agriculture for advice on specific issues for their area.

Testing for RLN

1. *Test your farm.* If RLN infestation is suspected, growers are advised to check the crop roots. Carefully dig up and wash the soil from the roots of an infected plant. This can reveal evidence of infestation in the roots, which warrants laboratory analysis. Testing services are available at DDLS at DPIRD.
2. PreDicta B. A DNA-based soil-analysis service is available that is delivered by accredited agronomists and can detect *P. neglectus*, *P. thornei* and *P. quasitereoides*.

8 GRDC (2015) Tips and tactics: root lesion nematodes, Western Region. Fact sheet, www.grdc.com.au/TT-RootLesionNematodes

Diseases

Key messages

- Chocolate spot (*Botrytis fabae*) can cause extensive losses and is the major disease of faba beans in WA.
- In central and southern areas of WA use varieties that are at least moderately resistant to Ascochyta blight such as Fiesta VF.
- Rhizoctonia bare patch (*Rhizoctonia solani*) occurs on most soil types in the WA wheatbelt.
- Ascochyta blight occurs in all faba bean growing areas of Western Australia.
- The weather is the principal factor in translating disease risk into disease severity.
- Managing foliar disease in faba beans is all about reducing the risk of infection.

9.1 Fungal disease management strategies

Disease management in pulses relies on an integrated management approach involving variety choice, crop hygiene and the strategic use of fungicides. The initial source of the disease can be from the seed, the soil, the pulse stubble and self-sown seedlings, or in some cases, other plant species. Once the disease is present, the source is then from within the crop itself.

The impact of disease on grain quality in pulses can be far greater than yield loss. This must be accounted for in thresholds because in pulses, visual quality has a significant impact on market price.

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 points in disease development, and all can be represented by the classical disease triangle (Figures 1 and 2). Diseases such as Ascochyta blight and Phytophthora root rot can cause total crop failures very quickly, whereas Botrytis grey mould and root-lesion nematodes may 'tick' away over the season and mask their true effects on crop performance and yield. [1]

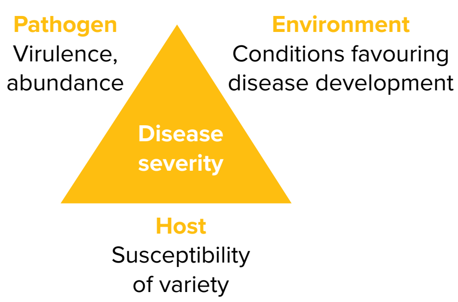

Figure 1: *The fungal-disease triangle.*

Source: Agrios 1988

1 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

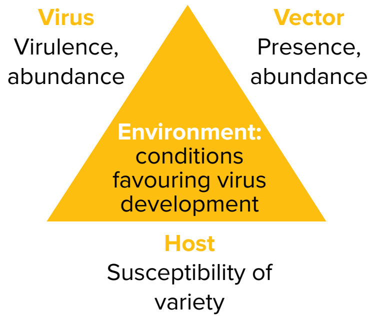

Figure 2: *The virus-disease triangle, which also applies to some bacteria.*

Source: Jones 2012

Disease management should be a consideration when planning any rotation, particularly at the beginning of the season. This is especially important for faba beans where the first action of defence against diseases begins with paddock selection. Other criteria such as seed quality and treatment are also vitally important.

Determine which diseases are the highest priorities to control in the pulse crop being grown, and if possible sow a variety that is resistant to those diseases. Strategic fungicide application combined with paddock selection is also part of an overall program to minimise the impact of disease. Fungicide disease-control strategies alone may not be economic in high-risk situations, particularly if susceptible varieties are grown.

Variety selection

Growing a resistant variety reduces the risk and reliance on foliar fungicides.

In practical terms, under average conditions for disease development, no economic yield loss is expected in resistant varieties, and control measures are unlikely to make the crop more profitable. Resistance does not mean immunity though:

- Varieties with a disease description of moderately resistant are expected to sustain low to moderate yield loss and control measures are likely to be cost-effective.
- Varieties with a disease description of moderately resistant to moderately susceptible are expected to sustain moderate to high losses and control measures are necessary to ensure a profitable crop.
- Varieties with disease description of moderately susceptible or worse will sustain very high to total yield loss and control measures are essential to produce a harvestable crop.

Pulse varieties are now rated for Ascochyta blight on both foliage and on pods and seeds because there are differences in their susceptibility and resistance. This may influence control strategies and timings during podding so as to preserve seed quality, and hence marketability. [2]

2 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

Table 1: *Faba bean variety ratings for the common bean diseases in Australia.*

Variety	Ascochyta blight		Chocolate spot	Rust	Cercospora spot	PSbMV Seed staining
	Foliage	Seed				
Ascot VF	R	R	VS	S	S	–
Aquadulce	MS	MS	MS	MS	S	MS
Cairo⊕	VS	VS	VS	MS	–	–
Doza⊕	VS	VS	MS	MR-R	S	–
Farah⊕	MR-R	MR-R	S	S	S	S
Fiesta VF⊕	MS-MR	MS	S	S	S	S
Fiord⊕	MS	MS	VS	S	S	S
Icarus	VS	VS	MR	MR	–	–
Manafest	VS	VS	MS	MS	–	–
Nura⊕	MR-R	MR-R	S	MS	S	VS
PBA Kareema⊕	MR-R	MR-R	MS	MS-MR	S	
PBA Samira⊕	R	R	MS	MS	S	S
PBA Rana⊕	R	R	MS	MS-MR	S	MR-R
PBA Warda⊕	S	S	MS	MR-R	S	–

VS, very susceptible; S, susceptible; MS, moderately susceptible; MR, moderately resistant; R, resistant
Source: Pulse Australia

Distance

Proximity to stubble of the same pulse from the previous year will affect the amount of infection for some diseases. Aim for a separation distance of at least 500 m.

Paddock history and rotation

Aim for a break of at least four years between planting the same pulse crop. A high frequency of crops such as faba beans, lentils, vetch, field peas, chickpeas, *Lathyrus* species, or clover pasture puts pulses at greater risk of multi-host fungal pathogens such as *Phoma*, *Sclerotinia* and *Botrytis* species. Ascochyta blight species are more specific to each pulse crop but three to four year rotations are still important. Canola can also increase the risk of Sclerotinia rot.

Paddock selection

The selection of the most appropriate paddock for growing faba beans requires consideration of a number of important factors, many of which are related to the modes of survival and transmission of pathogens such as *Ascochyta fabae*.

- Rotation
  - » Develop a rotation of no more than one year of faba beans in four years.
  - » Plant faba 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 (aphids may be vectors for viruses).
  - » Consider previous crops that may have hosted pathogens such as *Sclerotinia* spp., *Rhizoctonia* solani. and *Phoma medicaginis*.
  - » *Ascochyta fabae* and *Botrytis fabae* are faba bean specific, whereas *Botrytis cinerea* has a wide host range including lentil and weeds such as *Euphorbia* spp., groundsel and emu-foot.
- History of faba bean diseases

- » A previous occurrence of soil-borne diseases (Sclerotinia stem rot, Stem nematode or *Pratylenchus* nematodes) constitutes a risk for subsequent faba bean crops for up to 10 years.
  - » Plant at least 500 m (preferably more) away from the previous year's faba bean crop.
- Weeds
  - » Nearly all weeds host *Sclerotinia* spp.
  - » 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, CMV).
- Herbicide history
  - » Determine whether triazine, 'imi' or sulfonylurea herbicides been applied in the last 12 months
  - » The development of some diseases is favoured in herbicide-weakened plants.
  - » The presence of herbicide residues in the soil may cause crop damage and thus confusion over in-field disease diagnosis. [3]

Hygiene

Take all necessary precautions to prevent the spread of disease. Reduce last year's pulse stubble if erosion is not a risk, and remove self-sown pulses before the new crop emerges.

Control of volunteer faba beans during summer–autumn and in fallows is vital to avoid the carryover of inoculum of chocolate spot, rust and Ascochyta blight pathogens. Some broadleaf weeds are alternative hosts of one or more of the viruses that affect faba beans, and of *Sclerotinia* species, and should be killed before planting and while the crop is growing.

Pathogens such as *Ascochyta fabae* can also be transmitted via infected stubble and soil. Soil and stubble movement may occur by machinery, during windy and/or wet weather, and by flooding. Therefore, it is essential all headers and sowing equipment be thoroughly cleaned to remove grain, soil and stubble before moving from property to property, and if possible in particularly high-risk disease situations, between paddocks.

Spray rigs should also be cleaned to reduce the risk of transmitting diseases, particularly if contractors are used.

Paddock inspections should be carried out using clothing suitable to the task and, ideally, footwear should be disinfected before entering a crop. [4]

Seed quality and dressings

Use seed from crops where there was no disease or low levels of disease, especially at podding. Avoid sowing seed that is known to have disease infection, particularly of the susceptible varieties. Have seed tested for disease status where recommended.

Use only seed of high quality (in purity, germination and vigour). Source seed from a paddock where diseases, particularly those that affect pods, have not been detected. In particular, seed from a crop known to have been heavily affected by Ascochyta blight should not be used.

Treatment of seed with a fungicide dressing is an option, but not essential; it controls seed-borne Ascochyta blight and Botrytis grey mould (BGM), and several soil-borne fungal diseases (Table 2). [5]

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3 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

4 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

5 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

Table 2: *Seed dressings registered for use with faba beans (but not often used).*

Active ingredient:	Thiram	thiram + thiabendazole
Example trade name:	Thiram®	P-Pickel® T
Ascochyta blight	NR	NR
Botrytis grey mould	NR	NR
Damping off	–	R
Fusarium diseases	–	R
Phoma root rot	–	–
Phytopthora root rot	–	–
Pythium diseases	–	R
Jurisdiction	All states	All states

R, claim on registered product label; NR, not registered for use in this crop.
Refer to the current product label for complete directions for use before applying product.

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 beans.

Registered labels and current permits can be found on the website of the Australian Pesticide and Veterinary Medicine Authority (APVMA).

Seed dressings are partially effective early, particularly for diseases such as seed-borne Botrytis grey mould, Phoma blight and Ascochyta blight. They are not effective on viruses and bacterial diseases.

Sowing date

To minimise the risk of foliar disease, do not sow too early. This will help 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 species and your region.

Sowing rate

Aim for the optimum plant population for the region, sowing time, crop type, and 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 usual will help reduce the emergence of infected seedlings. The seeding rate must be adjusted upwards to account for the likelihood of fewer seedlings emerging and establishing.

Foliar fungicide applications

Disease-resistant varieties do not require the intense, regular application of foliar fungicides that susceptible varieties need to control foliar diseases. Some pulses may require fungicide treatment for Botrytis grey mould (BGM) if a dense canopy exists. Successful disease control with fungicides is dependent on the timeliness of spraying, the 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.

Foliar fungicides are essential for the management of Ascochyta blight in all varieties, and are an important tool for the management of BGM. Varieties with higher levels of Ascochyta blight resistance do not require as many sprays as susceptible varieties. The success of foliar fungicides depends on timeliness of spraying (hence the importance of regular crop monitoring), appropriate fungicide selection, and correct application. Early detection and fungicide application is vital.

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 beans. *Check current registrations* on the APVMA website. Registered labels and current permits can be found on this site. [6]

A fungicide sprayed at the commencement of flowering protects early podset. Additional protection may be needed until the end of flowering in longer growing seasons. Fungicides last around two to three weeks.

In periods of rapid growth and intense rain (50 mm over several days), the protection period will reduce to ~10 days. All new growth after spraying is unprotected.

The need for and timing of repeat fungicide sprays depends on:

- the amount of unprotected growth
- rainfall after spraying
- the likelihood of a further extended rainy period [7]

Mechanical damage

Any physical damage due to excessive traffic, wind erosion, frost, hail, post-emergent rolling or herbicide damage can lead to the increased spread of foliar disease in pulses.

Controlling aphids

Controlling aphids may reduce the spread of viruses, but will not eliminate them. Protective insecticide treatments are unlikely to be successful if applied strategically, or economic if applied regularly. Usually the virus has spread by the time the aphids are detected.

Harvest management

Early harvest will help reduce the infection of seed, and is also important for grain quality and to minimise harvest losses. Crop desiccation enables an earlier harvest, reduces moisture risk and adverse weather risks. Moisture contents of up to 14% are allowable at delivery. Do not desiccate before physiological maturity as this can affect grain quality. [8]

MORE INFORMATION

Pulse Australia (2016) Faba Bean Fungicide Guide: 2016 Season

G M Murray and J P Brennan (2012) The current and potential costs from diseases in pulse crops in Australia. GRDC.

9.1.1 Risk assessment

Risk assessment is the prediction of likely damage from a faba bean disease. It can be used at the paddock, farm, regional, state or national level. The choice of variety, disease management options and fungicide availability are some of the factors used to determine risk. Seasonal conditions and sowing times have a huge impact on risk as well.

The distribution and dispersal (large-scale spatial patterns) of a pathogen contribute to the regional occurrence of a disease. This regional pattern was evident in the chocolate spot epidemics in different states in the early years of faba bean production using the variety Fiord⚷. See Tables 3 and 4.

Increased distance of new crop from inoculum on infested stubble and old crop volunteers meant the limited pressure of the fungus in these areas had less impact than in the more intensive systems.

The risk of severe faba bean diseases is also intimately linked with weather conditions, i.e. rainfall, humidity and temperature.

Modelling pulse disease, including those of faba beans, in Australia is in its infancy. However, we do have a good understanding of the epidemiology of the predominant diseases and their close association with weather conditions. Hence, fungicide

6 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

7 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

8 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

protection applied before rainfall events is an integral part of an overall disease-management strategy. [9]

Table 3: *Carryover of major faba bean diseases showing their relative importance as sources of infection.*

Disease	Stubble	Seed	Soil
Ascochyta blight	★★★	★★	★
Chocolate spot (*Botrytis*)	★★★	★	★
Cercospora leaf spot	★★		★★★
Rust	★		

Table 4: *Diseases occurring on pulses with potential for cross-infection.*

	Chickpea	Faba beans	Lentils	Lupins	Peas	Vetch
Botrytis grey mould						
Botrytis cinerea	★★	★★	★★	★	★★	★★
Chocolate spot						
Botrytis fabae	★	★★	★★			★★
Cercospora leaf spot						
Cercospora zonta		★★				
Sclerotinia disease						
Sclerotinia sclerotiorium	★★		★★	★★	★★	
Sclerotinia trifoliorium	★★	★★		★★		
Bacterial blight						
Pseudomonas andropogonis	★					
Pseudomonas syringae pvv. *syringae*		★★	★		★★	
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* and *Ascochyta*)						
Mycosphaerella pinodes	★★	★	★		★★	★
Anthracnose						
Colletotrichum gloeosporioides				★★		
Brown leaf spot						
Pleiochaeta setosa				★★		
Grey leaf spot						

9 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

	Chickpea	Faba beans	Lentils	Lupins	Peas	Vetch
Stemphylium botryosum	★		★★	★★		
Downy mildew						
Peronospora viciae					★★	★
Powdery mildew						
Erysiphe polygoni					★★	
Septoria leaf spot						
Septoria pisi					★★	
Phomopsis disease						
Phomopsis leptostromiformis				★★		
Rust						
Uromyces viciae-fabae[A]		★★			★	★★
Root-lesion nematode						
Pratylenchus neglectus	★					
Pratylenchus thornei	★★	★★				★★
Stem nematode						
Ditylenchus dipsaci	★	★★			★★	★
Viruses						
Bean yellow mosaic virus		★		★★		
Cucumber mosaic virus	★	★	★★	★★		
Luteoviruses complex (e.g. Bean leaf roll virus and Bean western yellows virus)	★★	★★	★		★★	★★
Tomato spotted wilt virus hosted by lupins can cause cross infection in faba beans				★		
Pea seedborne mosaic virus					★★	
Alfalfa mosaic virus	★★	★	★★			★
Wilt						
Fusarium oxysporum[A]				★★	★★	
Root rots						
Fusarium	★	★	★	★	★	★
Macrophomina	★				★★	
Phytophthora medicaginis	★★					
Pleiochaeta setosa			★★			
Pythium[B]	★		★	★	★	
Rhizoctonia	★	★★	★★	★★	★★	★★
Sclerotinia[C]	★		★	★	★	

★ Disease occurs in this crop but does not caused major damage; ★★ Disease has caused major damage to this crop

A Strain differences between crops.

B Pythium and Botrytis grey mould is worse (★★★) in white peas than dun peas (★★)

C Sclerotinia (root rot) is worse (★★) in Kabuli than Desi (★). [10]

10 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

9.1.2 Regular crop monitoring

The main diseases where monitoring is necessary are chocolate spot (caused by *Botrytis fabae*) and Ascochyta blight (*Ascochyta fabae*). By following the monitoring process recommended for these diseases, farmers have the opportunity to assess the impact or presence of 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.

Chocolate spot

Chocolate spot is more likely to occur in bulky crops where the canopy closes. The critical stage for the first inspection will be just before flowering commences, as temperatures begin to increase, and then regularly through the flowering and seed-filling period. Lesions occur on leaves and flowers first, and can also occur on stems and pods. Flower abortion and drop can occur.

The first symptoms are small brown spots on leaves and flowers. They rapidly develop into large, irregular-shaped lesions on leaves and into the decay of flowers, when conditions remain favourable for the disease.

Chocolate spot requires high leaf moisture or humidity (>70%) within the crop canopy and optimal temperatures of 15–28°C. When humidity levels decrease or maximum daily temperature exceed ~28°C, infection levels decline sharply.

See Section 9.9 Diseases.

Ascochyta blight

The initial symptoms of Ascochyta blight are lesions on the leaves and stems of young plants. A distinguishing feature is the fungal fruiting structures (small black dots) visible within the centre of lesions.

Monitoring should commence two to three weeks after emergence, or 10–14 days after rain. This is to allow time for the disease to develop after the occurrence of an infection, such as transmission from infected seed or rain-splashed inoculum. Infected seedlings may deteriorate quickly and plant parts above the lesion may break off, making symptoms difficult to detect.

Timing is critical. After the initial inspection, subsequent inspections should occur every 10–14 days after rain or heavy dew. During dry periods, inspections can be less frequent. Look for signs of lesions on the leaves, or wilting in upper foliage or small areas of dead or dying plants (which indicate a severe infection). If any of these signs are present, examine individual affected plants for symptoms of infection. [11]

See Section 9.9 Diseases

11 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

Table 5: *Faba bean diseases and fungicide control options throughout a season.*

Critical period	Disease		Fungicide*	Comments
	Target	Secondary		
First critical period	Ascochyta blight	–	Mancozeb or chlorothalonil	Early fungicide application is critical to restrict early development and spread of disease. 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.
Early vegetative (5–8 weeks after emergence)	Cercospora leaf spot	–	Tebuconazole or carbendazim	
	Cercospora leaf spot plus	Chocolate spot	Tebuconazole + mancozeb or use carbendazim	Cercospora spot is often first disease to appear.
	Ascochyta blight plus	Cercospora spot	Tebuconazole + Mancozeb or carbendazim + Mancozeb, or chlorothalonil by itself	Early chocolate spot control can be important in early sown crops.
	Cercospora leaf spot plus	Ascochyta blight	Either tebuconazole or carbendazim + either Mancozeb or chlorothalonil	Cercospora leaf spot occurs 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
	Rust plus	Chocolate spot	Mancozeb or chlorothalonil	Rust could be an early target in early sown crops as well. Use the lower rate on crops <20 cm in height. Use the higher rate for dense crops or if disease pressure is severe.
Second critical period	Ascochyta blight plus	Chocolate spot	Mancozeb or chlorothalonil	Early-mid-flowering protection before the disease establishes is recommended: before canopy closure.
Pre canopy closure, during flowering (13–16 weeks after emergence through flowering)	Chocolate spot plus	Ascochyta blight	Either carbendazim or procymidone + either Mancozeb or chlorothalonil	Protection of flowers to assist pod set is important. Chocolate spot occurs 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 plus	Cercospora	Carbendazim or chlorothalonil or procymidone + tebuconazole	If Ascochyta blight is detected, and/or chocolate spot appears in the upper third of the crop canopy, and rain or high humidity are likely, then apply fungicide if crop has sufficient yield potential.
	Severe chocolate spot	–	Procymidone	

Critical period	Disease		Fungicide*	Comments
	Target	Secondary		
Third critical period Late flowering to end of flowering when pods are filling (15–20 weeks after emergence)	Ascochyta blight &/or rust plus	Chocolate spot	Mancozeb or chlorothalonil	If Ascochyta is detected, rain is likely or new spots of chocolate spot appear or are likely to appear on unprotected leaves on the upper third of the plant, then apply or re-apply fungicide if the crop has sufficient yield potential. Rust occurs during flowering or pod filling. Observe all withholding periods.
	Chocolate spot plus	Ascochyta blight &/or rust	Either carbendazim or procymidone + either Mancozeb or chlorothalonil	
	Chocolate spot	–	Carbendazim or procymidone	

Note that metiram is considered comparable to mancozeb and can be substituted for it.

9.2 Symptom sorter

Faba bean diseases can present in a similar manner, for instance the symptoms of chocolate leaf spot, cercospora leaf spot and Ascochyta are similar. Without correct identification incorrect management strategies can be used. Tables 7 and 8 can be used to help diagnose diseases from other crop-damaging causes in faba beans.

Table 6: *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 and leaf spotting	Red-legged earth mite, chocolate spot
	Yellow/red	Stunted	Root rots, dodder
		Premature death	Root and crown rot
	Pale green	Leaf and 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/rabbit 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

Description	Crop effect	Plant symptoms	Disorder
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, Cercospora leaf spot, Alternaria leaf spot, hail
	Physically damaged	Leaf, stem & pods damaged	Triazine herbicide
	None obvious	Pods chewed	Native budworm
		Pod spotting	Oedema

Source: Faba Beans: The Ute Guide

Table 7: *Key features of the main faba bean diseases and disorders.* [12]

Disorder and cause	Seed-borne?	Symptoms	Distribution and occurrence	Survival and spread	Management
Waterlogging or root rotting (root anoxia—not a disease)	No	Slow death; little defoliation; roots not rotted but may be dark; plants hard to pull up	Patches; poorly drained areas; heavy rainfall; higher temperatures, i.e. later in season	Caused by insufficient supply of oxygen to roots	Avoid low lying or poorly drained paddocks or areas within paddocks. Sow in raised beds
Seed-borne root rot *Botrytis cinerea*, *Botrytis fabae* *Ascochyta fabae* (very rare)	Yes	Seedlings wilt and die, epicotyl rots	Rare, as seedling wilting and death is not common to either *Botrytis* or *Ascochyta* in beans. Occurs in random individual plants (not patches)	Seed	Quality seed; seed treatment, variety choice
Chocolate spot *Botrytis fabae* Including: Botrytis grey mould *Botrytis cinerea*	Yes/no	Leaf, flower, stem and pod lesions and rapid tissue death. Possibly lesions covered in mould	Occurs from late winter–early spring when canopy closes and warm humid conditions persist; individual plants but spread quickly to patches	Can be seed-borne, but mostly pathogen has airborne spores which can blow in	Sow a variety with best resistance available. Avoid highly susceptible varieties; use a foliar spray program; plant on wider rows; follow faba bean chocolate spot management package
Sclerotinia root and stem rot *Sclerotinia* spp.	Only as sclerotia in seed	Wilting and death; bleached root, collar and stem tissue; white cottony mould at site of lesion; sclerotia at lesions or inside stems	Root and collar lesions result from direct infection from sclerotia; stem lesions result from air-borne ascospores released from sclerotial apothecia, scattered or patches; favoured by denser canopies, wet events	Sclerotia persist in soil for many years; wide host range including pulses, canola, sunflowers and broadleaf weeds but not cereals or grasses	Sow seed that is clean of sclerotia. Avoid paddocks with history of *Sclerotinia* of its hosts; rotate with cereals; some varieties more susceptible

12 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

Disorder and cause	Seed-borne?	Symptoms	Distribution and occurrence	Survival and spread	Management
Rhizoctonia rot *Rhizoctonia solani*	No	Death of seedlings, stunting of survivors due to root damage, re-shooting after damping off of epicotyl	Can be a problem in irrigated crops grown immediately after cotton. Often occurs in 1–5m stretches of row	Survives in soil and on decomposing trash. Probably present in most soils	Allow time for decomposition of (preceding) crop debris. Tillage should help
Ascochyta blight *Ascochyta fabae*	Yes	Necrotic spotting on all plant parts; lesions with visible fruiting structures (pycnidia); stem lesions; plant death	Individual plants which can spread to small patches, which enlarge rapidly in after rain events to severely damage leaf, stem and pods, possibly killing areas of susceptible crops	Faba bean residue very important in spread especially header dust and surface water flow; infected seed; volunteers	Follow faba bean *Ascochyta* management package, which includes variety choice and foliar fungicides
Cercospora leaf spot *Cercospora zonata*	No	Small dark grey–black lesions on lower leaves early in the season. Change to brown/red as expand and can merge to large lesions. Defoliation in lower canopy at flowering	Scattered plants on infested soil, linked to faba bean history in paddock	Survives in soil and infested faba bean residue	Follow faba bean cercospora leaf spot management package published annually; includes foliar fungicides
Rust *Uromyces viciae-fabae*	No	Leaf, stem and pod pustules develop leading to tissue death	Occurs very early in early sown crops, but normally late in season when warm humid conditions persist; Most plants affected, but possibly in patches. Often in association with chocolate spot	Faba bean residue and self-sown seedlings very important in spread. Airborne spores can blow around	Avoid highly susceptible varieties; use foliar fungicide program; follow faba bean rust–*Ascochyta* management package
Root-lesion nematodes *Pratylenchus* spp	No	Often showing no symptoms. If severe, possibly poor growth; small black lesions on lateral roots sometimes visible	Can affect large areas of crop. *P. thornei* more prevalent on high clay content soils	Wide host range; survives & spreads in soil; anhydrobiosis allows nematodes to persist for prolonged dry periods	Farm hygiene; rotate species (faba bean is one); grow tolerant varieties
Stem nematode *Ditylenchus dipsaci*	Yes/no	Poor emergence and establishment, stunting and distortion of seedlings, swollen stem bases	Symptoms usually occur in patches, but the large sections of a crop can be affected in severe cases	Wide host range; survives and spreads in soil and plant residue	Farm hygiene; rotate species

Disorder and cause	Seed-borne?	Symptoms	Distribution and occurrence	Survival and spread	Management
Alfalfa mosaic virus Cucumber mosaic virus	Not in faba beans, but is in other pulses	Not necessarily an issue in faba beans. In other crops is initially bunching, reddening or yellowing, wilting or death of shoot tips; later discoloration	Initially scattered plants or patches, often at edges of crop; more common in thin stands and areas	Viruses persist and multiply in weeds and pasture legumes; aphid-borne	Establish uniform stand by using recommended sowing rates and times; sowing into standing stubble
Phloem-limited viruses (luteoviruses): Bean leaf roll virus Subterranean clover redleaf virus Beet western yellows virus Subterranean clover stunt virus	No	Death of entire plant; luteovirus-infected plants often have discoloured phloem	Close to lucerne, irrigated perennial clovers; seasons or districts with major aphid flights		Cereal stubble deters aphids; avoid sowing too early; grow resistant varieties

FAQ

9.3 Chocolate spot

9.3.1 Symptoms

Chocolate spot (*Botrytis fabae*) can cause extensive losses and is the major disease of faba beans in Western Australia (WA). The disease is seed-borne and crops may also be infected by wind-borne spores from residues of previous crops. As chocolate spot spores can survive in the soil for several years, there should be a rotation of at least three to four years before faba beans are grown on the same ground. [13]

The symptoms of chocolate spot are spots that range from small leaf spots to blackening of the entire plant. Leaves are the main areas affected, but under favourable conditions, the disease may also affect stems, flowers and pods (Photos 1–6).

The disease usually occurs in two phases: first a 'passive' phase where reddish-brown spots are peppered over the leaves and stem; and then an 'aggressive' phase, where tissue around the spots is rapidly killed, leaving large black or grey blighted sections on plant parts.

Photo 1: *Two examples of chocolate spot leaf lesions. Infections of chocolate spot in beans start as small brown spots and can expand across the leaf.*

Photos: SARDI

13 DAFWA (2015) Growing broad beans in Western Australia, Department of Agriculture and Food, Western Australia, https://agric.wa.gov.au/n/3762

Photo 2: *Poor podset and leaf loss from failing to protect against chocolate spot early.*

Photo: Pulse Australia

Photo 3: *Chocolate spot on flowers will prevent podset.*

Photo: SARDI

Photo 4: *Sporulation of chocolate spot on faba bean stems.*

Photo: Grain Legume Handbook, 2008

Photo 5: *Chocolate spot lesion on pod, leading to infection and staining on seed.*

Photo: SARDI

Photo 6: *Stained faba beans as a result of chocolate spot infection.*

Photo: SARDI

9.3.2 Economic Importance

Chocolate spot occurs in all areas where faba beans are grown. Losses range from minor to complete crop failure, depending on the severity and time at which infection occurs and the amount of spring rainfall.

In unprotected crops, the disease commonly reduces yields by 30–50% in a bad year, mainly by preventing podset (Photos 3 and 4).

Seed from badly affected plants may have a reddish-brown stain, which lowers its market value (Photo 6).

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 (*Alternaria alternata*) to infect the plants. Correct disease identification is necessary to avoid unnecessary spraying or incorrect fungicide use. [14]

9.3.3 Disease cycle

The fungus can survive in crop debris, in infected seed, or on self-sown plants. Infection usually begins when spores originating in infested faba bean trash are carried onto new crops by wind. Spores can be carried over long distances. Chocolate spot may also be introduced into new faba bean-growing districts by sowing infected seed. It can spread rapidly within a crop.

Chocolate spot is favoured by warm (15–25°C), humid conditions (>70% RH) that extend for four to five days. It typically develops later in the season, during flowering and after canopy closure. Yield loss due to chocolate spot results from pod abortion and plant damage. [15]

9.3.4 Control

The control of chocolate spot should follow the principles of integrated disease management (IDM) which include:

- crop rotation and paddock selection
- growing resistant varieties (Table 1)

14 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

15 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

- clean seed and fungicide seed dressings
- canopy management through time of sowing, seeding rate and row spacing
- regular crop monitoring
- strict hygiene on and off the farm
- strategic use of foliar fungicides.

Varieties with resistance to the disease should be grown in areas where the likelihood of chocolate spot is high.

Disease risk can be reduced by destroying all faba bean trash and self-sown plants before sowing, and by sowing disease-free seed in a crop rotation. Delayed sowing also reduces disease risk.

Seed dressings (Table 2) are not usually required, and only protect the emerging seedling from seed-borne *Botrytis* and common root rots.

Fungicides can be used to control the disease (see Table 4) and are generally used as protectants.

Fungicides available for chocolate spot include those containing mancozeb, chlorothalonil, carbendazim or procymidone. Copper products may have some efficacy. Chocolate spot is targeted in critical period 2, as well as critical period 3 (see Table 5).

If chocolate spot incidence 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. 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.

For carbendazim, observe the withholding period for grain prior to harvest (30 days). To ensure chocolate spot is controlled before it has a significant impact on the yield of the crop, the crop should be checked for disease every 7 days while the temperature remains below 15°C. If the weather is mild with day temperatures between 15°C and 20°C and humidity >70%, crop inspections should be made every 3 days.

Spraying to control chocolate spot 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. [16]

9.3.5 Variety choice

Moderately resistant (MR)

There are no moderately resistant (MR) varieties available currently.

Varieties with some resistance to chocolate spot may require fewer and later fungicide applications for chocolate spot (*Botrytis*) control. The disease simply moves slower in these varieties, but will be devastating if left unprotected in situations of high disease pressure. [17]

16 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

17 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

Moderately susceptible (MS)

Varieties: PBA Rana⍉, Nura⍉, PBA Samira⍉

If the disease is present or the risk is deemed to be high, apply an early foliar fungicide for chocolate spot, either just before canopy closure or before flowering. Repeating foliar fungicide applications during flowering and podding will help to ensure leaves are free of lesions. Application at late podding may be required to protect grain quality in high-risk situations or if the disease is present. 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 need just as many fungicide applications for Botrytis control as a susceptible variety. The disease does move slower in these varieties, but will be devastating if left unprotected in medium to high disease pressure situations. [18]

Susceptible (S)

Varieties: Farah⍉, Fiesta VF⍉

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 to be high. Repeat applications will be needed during flowering and podding, until flowering finishes and there is no more new growth. Ensure leaves are free of lesions so that grain can be filled and to protect grain quality in high-risk or disease-pressure situations. These varieties will have minimal Botrytis in the pods if the leaf canopy is kept clean of the disease. [19]

9.4 Ascochyta blight

9.4.1 Symptoms

Ascochyta blight (*Ascochyta fabae*) occurs in all faba bean growing areas of WA. It is yield limiting in the medium and high-rainfall areas of the central and southern agricultural regions. Ascochyta blight usually appears within 8 weeks of sowing. [20]

Ascochyta blight starts as grey spots that show through both sides of leaves (Photo 7). Ascochyta spots become irregularly shaped, and they may merge to cover most of the leaf surface (Photo 8).

Leaf tissue next to the affected patches may become black and die off. Many tiny black fruiting bodies develop within the patches as the disease progresses. The pale centres may fall out, leaving holes in leaves (Photo 9).

Patches on the stem tend to be elongated, sunken and darker than the leaf lesions, and are usually covered with scattered fruiting bodies. The stems may split and break at the point of infection, causing plants to lodge (Photos 10 and 11).

On pods, the infected patches are black and sunken (Photo 12). Well-developed patches can penetrate the pod and infect the developing seeds. Infected seeds may be smaller than normal and discoloured. Badly infected pods may split open and seeds can have brown or black stains (Photo 13).

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 (*Alternaria alternata*) to infect. Correct disease identification is necessary to avoid unnecessary spraying or incorrect fungicide use (Photo 14).

18 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

19 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

20 .DAFWA (2016) Faba bean: Ascochyta blight disease. Department of Agriculture and Food, Western Australia, https://agric.wa.gov.au/n/332

Photo 7: *Infections start as small grey spots and may spread to the leaf edge following moisture run. Inset: Ascochyta lesion.*

Photo: Grain Legume Handbook, 2008

Photo 8: *Typical Ascochyta blight lesion.*

Photo: SARDI

Photo 9: *Older infections turn pale with black specks.*

Photo: Grain Legume Handbook, 2008

Photo 10: *Stem infections are sunken with pale centres. Ascochyta blight on bean stems causes stem breakage and lodging.*

Photo: Grain Legume Handbook, 2008

Photo 11: *Severe stem infections can cause complete blight of stems (on left).*

Photo: Grain Legume Handbook, 2008

Photo 12: *Ascochyta blight pod lesions are black and sunken and affect seed quality. They range from small isolated spots to the large multiple infection sites shown here. Timely protection is required: it is all too late when it gets to this stage.*

Photo: DPI Vic

Photo 13: *Faba bean grain with Ascochyta blight damage.*

Photo: SARDI

Photo 14: *Spotting from herbicide application can look like Ascochyta blight or Cercospora leaf spot, but note the absence of pycnidia (fruiting structures).*

Photo: SARDI

9.4.2 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 (5–15°C) conditions and usually develops early in the growing season. Damage from stem infection often results in serious crop lodging in susceptible varieties. However, the development of this disease can also be important late in the season.

Pod infection with Ascochyta blight can cause seed staining and the subsequent downgrading of faba bean grain. [21]

9.4.3 Control

Use varieties that have some resistance. In the central and southern agricultural areas of WA, varieties that are at least moderately resistant to Ascochyta blight (such as Fiesta VF⚖) should be used. More resistant varieties (such as Farah⚖) will be required in southern high-rainfall areas that favour the disease.

Avoid paddocks in which faba beans have been grown in the past three to four years or which are within 500 metres of stubble from the previous year's crop.

In areas where faba beans have not been grown, or not grown for several years, take care not to introduce the disease by sowing infected seed.

Resistant varieties should not require foliar fungicide sprays for Ascochyta blight. On more susceptible varieties, in areas where Ascochyta blight occurs regularly, fungicidal sprays may be required early in the season. [22]

Seed dressings (Table 2) only protect the emerging seedling from seed-borne Ascochyta and seed-borne Botrytis infection. Seed dressings will not protect the emerged seedling from rain-drop-splashed Ascochyta or wind-borne Botrytis.

It is recommended that seeds not be treated.

Ascochyta management strategies should be based on the principles of IDM, which include:

- crop rotation and paddock selection
- growing resistant varieties (Table 1)
- clean seed and fungicide seed dressings
- regular crop monitoring
- strict hygiene on and off the farm
- strategic use of foliar fungicides

9.4.4 Variety choice

Resistant (R)

Varieties: PBA Rana⚖, Nura⚖, Farah⚖, PBA Samira⚖,

Only consider applying an early foliar fungicide for Ascochyta blight if the disease is present and the risk is high.

A foliar fungicide applied during podding is unlikely to be required to protect grain quality in most situations. These varieties have resistance to Ascochyta blight in the pods.

Varieties with resistance to Ascochyta blight require fewer and later fungicide applications for control, if at all. This may result in the early development of chocolate spot infection, which would have normally been controlled as a result of fungicide applied for early Ascochyta blight in less-resistant varieties. Early monitoring and control of chocolate spot is still critical in Ascochyta-resistant varieties.

Susceptible (S)

Varieties: Fiesta VF⚖

Foliar fungicide applications for Ascochyta blight control will be necessary in most areas, and commencing early. Apply a fungicide before the disease is detected, from early emergence (six to eight weeks) through flowering and until four weeks

21 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

22 DAFWA (2016) Faba bean: Ascochyta blight disease. Department of Agriculture and Food, https://agric.wa.gov.au/n/332

before maturity. Starting early with protective applications is critical, as control is often ineffective if fungicides are applied after the disease has taken hold. [23]

9.5 Sclerotinia stem rot

9.5.1 Symptoms

MORE INFORMATION

GRDC (2014) Sclerotinia stem rot in canola. Fact sheet. GRDC.

Reported incidences of Sclerotinia infection in lupin crops have increased across WA's southern grain-growing districts. While the focus of reports is on canola and lupins, other pulse crops, including faba beans, chickpeas, field peas and lentils, may be threatened by Sclerotinia. As there is already a high incidence of Sclerotinia in canola in some areas of WA, there are high levels of Sclerotinia in the soil, so the risk of Sclerotinia causing economic losses in lupins and other pulse crops has increased. However, the degree of incidence and severity of Sclerotinia in lupins, chickpeas, faba beans, field peas and lentils is not yet known and useful control strategies may need to be researched or given extension support. [24]

Sclerotinia stem rot (which is caused by *Sclerotinia trifoliorum* var. *fabae, S. sclerotiorum, S. minor*) can attack plants at any stage of growth. Sclerotia (2–5 mm in diameter) form on the surface of infected plants and in the central cavity of the stem. These sclerotia are usually white at first, then turn black. The disease usually affects isolated plants, rather than patches of plants, in crops.

In young plants the infection usually begins close to ground level and a slimy rot extends into the stem and down into the roots. Older plants can get the infection on any part of their stems, leaves or pods. Infected plants suddenly wilt and collapse and are easily pulled from the soil.

9.5.2 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 faba beans are not grown.

Sclerotinia may act as either a leaf or a root disease. The foliar form of the disease may be spread by airborne 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.

While damage to the foliage from any source encourages Sclerotinia infection, the fungus can also infect uninjured tissue.

Sclerotinia root disease occurs when soil-borne spores directly invade the root tissue. A slimy root rot develops and infected plants suddenly wilt and die.

9.5.3 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 so can be used in the rotation.

Lower seeding rates, wider row spacing and good weed control allow a more open crop, which remains drier and is less prone to disease.

23 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties.

24 A Meldrum (2015) Sclerotinia survey for lupins and pulses. Extension Hub, https://www.extensionhub.com.au/web/field-crop-diseases/display/-/asset_publisher/ZQCuEErcXxu9/content/sclerotinia-survey-for-lupins-and-pulses/pop_up?_101_INSTANCE_ZQCuEErcXxu9_viewMode=print&_101_INSTANCE_ZQCuEErcXxu9_languageId=en_AU

9.6 Botrytis grey mould

9.6.1 Background

Botrytis grey mould (BGM) in faba beans is caused by *Botrytis cinerea*. It is a minor problem compared with chocolate spot (*Botrytis fabae*). The control of BGM in faba beans is the same as for chocolate spot. As with chocolate spot, flowers are especially vulnerable to BGM infection.

9.6.2 Economic importance

Botrytis grey mould and chocolate spot are sometimes found in association. Occurrence is worst in wet seasons, particularly when crops develop very dense canopies.

Discoloured seed may be rejected or heavily discounted when offered for sale. If seed infection levels are >5% it may be worth grading the seed.

9.6.3 Biology and epidemiology

The life cycle of BGM in faba is similar to that of chocolate spot.

Botrytis cinerea has been recorded on over 138 genera of plants in 70 families. This wide range of hosts and saprophytic capacity means that the inoculum of *B. cinerea* is rarely limited; if conditions favour infection and disease development, BGM will occur.

This makes management of BGM different from that of Ascochyta blight, which is more dependent on inoculum, at least in the early phases of an epidemic. [25]

9.7 Root rots

9.7.1 Symptoms

Root rots in faba beans are caused by many pathogens: *Fusarium spp*. *Pythium spp*. *Rhizoctonia solani* and *Phoma medicaginis* var. *pinodella*.

Seedlings affected by root rot gradually turn black and their leaves droop. The plants usually do not collapse completely. The taproot may become quite brittle (except in Pythium root rot, where they become 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, which are often scattered through a crop, dry off prematurely.

In some cases, seeds may rot before they emerge.

9.7.2 Economic importance

Root rot can occasionally be a serious disease, especially when soils are wet for prolonged periods.

9.7.3 Disease cycle

As all the fungi responsible for root rot are soil dwellers, soil is the most important medium of transmission. The fungi can survive from crop to crop in the soil, either on infected plant debris or as resting spores.

25 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

Wet soils help these fungi invade plant roots, where they repress root development. Wet conditions also encourage the spread of the disease within a field. The reduced root development causes the plants to die when they are stressed.

Spores of the fungus produced on crop residue can be carried onto the new crop by wind. Infection can occur at any stage of plant growth, provided conditions are favourable. Moisture is essential for infection to occur.

During wet weather, the disease may spread further, with spores of the fungus being carried onto neighbouring plants by wind and rain-splash.

Severe pod infection can result in reduced seed set and infected seed.

MORE INFORMATION

C Benjamin (2013) New faba bean rust option. Ground Cover. No. 106. September–October 2013. GRDC.

9.7.4 Control

The disease can be reduced by crop rotation. As this disease may also affect other pulses, faba beans should be sown in rotation with another non-legume crop. Although faba beans are deemed to be reasonably tolerant of waterlogging, they should not be grown in areas subject to severe waterlogging.

Damping-off can be controlled using fungicidal seed treatment, but this is not common practice with faba beans.

Disease risk can be reduced by planting clean seed to prevent disease build-up. [26]

9.8 Rust

9.8.1 Symptoms

Rust is most prevalent in the warmer faba bean-growing areas, and is not widespread in WA. Rust (*Uromyces viciae-fabae*) appears on leaves as numerous small, orange–brown pustules, surrounded by a light yellow halo (see Photos 15 and 16). As the disease develops, severely infected leaves wither and drop off (Photo 17). The rust pustules on the stems are similar to, but often larger than, those on the leaves. Late in the season, stem lesions darken as resting spores of the fungus are produced in pustules (Photo 18).

Isolated rust pustules may also appear on the pods. A severe rust infection may cause premature defoliation, resulting in smaller seeds. [27]

26 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

27 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

Photo 15: *Young rust infections have a pale yellow ring; by comparison, there is with no ring around chocolate spot infection (at pencil tip).*

Photo: Grain Legume Handbook, 2008

Photo 16: *Bean rust shows as orange 'bumps' on leaves.*

Photo: SARDI

Photo 17: *Leaves can be heavily infected with rust.*

Photo: Grain Legume Handbook, 2008

Photo 18: *Rust on faba bean stem.*

Photo: Grain Legume Handbook, 2008

MORE INFORMATION

C Benjamin (2013) New faba bean rust option. Ground Cover. No. 106. September–October 2013. GRDC.

9.8.2 Disease cycle

The fungus survives on stubble trash and infects self-sown bean plants directly, without the need for alternative hosts. Rust spores can be blown long distances onto new crops by the wind. Pustules form on the first few plants to be infected, and the disease spreads from these. Rainfall or dew is necessary for infection, but as infection can occur after only 6 hours of leaf wetness, it does not require extended wet periods to take hold.

Rust can occur from early- to mid-spring on, and is favoured by warm temperatures (>20°C). [28]

9.8.3 Control

Growing resistant varieties will reduce the risk of disease infections (see Table 1). Prevention is difficult because the fungus spores can be carried such long distances by wind.

Risk of the disease can be reduced by burning or burying old faba bean stubbles, and by rotating crops.

Fungicides may be used to control the disease and prevent a rust epidemic (see Tables 3) in areas where the disease is most prevalent. Several sprays will be necessary for adequate disease control. [29]

28 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

29 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

9.9 Rhizoctonia bare patch

Description

Rhizoctonia bare patch (*Rhizoctonia solani*) occurs on most soil types in the WA wheatbelt. The fungus causes root disease that results in the development of bare patches that look similar in all crop and pasture species.

It survives as fine fungal threads in organic matter. Following summer–autumn rains the fungus grows out of this material to infect the roots of young seedlings. Distinct patches of stunted or dying plants start to show four to six weeks after sowing. Patches are roughly circular with a diameter varying from 0.5–5 m; they may be elongated in the direction of sowing. There is almost no yield within the patches, and weeds in the patch are usually also affected.

Rhizoctonia is likely to be more severe where the fungus has been allowed to infect grass weeds or volunteer cereals prior to seeding.

Management strategies

Rhizoctonia bare patch has a wide range of hosts and cannot be controlled by rotating crops.

Tillage to a depth of 10–15 cm at about the time of sowing reduces the number and severity of patches. Modification of seeding machinery to cultivate 5–10 cm below the sowing depth will provide effective disease control in direct-drilled crops. Patches can also be controlled by deep ripping (25–30 cm) immediately before or after seeding. [30]

Summer rainfall events of at least 20 mm in the absence of weeds will reduce the inoculum levels in the soil and may reduce the disease impact. Early green-bridge control (i.e. control of weeds and crop volunteers) is a helpful cultural practice in paddock preparation. [31]

MORE INFORMATION

GRDC (2016) Rhizoctonia: western region. Tips and Tactics. GRDC.

GRDC (2014) New treatment for Rhizoctonia. Driving Agronomy Podcasts. 21 July 2014. Audio file. GRDC.

A Wherrett (2016) Rhizoctonia – Western Australia. Fact sheet. Soil Quality.

9.10 Viruses

Fortunately only few viruses are of major economic importance in Australia (Table 9).

Major viruses known to infect faba beans in Australia include:

- Bean leaf roll virus (BLRV)
- Beet western yellow virus (BWYV)
- Soybean dwarf virus (SBDV), syn. Subterranean clover red leaf virus (SCRLV)
- Subterranean clover stunt virus (SCSV)
- Clover yellow vein virus (ClYVV)
- Bean yellow mosaic virus (BYMV)
- Pea seed-borne mosaic virus (PSbMV)

Less common viruses that occur in Australia are:

- Alfalfa mosaic virus (AMV)
- Tomato spotted wilt virus (TSWV)
- Broad bean wilt virus (BBWV)
- Cucumber mosaic virus (CMV)

Except for TSWV, which is transmitted by specific thrips species, these viruses need aphid vectors to spread from infected to healthy plants.

30 DAFWA (2015) Diagnosing rhizoctonia bare patch in grain legumes. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-rhizoctonia-bare-patch-grain-legumes-0

31 DAFWA (2016) Control of green bridge for pest and disease management. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/grains/control-green-bridge-pest-and-disease-management

Table 8: *Virus categories and general symptoms*

Virus	Aphid transmission	Seed transmission*	Visual symptom type	Visual symptoms	Virus type (genus)
AMV Alfalfa mosaic virus	Non-persistent	Yes	Shoot tip	Necrotic or chlorotic local lesions, sometimes mosaics that do not necessarily persist	Alfamovirus
BBWV Broad bean wilt virus	Non-persistent	No	Mosaic, shoot tip	Vein clearing, mottling and necrosis of shoot apex, plant wilts, mottled, malformed and stunted	Fabavirus
BLRV Bean leaf roll virus	Persistent	No	Top yellowing	Upward leaf-rolling accompanied by interveinal yellowing of older leaves and flowers abscised	Luteovirus
BWYV Beet western yellow virus	Persistent	No	Top yellowing	Interveinal yellowing of the older or intermediate leaves. Mild chlorotic spotting, yellowing, thickening and brittleness of older leaves	Luteovirus
BYMV Bean yellow mosaic virus	Non-persistent	Yes	Mosaic	Transient vein chlorosis followed by obvious green or yellow mosaic. Usually no leaf distortion	Potyvirus
CMV Cucumber mosaic virus	Non-persistent	Yes	Shoot tip	Mosaics, stunting and possibly some chlorosis	Cucumovirus
ClYVV Clover yellow vein virus	Non-persistent	No	Shoot tip, mosaic	Mosaics, mottles or streaks, vein yellowing or netting	Potyvirus
PSbMV Pea seed-borne mosaic virus	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 Subterranean clover red leaf virus	Persistent	No	Top yellowing	Mild yellowing, stunting and reddening	Luteovirus
SCSV Subterranean clover stunt virus	Persistent	No	Top yellowing	Top yellows, tip yellows or leaf roll. Leaf size reduced, petioles and internodes shortened	Nanavirus

Virus	Aphid transmission	Seed transmission*	Visual symptom type	Visual symptoms	Virus type (genus)
TSWV Tomato spotted wilt virus	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 beans is minimal for all viruses, and of no epidemiological significance. It is, however, significant in terms of quarantine and keeping foreign virus strains out of Australia

Source: PBA

In some seasons, viruses can become a problem in faba bean crops. Viruses such as BLRV, BWYV and, to some extent, (PSbMV) are not seed transmitted, but they become established after aphid-vector activity.

The most important factors that predispose pulse crops to severe virus infection are:

- Infected seed or proximity to a substantial virus reservoir (e.g. lucerne, summer weeds, field peas for PSbMV).
- High summer–autumn rainfall and the subsequent uncontrolled multiplication of aphids on host plants. Early aphid flights to newly emerged crops can cause early infection and economic loss as infected plants act as a reservoir for further spread of infection within the crop.

Photo 19: *Tomato spotted wilt virus (TSWV) ring spot lesions.*

Photo: Joop Van Leur, NSW DPI

Photo 20: *Tomato spotted wilt virus (TSWV) stem and tip necrosis.*

Photo: Joop Van Leur, NSW DPI

Photo 21: *Tomato spotted wilt virus (TSWV) pod necrosis.*

Photo: Joop Van Leur, NSW DPI

Photo 22: *Necrosis of the growing tip can be caused by thrips feeding, not by TSWV.*

Photo: Joop Van Leur, NSW DPI

Photo 23: *Stem necrosis can be caused by other causes than TSWV, in this case chocolate spot.*

Photo: Joop Van Leur, NSW DPI

Photo 24: *Stem necrosis can be caused by other causes than TSWV, in this case frost.*

Photo: Joop Van Leur, NSW DPI

Photo 25: *Bean yellow mosaic virus (BYMV) in faba bean.*

Photo 26: *Bean seed showing Pea seed-borne mosaic virus (PSbMV) marking that can affect marketability.*

Photo: R. Kimber, SARDI

Photo 27: *Subterranean clover stunt virus (SCSV) in very early-sown beans.*

Photo: Wayne Hawthorne, Pulse Australia

Photo 28: *Soybean dwarf virus (SBDV) is also known as subterranean clover red leaf virus (SCRLV).*

Photo: Joop Van Leur, NSW DPI

9.10.1 Control

Aphids are the major means by which viruses enter faba bean crops. Aphids move between adjacent plants to feed, before colonising faba beans plants. The result is that faba bean crops show a characteristic scattered distribution of patches of virus-infected plants. This contrasts with crops such as chickpeas, in which aphids do not colonise, and only individual plants are infected.

Aphid activity is influenced by seasonal conditions and will require early monitoring in nearby crops and pastures.

There are no totally proven control measures for viruses. Virus management in pulses aims at prevention through integrated management practice that involves controlling the virus source and aphid populations, and minimising virus transmission into and within the pulse crop.

Application of seed and foliar insecticides aimed at preventing feeding by aphids can help, but needs further confirmation that they can prevent infection by viruses.

Rotate pulse crops with cereals to reduce virus and vector sources and, where possible, avoid proximity to perennial pastures (e.g. lucerne) or other crops that host viruses and aphid vectors. Eliminate summer weeds and self-sown pulses that are a green-bridge host for viruses and a refuge for aphids and their multiplication.

Virus risk can be managed by combining a number of different control measures:

- Suppressing the virus source within the crop. Sow seed with <0.1% seed infection.
- Distancing crops from lucerne, weeds and other species that act as a reservoir for viruses, disease and aphids.

MORE INFORMATION

GRDC (2010) Aphids and viruses in pulse crops. Fact sheet. GRDC.

GRDC (2010) Green bridge. Fact sheet. GRDC.

GRDC (2015) Reducing aphid and virus risk. Tips and Tactics. GRDC.

E Leonard (2010) Smarter pest management. Ground Cover. No. 86. May–June 2010. GRDC.

- Controlling volunteer weeds during summer and autumn.
- Using a seed treatment of Gaucho 350SD® (imidacloprid), which is registered for early aphid protection to control persistently transmitted viruses.
- Retaining cereal stubble to deter aphids and decrease aphid landing rates.
- Sowing at recommended plant densities to achieve early closure of the crop canopy (closed canopies deter aphids)— note high seeding rates and narrow row spacing to provide early canopy closure assists in aphid control, but conflicts with management of fungal diseases.
- Sowing at recommended times to avoid autumn aphid flights.
- Ensuring that faba bean plants are made less attractive to aphids by minimising seedling disease, herbicide damage and poor nutrition.

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. [32]

9.11 Sample preparation for diseased plant specimens

For accurate diagnoses it is important that specimens are carefully selected, well presented and submitted with the correct forms.

For information about plant disease and virus testing, sample submission forms and sampling techniques, contact:

DDLS Specimen Reception
Tel: 08 9368 3351
Email: ddls-stac@agric.wa.gov.au

32 Pulse Breeding Australia (2013) Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 6—Disease Management.

Plant growth regulators and canopy management

Not applicable for this crop.

Crop desiccation/spray out

Key messages

- Early desiccation should be avoided because it will result in yield and quality losses.
- Windrowing faba bean crops encourages uniform maturity in paddocks that are ripening unevenly.
- Crop-topping can limit weed seed-set from survivors of normal in-crop weed control.

11.1 Desiccation

Desiccation prepares the pulse crop for harvesting by removing moisture from plants and late-maturing areas of the paddock.

Pulses can be desiccated pre-harvest to enable earlier harvest and to dry out green weeds. Desiccation is an aid to a timely harvest, particularly where uneven ripening occurs across a paddock, and helps to avoid weather damage. Timing is based on crop physiological maturity.

In faba beans, desiccation may be initiated when seed from the top of the plant has a black scar (hilum) and the lower 25% of pods are black. At this stage, the upper pods are still bright green, and the lowest pods have seeds with a completely black hilum. [1]

If the seed is to be retained for sowing, do not use glyphosate to desiccate faba beans.

Desiccants are applied when the grain is 75–90% mature, to avoid reducing the quality of the harvested grain.

Desiccation is a valuable management tool especially under conditions where:

- There is a problem with green weeds at harvest.
- Improved harvest efficiency is needed.
- Desiccation eliminates many of the problems associated with green stems and gum build-up, which cause uneven flow of material through the header, and 'jamming' problems.
- Minimising jamming enables drum speeds to be reduced in many cases, resulting in a reduction in cracked or damaged grain.
- 'Early' summer rain causes reshooting and re-flowering of faba beans.
- There are problems with patchy or delayed crop maturity on heavy clay soils.
- 'Early harvest management' is being adopted.

The benefits from crop desiccation are similar to those from windrowing, and include more uniform maturity, reduced problems associated with late weed growth, and advanced harvest date. Unlike windrowing, the crop is not placed on the ground so there is less risk of wet weather causing problems.

Timing is critical, and early desiccation should be avoided because it will result in yield and quality losses. Premature desiccation may cause staining of the seed coat, an excessive number of green cotyledons in the sample, or small or wrinkled seed, all of which can decrease marketability.

Crop damage from ground rigs can also be an issue, particularly in tall crops. Tramlining may help, and this should be considered at sowing time if crop desiccation is likely to be used. [2]

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8–Desiccation, Harvest & Storage.

2 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8–Desiccation, Harvest & Storage.

11.1.1 Timing of desiccation

The optimal stage to desiccate the crop is when 90–95% of seeds have reached physiological maturity. Our best guide presently is to base this on a visual inspection of the seeds within the top 25% of uppermost pods on each main fruiting branch (Figure 1).

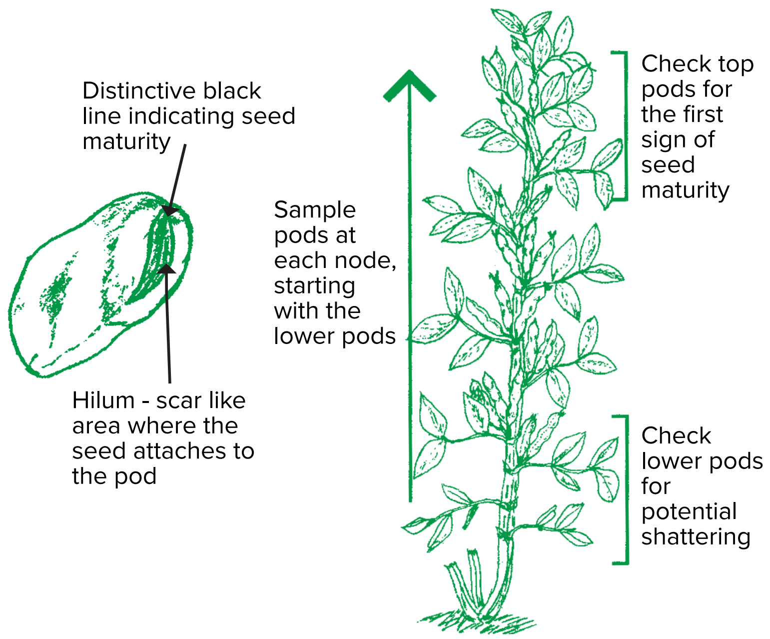

Figure 1: *Assessing correct timing of desiccation.*

Source: Gordon Cumming

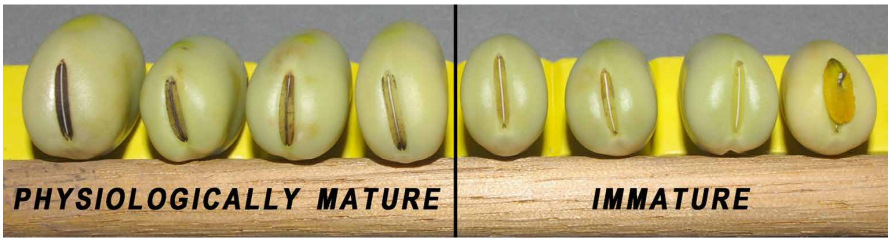

Photo 1: *Assessing correct timing of desiccation.*

Photo: Grain Legume Handbook 2008

11.1.2 Effect of desiccants on green, immature seeds

Application of 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 discoloration of the seed coat
- a reduction in seed viability (an increase in dead or abnormal seeds)

In faba bean crops intended for use as seed or for sprouting markets, glyphosate should not be used because it will affect seed germination (Table 1), even when applied after the crop has matured.

Table 1: *Effects of desiccation 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 plus 6 days	64	29	93
Windrowed	Seed physiological maturity	89	2	91
	Seed physiological maturity plus 6 days	85	7	92

Source: Matthews and Holding 2004

11.1.3 Products registered for the desiccation of faba bean

Extracts from the product labels of Reglone® and Roundup PowerMax® are presented in Table 2. [3]

Table 2: *Products registered for desiccation of faba bean.*

Active ingredient	Example trade name	Rate	Critical comments
Diquat	Reglone (200 g/L)	2–3 L/ha	Spray as soon as the crop has reached full maturity. Helps overcome slow and uneven ripening and weed problems at harvest. *Do not* harvest for 2 days after application
Glyphosate	Roundup Attack (570 g/L)	0.645–1.7 L/ha	Apply when physiologically mature and <15% green pods. Use higher rates where crops or weeds are dense and where faster desiccation is required. *Do not* harvest within 7 days of application

Note: always read the label supplied with the product before each use.

Warning: do not use Glyphosate to desiccate faba beans that are to be used for seed or sprouting as germination is affected (see Table 1).

MORE INFORMATION

Pulse Australia (2015) Desiccation and croptopping in pulses.

Australian Pesticides and Veterinary Medicines Authority.

DAFWA (2014) Weed control in mature crops and pre-harvest desiccation. Fact sheet.

11.2 Crop-topping

Crop-topping is part of an integrated weed management (IWM) strategy; it should not be considered a sole strategy.

Crop-topping is the late application of herbicides to prevent weed seed-set from survivors of normal in-crop weed control without substantially affecting crop yield and grain quality. It can be used to control 'escapees' from other weed-management treatments, as a late post-emergent salvage treatment, or for managing herbicide resistance. [4]

Crop-topping can deliver a number of benefits in addition to reducing weed seedset, including:

3 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8–Desiccation, Harvest & Storage.

4 DAFWA (2016) Crop-topping pulse crops. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/lupins/crop-topping-pulse-crops

- improved harvest due to even maturity of crops (particularly pulses)
- improved harvest, grain quality and storage by desiccating late weed growth in seasons with late rain [5]

Timing is aimed at the 'soft dough' stage of the target grass-weed species, typically annual ryegrass, to stop seed-set. If wild radish is the target, the herbicide should be applied at the pre-embryo stage. In most crops, targeting wild radish exposes the crop to a heightened risk of damage.

Crop-topping faba beans can result in discoloured seed coat or cotyledons (kernels), leading to either rejection or severe downgrading at delivery. Similarly, in other pulses growers need to be aware of grain-quality defects if crop-topping is done earlier than crop desiccation or windrowing.

Timing of crop-topping can be marginal in faba beans. Fiord⁽ᴰ is the earliest maturing faba bean variety, but in many cases, even Fiord⁽ᴰ will not mature early enough to enable efficient crop-topping without affecting grain quality and yield.

Crop-topping prematurely can potentially lead to a loss of grain quality, particularly if it occurs just before a significant rainfall event. Also some of the smaller pods near the top of the plant are more exposed to direct contact by the desiccant spray. Seeds in these less mature pods are not at physiological maturity (black-hilum stage) when they dry down.

The rate of product application or desiccant product choice can also influence speed of dry-down. [6]

Photo 2: *Faba bean crop mature enough for crop-topping.*

Photo: W. Hawthorne, Pulse Australia

5 GRDC (2014) Integrated Weed Management Hub Section 5: Stopping weed seed set. https://grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set#desiccation

6 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8–Desiccation, Harvest & Storage.

Photo 3: *A faba bean crop that has been crop-topped, and shows leaves that are drying down.*

Photo: W. Hawthorne, Pulse Australia

11.2.1 Glyphosate and paraquat

MORE INFORMATION

[R Barr (2016) Paraquat preferred for crop-topping pulses. GRDC Ground Cover Issue 124.]

Both glyphosate and paraquat are registered for crop-topping pulses, however, growers should consider choosing paraquat rather than glyphosate where possible to minimise resistance development.

A key tactic of integrated weed management (IWM) is to rotate modes of action as much as possible. While glyphosate is heavily relied upon in grain growing, paraquat can be a sensible choice for crop-topping pulses to avoid the overuse of glyphosate.

Paraquat can be applied up until the soft dough stage of ryegrass, whereas effective control with glyphosate needs to be at the milky dough stage. This means growers using paraquat can wait a little longer to allow the crop to mature and minimise yield losses. [7]

11.3 Seed and pod development

The maturation of pods and seed is staggered up each podded branch and between branches. The effects of higher temperatures and varying degrees of moisture stress on the plant mean that maturity time is generally more compressed and of shorter duration than flowering.

A problem often confronting agronomists and growers is how to optimise the timing of the desiccant spray when there are various stages of seed maturity on individual plants, as well as across the paddock.

This can be further compounded by soil-type variation or paddock micro-relief.

Inspection of commercial crops nearing desiccation point often reveals that while the lower 30% of pods have dried to <15% seed moisture (seeds have detached from the pod), the upper 25% of pods on each fruiting branch are still at 30–40% moisture content and at varying stages of maturity. [8]

7 R Barr (2016) Paraquat preferred for crop-topping pulses. GRDC Ground Cover Issue 124, September-October 2016. https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-124-SeptemberOctober-2016/Paraquat-preferred-for-croptopping-pulses

8 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8–Desiccation, Harvest & Storage.

11.4 Windrowing

Windrowing of faba beans has become common in some areas as growers try to reduce problems associated with direct-heading, uneven crop maturity or weed-seed management. It is primarily used to bring the harvest date forward, uniformly ripen the crop, and protect the crop from shattering when harvest is to be delayed. It can also be a part of general management to reduce seed-set of weeds.

Windrowing faba bean crops provides a number of benefits:

- It aids uniform maturity of the crop in paddocks that are ripening unevenly.
- Problems caused by late-maturing weeds are avoided. These include delayed harvest, which increases the risk of staining caused by the weather and disease, and storage problems from green-weed contamination.
- It can advance harvest date when done as soon as the crop is mature, avoiding clashes with other crops such as cereals.
- Weed seed is moved into a windrow that can be burnt after harvest.
- Low pods are harvested rather than being left behind, because of the lower cutting height possible with a windrower.
- Excessively tall crops can be better handled at harvest. When tall crops are direct-headed, the reel can be in the way, pushing plants forward, and causing problems with feeding material into the header and losses on the cutter bar. Direct-heading of very tall and lodged crops is also very slow. Windrowing can dramatically increase header efficiency.

Windrowing should only be used if direct-heading of the faba bean crop is likely to cause problems, and should not be considered necessary every year.

There are several risks to windrowing crops:

- Windrowing too early (prior to crop maturity) can cause significant yield and quality losses. Small and shrivelled seed will result from the drying down of immature seed.
- Windrowing too late can cause shatter losses as the cutter bar hits the crop.
- The seed coat can discolour if left too long in the windrow, especially in wet conditions when mould growth and seed staining can occur.
- Summer storms after windrowing can cause moisture to be retained in the windrows, making it difficult to pick up the windrow without mud, and potentially leading to quality deterioration.

Timing of windrowing is critical and should be based on seed maturity rather than measurements such as leaf colour and drop, or pod colour, as these can be misleading. Leaves can be prematurely lost and pods blemished by disease.

The cutting height for windrowing should be just below the bottom pods, with the reel following the top of the crop. The reel speed should be quite slow. The delivery opening in the windrower should be large enough to prevent blockages or there will be lumps in the windrow. Windrows should be dense and tightly knit for best results (Photos 4 and 5).

Curing should take about 10–12 hot days. However, heavy infestations of wild radish and other weeds could delay drying.

Pick-up fronts are the most common type for harvesting windrows. However, crop lifters placed close together on open fronts have also been used with some success. [9]

9 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8–Desiccation, Harvest & Storage.

Photo 4: *Faba bean windrows.*

Photo: W. Hawthorne, Pulse Australia

Photo 5: *Inside an opened windrow of faba bean.*

Photo: W. Hawthorne, Pulse Australia

MORE INFORMATION

DAFWA (2012) Burning windrows for weed control–video

GRDC (2010) Stewardship for late season application of herbicides in winter crops. Fact sheet.

Harvest

Key messages

- Yield losses increase significantly the longer harvest is delayed.
- Early-harvested grain means less disease and weathering, and better colour.
- Rotary harvesters cause less grain damage than conventional harvesters.
- Even at low moisture content, early-harvested faba bean seed is more resilient against breakage during harvesting and subsequent handling.

FAQ

12.1 Timing the harvest

Early harvest of pulses is critical, because delays can result in significant yield losses due to lodging, shattering and pod loss. Grain quality, and hence price, can also suffer through mechanical damage or weathering and seed staining. Moisture levels at harvest affect the quality of the grain in storage.

If harvesting grain for seed, germination rates are improved if grain is harvested at 12–14% moisture and then stored in aerated silos or immediately graded and bagged. Crop desiccation with herbicides prior to crop maturity may reduce grain quality and seed germination.

A grower's decision to delay faba bean harvest is usually influenced by the following factors:

- Faba bean harvest can clash with cereal harvest. Faba beans are still largely considered a 'secondary' crop, with wheat or barley taking precedence at harvest time.
- The perception that faba beans 'weather' reasonably well, although this is a fallacy (see later discussion).
- Uneven ripening of faba bean crops can occur if not desiccated or windrowed, especially when grown on heavy clay soils or variable soil types. Having a good even plant stand helps to keep the crop even as dry-down occurs prior to harvest.
- Faba beans are considered slower or more difficult to harvest. This does not have to be the case if desiccation is used, and the header is modified to suit them. [1]

12.1.1 Yield losses

Yield losses increase significantly the longer harvest is delayed.

Although faba beans are not normally prone to pod splitting and shelling out in all but extreme wet-weather conditions, they are very prone to pod splitting and pod drop after wet weather once the plant has dried down. Weathering of the grain can also occur in split pods.

Yield losses of up to 30% have been recorded in the field:

- It is estimated grain losses due to a two to four week delay in harvest range from A$93–$238/ha, depending on seasonal conditions.
- Most of the losses are due to pod loss at the header front, or unthreshed pods lost out the back of the machine.

Lodging can increase as faba beans are left standing, and the risk is higher if the crop is high-yielding and has been planted on wide rows.

Loss of moisture below the national pulse receival standard of 14% moisture content results in a substantial loss to the grower, as this example shows:

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

- 500 t of faba bean at 14% grain moisture, valued at $450/t, is worth $225,000.
- The same grain harvested at 8% moisture delivers 470 t, so at $450/t is worth $210,600.
- This is a loss to the grower of $14,400. [2]

12.1.2 Deterioration in grain quality

Grain quality deteriorates the longer mature faba beans are left exposed to weathering in the field.

The seed coat of faba bean is very prone to cracking if it has been exposed to wetting and drying due to rain or heavy dew. Expansion of the seed as it absorbs moisture, and then contraction as it dries, weakens the seed coat. This renders it much more susceptible to mechanical damage during harvest and handling.

Levels of cracked and damaged grain can be as high as 50% in extreme cases of field weathering and prolonged rainfall.

Early-harvested faba bean seed is much more resilient to breakage during harvesting and subsequent handling, even at low moisture contents.

Some faba beans are processed into dhal or flour by removing the seed coat (hull) and splitting the cotyledons. Visual appearance is still critical for marketing though. Older seed that has darkened with age splits better than new-season grain. The milling process uses abrasive mills to gradually abrade the seed coat from the cotyledons, so the process relies on the seed coat being firmly attached to the cotyledons.

Cracking and weakening of the seed coat prior to processing substantially reduces the recovery percentage of splits, as well as reducing the quality of the final product.

Field-weathered faba beans after rain are also more difficult to thresh out at harvest, and often contain much higher levels of unthreshed pods and pod material.

Faba bean seeds discolour and darken when exposed to field weathering. Darkening of the seed coat is caused by oxidation of polyphenol compounds (tannins). The following conditions play a major role in accelerating seed coat darkening:

- rainfall
- cool–mild temperatures
- high humidity
- sunlight

Usually, there is no direct penalty or discount for a moderate degree of seed coat darkening; however, 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 faba bean-exporting countries (particularly France and the UK). We are likely to see much greater segregation according to seed coat colour, and premiums paid for lighter coloured, large-seeded faba bean types, as new varieties with these traits are developed and the Australian industry becomes more quality-conscious.

Several other problems can lessen seed quality:

- Weathering of seed due to delays in harvesting can substantially increase mould infection levels. High levels of mould infection will also cause darkening of the seed coat. Humid (>70% relative humidity), wet conditions favour the development of a range of fungi in late-harvested faba bean crops.
- Increased risk of late Ascochyta infection can develop on dry senescing pods under wet conditions, and can penetrate through to the seed in susceptible varieties. The current export receival standard for visible Ascochyta lesions is a maximum of 1% on the seed cotyledon (kernel).

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2 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

MORE INFORMATION

The current Australian Pulse standards

- Native budworm (*Helicoverpa punctigera*) can occasionally attack senescing faba beans, particularly where rainfall has softened the pod. Insect-damaged seeds are classified as defective faba beans, and they cannot exceed the tolerance level of 3%. [3]

12.1.3 Missed marketing opportunities

Delayed harvest often means that growers miss out on premiums paid for early-harvested crops of good quality. This is the case in most years, with the possible exception occurring where major production problems have been encountered and there is a 'shorts' market place. Weathering and mechanical damage is also more likely in late-harvested crops.

Early harvest gives the grower some degree of control over how and when the crop is marketed, whereas growers of late-harvested faba beans can often be 'price-takers' in a falling market, or may encounter delivery delays. [4] If the market starts to slide, many farmers will put the faba beans into storage and market them away from the harvest period, often prepared to leave them in storage until they get the price that they want.

12.2 Implementing early-harvest management

A range of management components contribute to an early-maturing crop, and all can be important at different times and for different reasons. It is important to understand the potential and limitations of each component. Optimal results in terms of yield, profit and timing will come from these components being applied in the most appropriate and balanced way, and as dictated by seasonal conditions.

These components include:

1. Sowing

- Sow at the earliest opportunity, but within the preferred planting window for your area.
- Moisture-seeking equipment and/or press-wheels can significantly enhance seeding opportunities under marginal soil moisture conditions. The success of moisture seeking, particularly in marginal conditions, is increased greatly by running a set of Kelly discs (or something similar) over the paddock immediately after planting and before applying residual herbicides. This seems to prevent drying down into the disturbed soil and helps to achieve a more uniform establishment of the crop.
- Use adapted varieties that meet your target for early harvesting.
- 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.

2. In-crop management

- Control Botrytis grey mould if present during flowering.
- Control native budworm during flowering to maximise early podset.

3. Harvest management

- Consider windrowing to enable earlier maturity and harvest date.
- Consider using a desiccant to dry late plants and any weeds.
- If using glyphosate (or equivalent registered products) to terminate crop growth at the 80–90% black–brown pod stage, be aware of potential impacts on seed quality.
- Set up the header to operate efficiently at 14–15% grain moisture content.

3 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

4 Pulse Breeders Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

MORE INFORMATION

R Barr (2016) Paraquat preferred for crop-topping pulses. GRDC Ground Cover Issue 124, September-October 2016.

- A major advantage of high-moisture harvesting is that harvest can commence earlier in the season and earlier each day. For example, harvesting at 14% moisture content rather than 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. [5]

12.3 Harvesting and header settings

Faba beans can be harvested with minor adjustments and modifications to machinery. They are easily threshed, so open the concave clearance and reduce the drum speed.

If there are many summer weeds, the drum speed may need to be increased to ensure weeds do not block the machine. Pulses are larger than wheat, so a concave with many wires or blanked-off sections can stop grain separation. To get the best performance, alternate wires and blanking-off plates will have to be removed. Maximum wind settings and barley sieve settings should ensure a good sample (Table 1).

When harvesting pulses for seed, take extra care to reduce grain cracking, even if this means making a poor sample. Gentle harvesting will give the best seed quality. Rotary harvesters are gentler on the crop and generally cause less grain damage than conventional harvesters.

Faba beans vary in height from 15 to 80 cm, with pods held up in the canopy. This means direct heading without crop lifters is possible with open-front and closed-front machines. Some fingers may have to be removed when using closed-front machines. Adjust thresher speed (400–600 rpm) and concave (10–30 mm) to suit. Removing alternate wires and blank-off plates from the concave will help to reduce cracking. If possible, cover the rasp bars with plates.

Harvesting grain at high moisture levels up to 14% should minimise cracking. [6]

Table 1: *Harvester settings for pulses.*

	Chickpeas	Faba beans	Green lentils	Red lentils	Lupins	Field peas	Vetch
Reel speed	Medium	Slow	Slow	Slow	Slow	Medium	Slow
Spiral clearance	High	High	Low	Low	High	Standard	Low
Thresher speed (rpm)	400–600	400–600	350–450	350–450	400–600	400–600	400–600
Concave clearance (mm)	10–30	15–35	20–30	10–20	10–30	10–30	10–30
Fan speed	High	High	High	High	High	High	Medium
Top sieve (mm)	32	32–38	32	16	32	25	25
Bottom sieve	16	16–19	8–16	3–10	16	16	10–16
Rotor speed (rpm)	700–900	700–900	350–450	350–450	700–900	700–900	Slow

Source: Grain Legume Handbook, 2008

5 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

6 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course Module 8-Desiccation, Harvest & Storage, 2013.GRDC/Pulse Australia.

12.4 Modifications and harvest aids

A straw chopper may be of value to chop up the stubble and spread it uniformly. Crop lifters are not required unless the crop is badly lodged or late-sown and drought-affected.

Finger reels are less aggressive than bat reels and cause fewer pod losses. Set the finger tine reel to force the material down onto the front. Moving the broad elevator auger forward can improve the feeding of light material.

Vibration due to cutter-bar action, plant-on-plant or reel-on-crop impact, and poor removal of cut material by the auger all cause shattering and grain loss.

Double-acting cutter-bars reduce cutter-bar vibration losses. Four-finger guards with open second fingers also reduce vibrations (Figure 1).

A lupin breaker is a cheap and simple device that can increase harvesting capacity to reduce grain loss. It is a small, serrated plate that attaches to the front spiral and creates an aggressive, positive feed action to clear-cut material from the front of the knife.

Figure 1: *Four-finger guards to reduce vibration.*

Source: W. Hawthorne, Pulse Australia

Other options are available to improve pulse harvesting (Photos 1–4). The costs and benefits must be assessed, because a small area of pulses may not justify the cost of some of the above modifications. [7]

Aussie-Air

The Aussie-Air directs an air blast through the reel fingers, and is suitable for both heavy and light crops.

The manufacturer claims an extra 15 horsepower is required to drive an Aussie-Air, but there is also an overall lesser horsepower requirement because of wider concave clearances. The actual horsepower required should be no more than for a heavy cereal crop.

7 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

Harvestaire

The Harvestaire (Photo 4) replaces a reel with a manifold that directs a blast of air into the front:

- The manifold causes some interference with the incoming crop.
- Correct orientation of air blast is very important.
- An optional secondary fan to increase the air blast is worthwhile.
- The device is more effective in light crops.

Vibra-mat

The Vibra-mat (Photo 4) is a vinyl mat that vibrates with the knife, stops bunching at the knife of open front headers, and helps the table-auger to clear-cut materials. Its chief advantage is that it is very cheap. It is more effective in light crops.

It is important to match groundspeed to table-auger capacity and crop density: too slow and the plants will not have enough momentum to carry to the front; too fast and the cut crop will not be cleared from behind the knife.

Extension fingers

Plastic extension fingers, ~30 cm long, that fit over existing fingers can save significant losses at the knife for little financial outlay (Photo 3). Pods that would have fallen in front of the knife are caught on the fingers and pushed into the comb by the incoming crop.

Extended fronts

Extended fronts are now available for some headers and reduce losses at the knife by increasing the distance between the knife and auger to a maximum of 760 mm. This helps to stop losses caused by material bunching in front of the auger, where pods can fall over the knife and be lost.

Platform sweeps

Platform sweeps are used in conjunction with extended fronts. They consist of fingers that rake material towards the auger to help eliminate bunching. They can also be used on conventional fronts.

Draper fronts

Draper fronts such as MacDon® and Honeybee® have large clearances behind the knife and carry the crop to the elevator. The front can also be used for cereals without modification. [8]

8 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

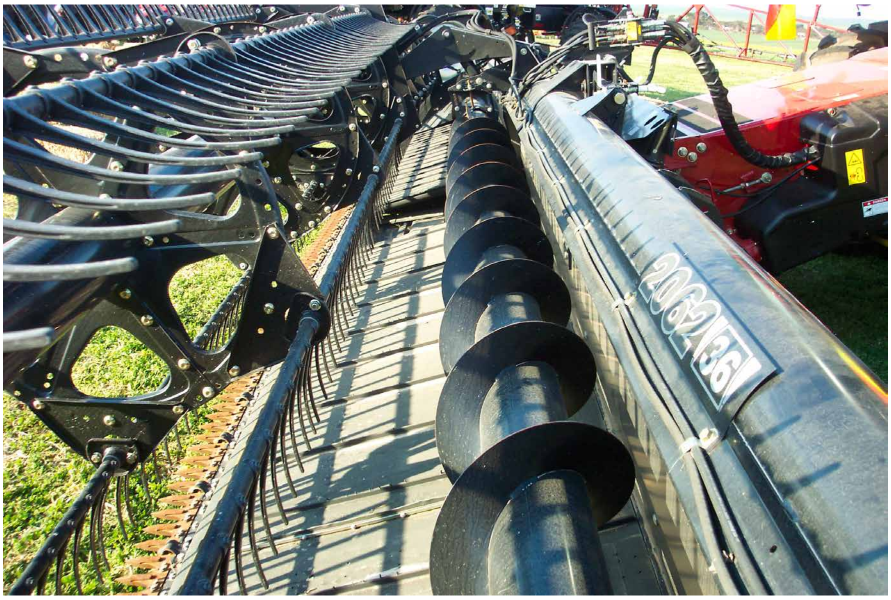

Photo 1: *Belt-front fitted with cross-auger.*

Photo: W. Hawthorne, Pulse Australia

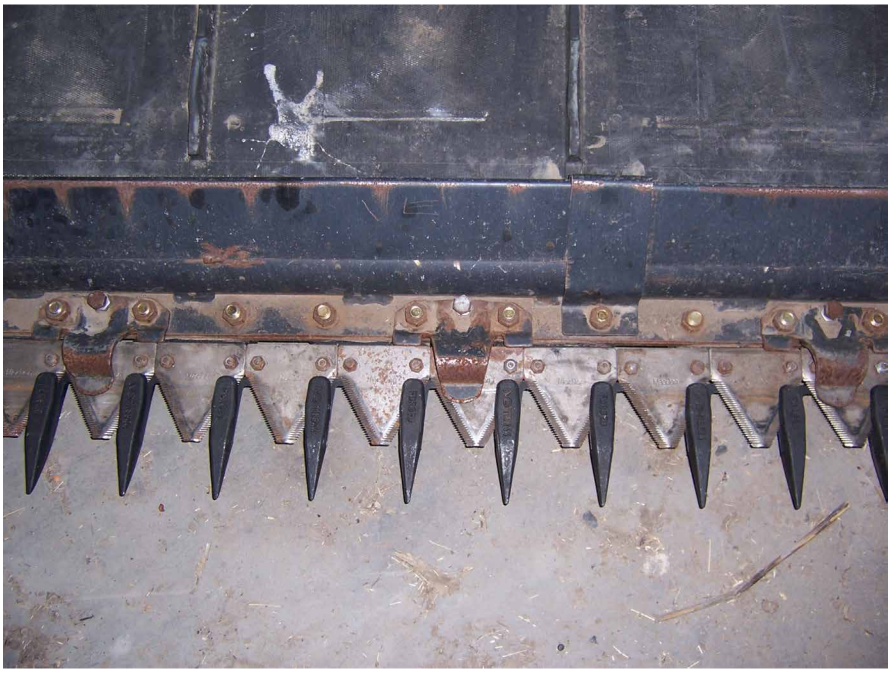

Photo 2: *Short fingers on a flex-front.*

Photo: Grain Legume Handbook, 2008

Photo 3: *Plastic extension fingers fitted to a draper front.*

Photo: G. Cumming, Pulse Australia

Photo 4: *Harvestaire front combined with extension fingers and a blue Vibra-mat.*

Photo: G. Cumming, Pulse Australia

12.5 Achieving a clean sample

Harvesting faba beans can be costly if debris such as stones, sticks or too much dirt is picked up with the crop. Machinery damage can be reduced by a variety of practices.

Rolling for harvest efficiency

Harvester damage may be reduced by rolling paddocks after sowing to flatten and firm soil and depress obstacles such as stumps and stones.

A flat soil surface at harvest becomes even more essential when crops are short in height at maturity or are tall but have lodged. Rolling after sowing to aid harvesting is required where the height of the crop to the lowest pods is low, which occurs particularly in lower rainfall areas or late-sown crops. Taller faba beans in higher rainfall or irrigation areas may also need rolling if lodging by harvest time is likely.

Another reason for rolling soils is to leave a flat soil surface for post-sowing herbicides to prevent herbicides washing out and accumulating in furrows.

Rolling also improves seed–soil contact in sandy, non-wetting soils, although press wheels normally will have achieved this.

Perforated screens

Perforated screens fitted on the bottom of the broad elevator, cross-augers, and grain and seconds elevators reduce the amount of dirt in the sample.

The perforated screen at the broad elevator is large and removes the dirt before it enters the main working mechanism of the harvester.

Harvester speed

Excessive harvester speeds will cause large losses of grain and force more dirt into the harvester. Generally, speeds >8 km/h are not recommended, irrespective of the type of harvester front used.

Harvesting in high humidity

Harvesting in humid conditions, when pods are less prone to shatter, can reduce grain losses. However, more unthreshed pods may appear in the grain sample. It is more difficult to harvest faba beans at night unless using a pick-up front or some positive height control, which will stop the front from digging into the dirt. Some growers have fitted wheels on the outer end of their fronts, as a depth-stop. Others have bought ultrasonic automatic depth controls to control header height.

Pick-up fronts

Pick-up fronts the same as or similar to those used for picking up windrows can be used to harvest windrowed faba beans. The pick-up fronts greatly reduce the amount of dirt entering the harvester and make harvesting easier, because harvesting height is not as critical as with a front fitted with lifters.

Pick-up fronts also make harvesting at night easier. The fingers on the pick-ups are closely spaced and they 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 cheaper, 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.

Flexible cutter-bar fronts (flexi-fronts)

The cutter-bars of flexi-fronts are hinged in short sections, allowing the whole front to flex and closely follow the ground contour. The use of skid plates are particularly good for short crops such as lentils and field peas, but can also be used on cereals by locking the hinged sections together. [9]

9 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

12.6 Lodged crops

If the crop has lodged, it is usually best to harvest in the opposite direction, or at right angles, to the direction the crop has fallen. Crop lifters may help, but can be difficult in control traffic situations.

If the crop was 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.

An even plant stand and the correct population density will minimise the impact of lodging at harvest time, because the plants lean on each other as they start to lodge and the header can usually still get under the lowest pods. [10]

12.7 Grower-kept sowing seed

The best area of a paddock should be selected and marked out well before harvest. Choose areas where weeds and diseases are absent and where the crop is vigorous and healthy, likely to mature evenly and develop good grain size. Also select areas at least 500 m away from other faba bean varieties, to reduce cross-pollination and, hence, contamination. Seed from this area should be harvested first, ideally at 11–13% moisture to avoid low-moisture grain that is susceptible to cracking.

Do not use glyphosate to desiccate the area that will be kept for seed. Desiccated crops are likely to produce poor germination quality seeds, so it is best to avoid keeping seeds from that area. Read the glyphosate label.

Seed-borne diseases can lower germination levels. Specialist laboratories can conduct tests for the presence in seed of a number of diseases, such as Ascochyta blight and Botrytis (chocolate spot or grey mould) in faba bean and chickpea.

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

The only way to accurately assess the germination rate, vigour and disease level of seed is to have it tested. [11]

12.7.1 Safe storage of seed

Retained seed must be stored correctly to ensure that its quality is maintained. Ideal storage conditions for pulses are at ~20°C and 12.5% moisture content.

Faba beans may be stored in sheds, bunkers, grain bags and silos. They do not suffer from pea weevil infestations; therefore, a sealed silo is usually not necessary. [12]

As with other grains, faba bean seed quality can deteriorate in storage, and the most rapid deterioration occurs under conditions of high temperature and moisture. Crops grown from seed stored under these conditions may have poor germination and emergence.

It is best not to store faba beans in bunkers or in grain (or 'sausage') bags for any length of time, because pockets of moisture can lead to black, mouldy grain, which can contaminate the remainder of the product (see Section 13). Black, mouldy grain can also taint the sample with an unpleasant odour, rendering it unacceptable for consumption. [13]

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10 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

11 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

12 Victoria DEPI (2013) Growing faba bean. Note AG0083, http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/growing-faba-bean

13 W Hawthorne (2008) Faba beans—For quality markets. Australian Pulse Bulletin No.14. Pulse Australia. http://pulseaus.com.au/storage/app/media/crops/2008_APB-Faba-beans-quality-markets.pdf

Reducing moisture and temperature increases longevity of the seed, although storage at very low moisture contents (<10%) may render faba beans more vulnerable to mechanical damage during subsequent handling. See Table 2 for an example with chickpea.

Table 2: *Effect of moisture content and temperature on storage life of chickpea seed.*

Storage moisture (%)	Storage temperature (°C)	Longevity of seed (days)
12	20	>200
	30	500–650
	40	110–130
15	20	700–850
	30	180–210
	40	30–50

Note: Most sowing seed will need to be stored for a period of ≥180 days

Source: Ellis et al. 1982

Storage at >13% moisture under Australian conditions is not recommended. Reducing temperature in storage facilities is the easiest method of increasing seed longevity. Not only will it increase the viable lifespan of the seed, it will slow the rate at which insect pests multiply in the grain.

To reduce temperature in grain silos:

- Paint the outside of the silo with white paint. This reduces storage temperature by as much as 4–5°C and can double the safe-storage life of grains.
- Aerate silos with dry, ambient air. This option is more expensive, but in addition to reducing storage temperatures, it is effective in reducing moisture of seed harvested at high moisture content.
- Heat-drying of faba bean sowing seed should be limited to temperatures <40°C. [14]

14 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 4–General Agronomy.

Storage

Key messages

- Good farm hygiene, storage choice and aeration cooling are important for maintaining grain quality.
- Harvesting grain at a higher moisture content (up to 14%) reduces field mould and mechanical damage, but increases the risk of deterioration during storage.
- High-moisture grain can be stored for short periods with aeration cooling, prior to drying or blending.
- Aeration cooling can reduce grain temperature and insect breeding, and aid in maintaining grain quality.
- Monitor stored grain monthly for moisture, temperature and pests.

13.1 Handling faba and broad bean

Faba beans are a very large, plump grain and are prone to mechanical damage during handling. This applies to over-dry grain (<10% moisture content) and to crops that have been exposed to weather damage prior to harvest.

Grain may be handled up to six times before delivery to receival points, so it is important to:

- minimise the number of handling stages wherever possible; and
- use efficient handling techniques that minimise damage.

The use of belt conveyors can reduce damage compared with conventional spiral augers.

If using augers:

- Operate slowly and full.
- Use large-diameter augers.
- The flight pitch should be greater than the auger diameter.
- Keep the auger length as short as possible.
- Keep auger incline as low as practical.
- Check the flight casing clearance; optimal clearance is typically 50% of grain size to minimise the amount of grain that becomes wedged between the auger spiral and the casing.
- Auger drives should be at the discharge end, not on the intake.

13.2 Grain cleaning

Cereals can be cleaned from most pulses with a 3 or 4mm rotary screen. The 3.75mm slotted screen is popular and will help screen out split grain. The paddles or agitators in rotary screens should be 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 and so avoid the problem. [1]

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

13.3 Grain quality

It is very important to monitor the quality of grain before and during harvest. Seed coat and kernel (cotyledon) can be discoloured by crop-topping or premature desiccation in parts of the paddock if ripening is uneven. Staining of seed caused by green plants in the crop or an admixture of splits, weeds, stones, etc., will only reduce the value of the grain and can lead to rejection or premium dockages.

Visual appearance is vital. Human food markets demand a quality sample without cracking, staining, de-hulled seeds or insect damage. Pulse samples showing no header damage will always be more acceptable to a buyer.

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 pest problems associated with storage.

13.3.1 Storage life

The storage life of pulses is determined by temperature, moisture content, insects and diseases. Careful management of these factors is essential to avoid deterioration during storage. Pulse grain with high germination potential and good vigour can remain viable in storage for at least three years, provided the moisture content of the grain does not exceed 11% and cool grain temperatures are maintained.

When grain enters storage, it needs regular monitoring, so that early action can be taken if insect or grain-quality problems arise. Monitoring grain at least monthly for insects, moulds, grain temperature and moisture should be standard practice.

Critical points to remember with regard to storing pulses:

- Store pulses dry and cool to maintain quality. Aeration cooling will assist with holding higher moisture content pulses for short periods before drying or blending.
- Meticulous hygiene and aeration cooling are the first lines of defence against storage-pest infestations.
- Fumigation is the only option available to control a pest infestation in stored pulses. Only fumigate in a gas-tight, sealable storage unit to achieve control of all life-cycle stages of the pest.
- Minimising mechanical damage to pulse seeds will maintain market quality and seed viability, and seed will be less attractive to storage pests.

Growers contemplating medium–long term storage (six to 12 months) need to be aware that faba beans continue to age after harvest, and quality will deteriorate in sunlight and over time. All faba beans will darken considerably in storage, and the rate of seed coat darkening (deterioration in grain colour) will be accelerated by:

- high seed moisture content
- high temperatures
- high relative humidity
- poorer condition of the seed at harvest
- sunlight [2]

To maintain lighter seed-coat colour and minimise darkening of seed, any pulses stored at >12% moisture content will require aeration cooling to maintain quality.

Mature seed that has suffered field weathering before harvest will deteriorate a lot quicker in storage, even if stored under acceptable levels of temperature and relative humidity. Growers should avoid even short to medium term storage of weather-damaged grain.

MORE INFORMATION

GRDC (2014) Storing pulses. Fact sheet.

GRDC (2015) GCTV Stored Grain: Storing Pulses. Video

Vigilant monitoring protects grain assets, Stored Grain Information Hub.

2 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

13.3.2 Moisture

For storage, pulses harvested at ≥14% moisture require aeration and drying, or blending with dry grain, to preserve seed germination and viability. As a rule, every 1-percentage point rise in moisture content above 11% will reduce the storage life of pulse seed by one-third.

For most storage situations, grain is best stored using aeration cooling. Generally, a silo is only left sealed for a short period of 1 or 2 weeks for fumigating insects. If grain is sealed in a silo, it must be of sufficiently low moisture content to prevent moisture migration.

Moisture sources

Grains. Because grain and seed are living they release moisture as they respire. In silos with no aeration, 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.

Grain insects. Insects or mites in the grain respire and release moisture and heat into air spaces. If grain is stored at >14% moisture content, enough moisture may be carried into the upper grain layers to place that grain at risk of mould. Normally, there is no moisture migration in an aerated silo as the entire stack is cooled to one temperature (≤23°C).

Condensation impact. Moisture carried into the silo headspace can condense on a cold roof and fall back into the grain as free water. This can then cause a circle of mould or germinated grain against the silo wall.

Leaks in silo. Water entering through structural damage will increase grain moisture content allowing mould and insect growth. [3]

13.3.3 Temperature

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 <20°C. In general, each 4°C rise in average stored temperature will halve the storage life of the grain.

Grain is a good insulator against heat transfer, so the sun's heat on the north and west walls of the silo plus the roof does not penetrate much further than 30 cm beyond the silo wall. However, having light silo walls will help keep temperatures down. Painting a silo white is practical way of reducing the temperature of stored grain next to the silo walls and in the silo headspace. Dark grey walls on silos will absorb more of the sun's heat. Small silos (<30 t) and field bins will have a larger proportion of grain exposed to these surface-temperature fluctuations, and will promote more rapid deterioration in grain quality. Combine aeration cooling plus white paint or bright, reflective surfaces on small silos storing planting seed or other grains. [4]

13.3.4 Silo capacity

The approximate weight of grain stored in a cubic metre of silo is shown in Table 1. 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 grain size, variety and season.

3 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

4 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

Table 1: *Calculating silo capacities.*

Grain	Volume (m^3)	Weight (kg)
Broad beans	1	645
Chickpeas	1	750
Faba beans	1	750
Field peas	1	750
Lentils	1	800
Lupins	1	750
Vetch	1	750
Wheat	1	750
Barley	1	625
Oats	1	500
Example silo of faba beans	67.4	50,550

Source: Grain Legume Handbook, 2008.

13.3.5 Cooling grain and aeration cooling

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 and condensation inside the silo is reduced.
- Insect life cycles are slowed (or cease in some instances) and hot spots are prevented.
- Mould growth is reduced.
- Darkening of the seed coat is slowed.

Aeration cooling is a vital tool when storing pulses in a silo. It allows for longer-term storage of low-moisture grain by creating cool, uniform conditions that maintain seed quality, protect seed viability, and reduce mould and insect development. Its use also allows grain to be harvested earlier and at higher moisture levels, thereby capturing grain quality and reducing mechanical seed damage.

Aeration systems

Aerated silos are fitted with fans that push air through the grain to cool it and equalise the moisture and temperature throughout the silo. An aeration system requires a waterproofed vent on the top of the silo to allow air to escape freely. The vent needs to be sealable if fumigation is required.

The aeration system used should provide the appropriate airflow rates to protect the grain and maintain quality. Aeration cooling can be achieved with airflow rates of 2–4 litres per second per tonne (L/s/t). For example, a small, single-phase aeration fan driven by a 0.37 kW (0.5 horsepower) electric motor for silos ~70–100 t capacity should deliver this airflow rate.

Controlled aeration should reduce grain temperature to ≤23°C. Controlling aeration cooling is a three-stage process:

- continual aeration, to maximise airflow through the grain as it goes into storage;
- rapid cooling, which occurs after initial cooling to quickly bring the temperature of the grain down; and
- maintenance cooling, once the grain has been cooled.

MORE INFORMATION

C Warrick (2011) Aerating Stored Grain: Cooling or Drying for Quality Control. GRDC.

GRDC (2012) Performance testing aeration systems. Fact sheet.

GRDC (2013) Dealing with high-moisture grain. Fact sheet.

For general information on handling, drying and cooling, read the website of Agridry Rimik.

The degree of cooling achieved during storage depends on the moisture content of the grain and the humidity and temperature of the incoming air. Automatic aeration controllers are used to turn fans on and off, and to select the optimum ambient temperature and humidity conditions. This provides the most reliable results. [5]

13.3.6 Drying grain and aeration drying

Continuous-flow or batch dryers provide reliable drying, although they can reduce grain quality if run at too high a temperature. Do not exceed 45°C when using heat to dry faba beans. Check the specifications or talk to the manufacturer about safe conditions for drying pulses.

High-capacity aeration drying systems can also be used to dry grain, and are ideally suited for drying grain harvested at 15–16% moisture content. Aeration drying gives a lower risk of cracking and damaging pulses than hot-air dryers. Aeration drying requires much higher-performance fans to move high volumes of air through the grain at a faster rate than that required for cooling only.

Airflow rates of at least 15–25 L/s/t are required for reliable aeration drying. By comparison, airflow rates as small as 2–4 L/s/t can achieve aeration cooling.

Careful selection of ambient air temperature and dryness using an automated controller can remove moisture from the stored grain over a period of 1 or 2 weeks. [6]

13.4 Insect pests in storage

Insects are not considered a major problem in stored faba beans.

The only exception appears to be in cases where faba beans are loaded into storages containing residues of cereal grain already infested with cereal pest insects such as flour beetles (*Tribolium* spp.) and grain borers (*Rhyzopertha* spp.). These prior infestations can develop and spread in the faba beans.

The key to control is maintaining excellent hygiene in and around storage facilities. Combined with aeration cooling, this should prevent infestations developing.

Most insect development ceases at temperatures <20°C. Freshly harvested grain usually has a temperature of ~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 (Table 2).

5 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

6 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

Table 2: *Effect of grain temperature on storage pest insects and mould.*

Temperature (°C)	Insect and mould development
40–55	Seed damage occurs, reducing viability
30–40	Mould and insects are prolific
25–30	Mould and insects active
20–25	Mould development is limited
18–20	Young insects stop developing
<15	Most insects stop reproducing, mould stops developing

Source: GRDC (2014) Aeration cooling for pest control. Fact sheet

If insects in stored faba beans need treatment, the only control options are phosphine fumigation, an alternative fumigant, or controlled atmospheres such as carbon dioxide (CO_2) or nitrogen (N_2).

To ensure effective fumigation and control of all insect life stages, and to reduce the risk of resistance development, fumigation must be carried out in a sealed, gas-tight silo.

No insecticide sprays are currently registered for use on faba beans. Markets are particularly sensitive to insecticide residues, so detection of any residues on faba beans could result in the loss of a market, not just rejection of a contaminated delivery.

Residual sprays should not be used on storages and handling equipment that is to be used for faba beans.

The use of diatomaceous earth (DE), for example Dryacide®, as a structural treatment may be possible. Always check with the grain buyer for delivery standards or allowances before using any product that will come into contact with stored grain.

Not all silos can be sealed adequately to enable fumigation. However, all silos can have aeration added to them. So if the silo is not sealable, fitting aeration cooling fans will assist with controlling pests and maintaining grain quality. Well-managed aeration cooling, coupled with excellent hygiene, can overcome insect pest infestation problems in seven out of 10 years. [7]

MORE INFORMATION

GRDC (2013) Hygiene and structural treatments for grain storages. Fact sheet.

GRDC (2014) Storing pulses. Fact sheet.

GRDC (2013) Grain storage pest control guide. Fact sheet.

13.5 Farm and grain hygiene

Maintaining good farm and grain hygiene plays a crucial role in overcoming many problems associated with storage pests. Basic hygiene practices include:

- Remove all grain residues from empty storage facilities and all grain handling and carriage equipment before new grain is stored and equipment used.
- Clean up spillages around silos and remove or use all residues to prevent re-infestation.
- Always spread grain residues to a depth of <50 mm at a dump site to prevent it from becoming a breeding site for storage pests. Most of these insects are strong fliers, and move >1 to 2 km.
- Once storages and equipment have been cleaned, treat them with an inert dust (e.g. DE).
- Ensure that insect pests or weeds are not carried onto your property on farm equipment (e.g. harvesters); and thoroughly clean down equipment after use.

Storages should be cleaned before filling with new grain. However, if there is reason to believe there are stored-grain insect pests in a silo or in freshly harvested grain, fumigation can be carried out immediately to ensure that all stages are eliminated before any grain damage or weight loss occurs. If possible, as a valuable first step,

7 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

before fumigating, aerate freshly harvested grain to create uniform, cool conditions in the grain bulk. [8]

13.5.1 Controlling insects in storage with phosphine

While insect pests are not a major problem in stored faba beans, fumigation is the primary control measure if they are detected.

Currently, phosphine is the only fumigant registered for use in pulses, and it can only be used in sealed storage. It is illegal and dangerous to put phosphine into unsealed storage.

Provided fumigation is carried out correctly, it will destroy all stages of insects: adults, eggs, larvae, and pupae. This includes insects that may have developed some level of phosphine resistance. Effective fumigation with phosphine needs a concentration of 300 ppm (a chemical to air ratio) to be maintained for seven days (when grain is stored >25°C) or 200 ppm for 10 days (15–25°C). An unsealable silo will not hold these concentrations, even with a high dosage rate.

Poor fumigations may appear to have been successful when dead adults are observed, but many of the eggs, larvae and pupae will have survived and will continue to infest the grain. In addition, insects that survive are more likely to carry phosphine-resistance genes. This has serious consequences for future insect control across the entire industry.

Minimum fumigation exposure times for phosphine are:

- 7 days with grain temperatures >25°C
- 10 days at 15–25°C

Grain stored <15°C should not be fumigated with phosphine, because insects are hard to kill at low temperatures.

For large, sealable storages (e.g. >150 t capacity), a fumigation recirculation system should be fitted to ensure that gas is evenly distributed throughout the grain bulk in a timely manner during the fumigation exposure period.

Use phosphine carefully

Phosphine is a highly toxic substance. Always read safety advice on the label and comply with state legislative requirements. [9]

13.6 Silo or grain bags

Grain bags (known also as silo bags, sausage bags or harvest bags), are a form of sealed storage with no aeration, and are becoming increasingly popular. It is important to appreciate their role and how they function, particularly when used to store pulse grain. They should be used only as temporary storage because of the difficulty of maintaining grain quality (Photo 3).

Pulses are riskier grains than cereals to store in grain bags: pulse grain has been rejected by markets because of objectionable taints and odours derived during improper storage in a grain bag.

To maintain grain quality in storage, it is essential to bag the grain at the correct moisture content, and to ensure that the bag remains sealed throughout the entire storage period to prevent moisture ingress.

High-moisture grain, condensation, water aggregation under the film, or leaks can cause localised mould and widespread spoilage in pulses.

8 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

9 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

Even with adequate seals, hermetic conditions (low oxygen (O_2), high CO_2) to protect against insects and mould are difficult to achieve consistently because of either high grain temperatures or low grain moisture content at the time of storage.

Photo 1: *Silo bags should be considered as only temporary storage for pulse grains because of quality issues that can arise.*

Photo: W. Hawthorne, Pulse Australia

13.6.1 Pulse quality risks and grain bags

There are risks associated with storing pulses in grain bags:

- Pulse grain may not retain its quality and colour, especially if the seal is breached.
- Contamination and moisture can enter bags from vermin and other pests that create holes in the bag.
- Excessive grain moisture can result in condensation within the bag, causing pockets of mouldy grain along with an offensive, distinctive 'mouldy' odour throughout. There is a no tolerance of this in receival standards.
- Removing taints and odours in affected grain may not be possible, even with further aeration.
- Achieving and keeping hermetic conditions under Australian conditions is difficult, and bags should not be relied on as the only source of insect control during storage.
- Grain moisture content is critical. Pulses, particularly the larger-seeded ones such as faba beans, have bigger airspaces between grains than cereals, so moisture can move more freely in them. [10]

MORE INFORMATION

GRDC (2014) Successful storage in grain bags. Fact sheet.

10 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 8—Desiccation, Harvest & Storage.

Environmental issues

Key messages

- Frost damage is not always obvious and crops should be checked 5–7 days after a suspected frost.
- Faba beans have a medium tolerance to frost due to their thick pod walls.
- Faba beans are the pulse most tolerant to waterlogging.
- Disease resistance is especially important in drought-prone areas.

14.1 Temperature

Temperature, daylight, day length, and drought are the major factors affecting flowering in faba beans. Temperature is generally more important than day length. Flowering is invariably delayed under low temperatures but more branching occurs.

Progress towards flowering is rapid during long days. With short days, flowering is delayed but never prevented. However, some faba bean varieties are less sensitive to day length than others. This has enabled breeders to identify varieties that flower early in the short-day winter growing season in southern Australia. [1]

High temperatures

Separating the effects of very high temperature from those of water stress is difficult, because in rain-fed agriculture, they nearly always occur together.

There is, however, no doubt that high temperature is damaging: in all pulses, high temperature will cause premature cessation of flowering, and shedding of flowers and young pods. Planting early maturing faba beans, field peas, and lentils is an effective strategy to escape high temperature. [2]

Temperature and sowing time

The timing of sowing largely determines the timing of the crop's finish and the temperature environment in which it will finish.

Plants sown before the recommended sowing window tend to be more vegetative and suffer from:

- poor early podset because of low light or low temperatures (10°C) at flowering commencement
- higher risk of chocolate spot at flowering and through podding
- crops being more pre-disposed to lodging
- 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

Late-planted crops are more likely to suffer from:

- high temperatures and moisture stress during flowering and podding
- greater pressure from native budworms
- fewer branching and flowering sites, unless plant population is increased
- shorter plants and lower podset, which makes plants more difficult to harvest [3]

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course. Module 3–Varieties

2 DAWA (2005) Producing pulses in the northern agricultural region. Bulletin 4656. Department of Agriculture, Western Australia.

3 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean–Best Management Practices Training Course. Module 3–Varieties.

14.2 Frost

Frost is a complex and erratic constraint to Western Australian (WA) cropping systems, and can have dramatic consequences to a grower's business. Research that investigated trends since the 1960s has shown that:

- WA's frost window has widened, and on average frosts start three weeks earlier and finish 2 weeks later in the year.
- Consecutive frost events have increased by an average of up to three days at a time and mostly occur in August and September in the frost-prone regions.
- The frosts are getting colder, with minimum temperatures dropping. [4]

The sequence of weather events that typically generate damaging frosts is composed of the passage of a weak cold front, followed by cold southerly winds and the establishment of a ridge of high pressure. This results in cool daytime temperatures, light winds and clear skies overnight. [5]

Faba beans have a medium tolerance to frost due to their thick pod walls, which provide insulation to the developing seeds, but they are still quite susceptible to flower, yield and quality losses when frost intensity or duration is severe. Symptoms include:

- Growing points are sometimes distorted (bent) during early vegetative and flowering stages. This weakens the cells of the stem, allowing disease such as chocolate spot to invade easily.
- Flowers are killed by frost, leaving only a flower stalk.
- White or green mottling, and blistering of pods.
- Seeds developing in the pod are shrivelled or absent.
- Affected pods feel spongy and the seeds inside turn black. [6]

Tolerance to low temperature

Sub-zero temperatures in winter can damage the leaves and stems of the plant. Severe frosts can cause a characteristic 'hockey-stick' bend in the stem (Photo 1). However, faba beans have some ability to recover from this damage by being able to regenerate new branches. New growth occurs from the base of the frost-affected plants if moisture conditions are favourable.

Photo 1: *Severe vegetative frost can cause bends like a hockey stick in faba bean stems and branches in northern Australia.*

Photos: G Cumming, Pulse Australia

Frosts can also cause flower, pod and seed abortion. Pods at a later stage of development are generally more resistant to frost than flowers and small pods (Photo 2), but may suffer some mottled darkening of the seed coat (Photo 3).

4 GRDC (2016) Pre-seeding planning to manage frost risk in WA. GRDC Media Centre, https://grdc.com.au/Media-Centre/Hot-Topics/Preseeding-planning-to-manage-frost-risk-in-WA

5 DAFWA (2016) The science of frost. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/frost/science-frost

6 DAFWA (2016) Frost: diagnosing the problem. Department of Agriculture and Food, Western Australia, https://agric.wa.gov.au/n/66

Frost will normally affect the smallest pods first, even though they are the higher pods on the plant. Similarly, pod abortion induced by moisture stress is normally also noted on the last formed pods in the upper parts of the plant. Visual symptoms of frost and moisture stress damage to pods are, however, quite different.

In Western Australia, frost or low minimum temperatures (<5°C) during the reproductive stage will not physically damage the crop. There may be a slight leaf tipping on upper leaves to indicate a frost has occurred.

Frost during early flowering that affects early podset can be compensated for later by subsequent pods that set higher up the plant, provided the seasonal conditions are favourable to fill them. [7]

Photo 2: *Frost can cause flower or pod abortion (usually smaller pods). Damage to the seed depends on the size of the pod or seed and the severity of the frost.*

Photo: W. Hawthorne, Pulse Australia

7 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

Photo 3: *Frost can cause seed staining from 'burning' the seed coat next to the pod wall.*

Photo: W. Hawthorne, Pulse Australia

Tolerance to frost at either vegetative or reproductive stages is not a breeding priority in southern Australia. However, improved early podset under conditions of low temperatures and low light is a breeding priority. [8]

14.2.1 Managing frost damage

Although it is difficult to totally manage frost risk in pulses, it is important to know the period of highest probability of frost incidence. Aim to reduce exposure to frost or impact at vulnerable growth stages. Frost-zone management tactics include the following.

Use of the frost zone

Map the topography to show areas of greatest risk, and specifically manage these areas. The use of identified frost zones should be carefully considered. Avoid large-scale exposure to frost of highly susceptible crops.

Modify soil heat bank

The soil-heat bank is important for reducing the risk of frost. Farming practices that manipulate the storage and release of heat from the soil-heat bank into the crop canopy at night are important considerations to reduce the impact of a frost. These include:

8 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

- Practices that alleviate non-wetting sands, such as clay delving, mouldboard ploughing or spading.
- Rolling sandy soil and loamy clay soil after seeding.
- Reducing the amount of stubble.

Manipulate flowering times

Sowing time remains a major driver of yield in all crops, with the primary objective being to achieve a balance between crops flowering after the risk of frost has passed, but before the onset of heat stress. The loss of yield from sowing late to avoid frost risk is often outweighed by the gains from sowing on time to reduce heat and moisture stress in spring. [9]

14.3 Waterlogging and flooding

Pulses are generally not well suited to waterlogged soils. Faba beans are the pulse most tolerant to waterlogging and they exhibit some adaptation in new roots when the soil has been saturated for >2 weeks. Faba beans are able to produce good yields under waterlogged conditions that can cause failure of chickpea or lentil crops.

Importantly, the growth of faba beans will still be reduced when they are subjected to extended periods of waterlogging (>2 weeks), and chocolate spot disease is likely to be more severe. [10]

14.4 Drought

Drought tolerance through osmotic adjustment has not yet been demonstrated in faba beans, although it is found in many other legumes including chickpeas and field peas. Deeper root growth, leading to uptake of otherwise unavailable water, helps the plant to avoid drought by delaying dehydration, but genetic variation and heritability of the trait are essentially unknown for faba beans. [11]

9 GRDC (2016) Tips and Tactics. Managing frost risk: northern southern and western regions, https://grdc.com.au/Resources/Factsheets/2016/02/Managing-frost-risk-Northern-Southern-and-Western-Regions

10 DAWA (2005) Producing pulses in the northern agricultural region. Bulletin 4656. Department of Agriculture, Western Australia.

11 H R Khan, J G Paull, K H M Siddique and F L Stoddard (2010) Faba bean breeding for drought-affected environments: A physiological and agronomic perspective. Field Crop Research. 115 (3) 279–286, http://www.sciencedirect.com/science/article/pii/S037842900900238X

Marketing

Within the faba bean types, several market categories have emerged for Australian growers, including:

- a small-seeded (35–50 g/100 seeds) class, originally exported for human consumption markets but now considered too small in all but a few niche markets ('Fiord(b' size);
- the traditional, medium-seeded faba bean markets, where seed size and uniformity (50–70 g/100 seeds) is important to attract market interest; and
- a large-seeded class (70–90 g/100 seeds) that is sold into bulk Kabuli markets. [1]

The size and colour requirements of faba beans vary between importing countries and according to their end use:

- The predominant colour for international trade is beige or buff. Colour is largely genetically determined and highly heritable.
- Size can vary according to variety.
- Size can also be influenced by the region (rainfall, soil type, etc.) where it is grown, and by the season.
- Colour can also be influenced by the environment in which the crop is grown, post-harvest handling, time in storage and storage method.

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.

The grower will run through a decision-making process each season, because growing and harvesting conditions, and prices for grains, change all the time. For example, in the seven years to and including 2015, Port Adelaide faba bean values varied A$115–$250/t, a variability of 30–60% (Figure 1). For a property producing 200 tonnes of faba beans this means $23,000–$50,000 difference in income, depending on the timing of sales.

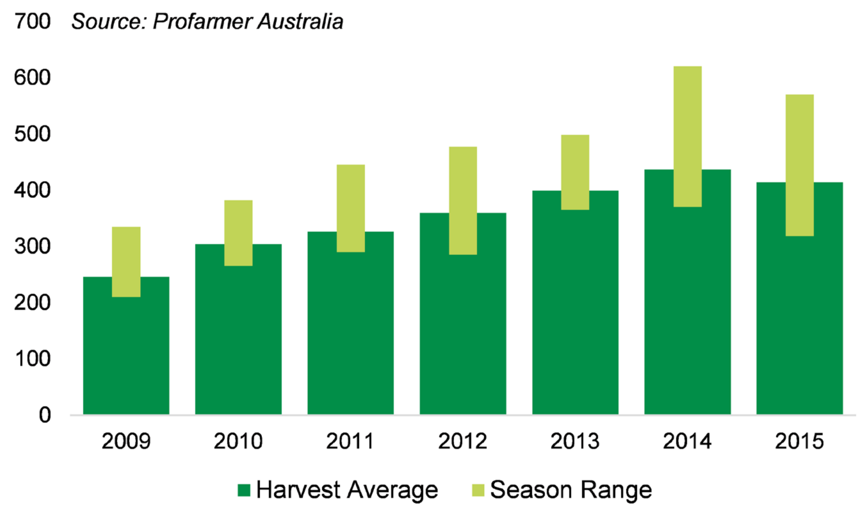


Figure 1: *Intraseasonal variance in Port Adelaide faba bean values.*

Source: Profarmer Australia

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 3–Varieties.

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 a target price and then work towards achieving the target price.

Unknowns include the amount of grain available to sell (production variability), the final cost of producing the grain, 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 are difficult to predict.

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

15.1.1 Be prepared

Being prepared by having a selling plan is essential for managing uncertainty. The steps involved are forming a selling strategy, and forming a plan for effectively executing sales. The selling strategy consists of when and how to sell.

When to sell

Knowing when to sell requires an understanding of the farm's internal business factors, including:

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

How to sell

Working out how to sell your grain is more dependent on external market factors, including:

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

The following diagram (Figure 2) lists the key principles to employ when considering sales during the growing season. Exactly when each principle comes into play is indicated where it occurs in the discussion of marketing planning and timing in the rest of section 15.

Figure 2: *Timeline of grower commodity selling principles.*

Source: Profarmer Australia

15.1.2 Establish the business risk profile

Establishing your business risk profile helps you determine when to sell: it allows you to develop target price ranges for each commodity, and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify the risks during the production cycle are described below (Figure 3).

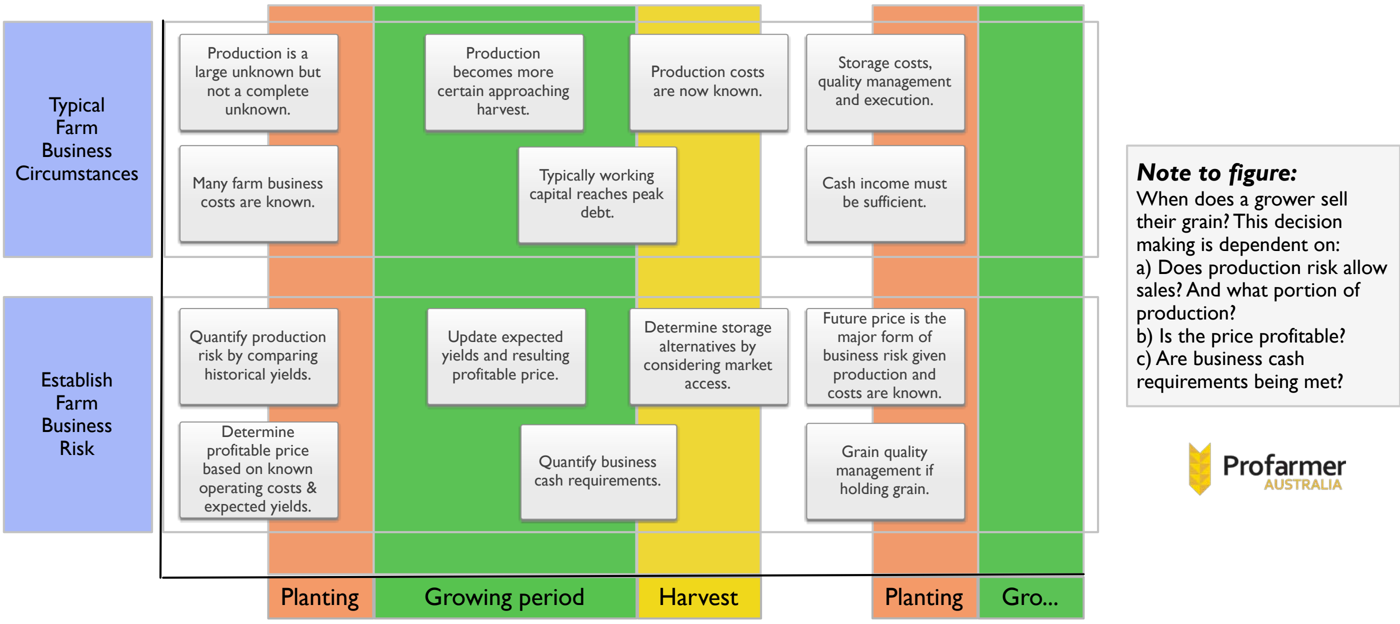


Figure 3: *Typical farm business circumstances and risk.*

Source: Profarmer Australia

Production risk profile of the farm

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

Principle: You can't sell what you don't have.

Therefore, don't increase business risk by over committing production. Establish a production risk profile (see Figure 4) by:

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

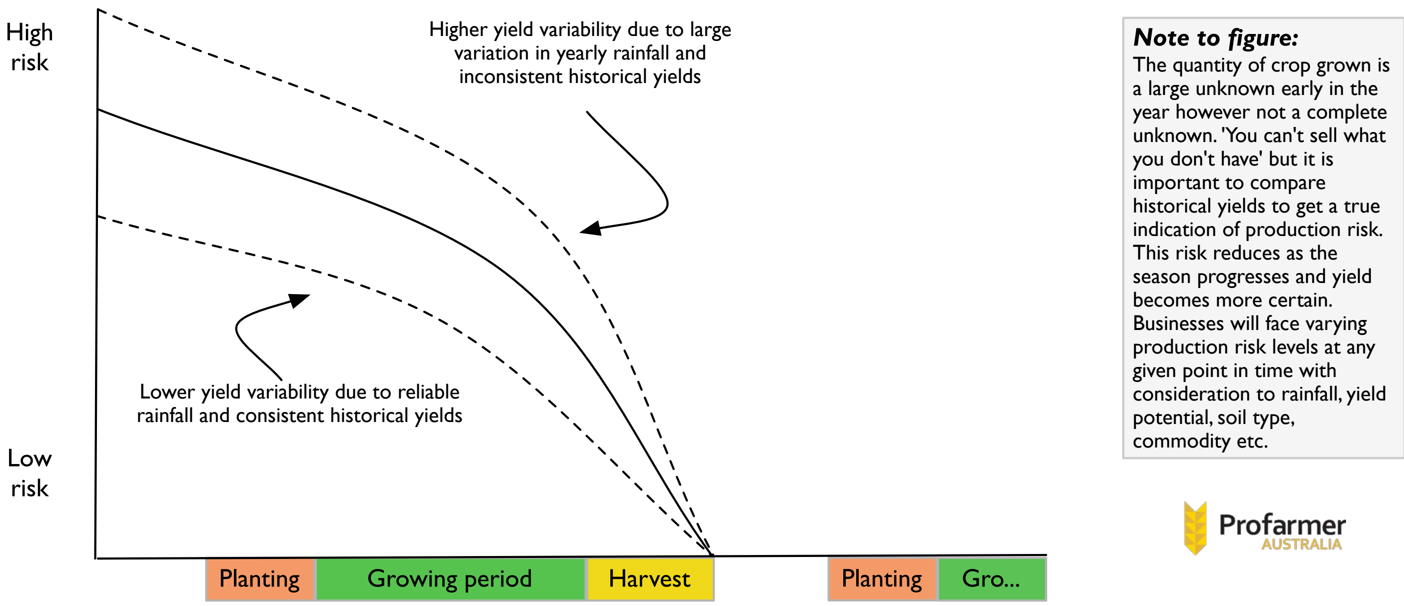


Figure 4: *Typical risk profile of a farm operation.*

Source: Profarmer Australia

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, which means knowing all farming costs, both variable and fixed.

Principle: Don't lock in a loss.

If committing production ahead of harvest, ensure the price will be profitable. The steps needed to calculate an estimated profitable price is based on the total cost of production and a range of yield scenarios, as provided below (Figure 5).

Estimating cost of production - Wheat	
Planted Area	1,200 ha
Estimate Yield	2.85 t/ha
Estimated Production	3,420 t
Fixed costs	
Insurance and General Expenses	$100,000
Finance	$80,000
Depreciation/Capital Replacement	$70,000
Drawings	$60,000
Other	$30,000
Variable costs	
Seed and sowing	$48,000
Fertiliser and application	$156,000
Herbicide and application	$78,000
Insect/fungicide and application	$36,000
Harvest costs	$48,000
Crop insurance	$18,000
Total fixed and variable costs	$724,000
Per Tonne Equivalent (Total costs + Estimated production)	$212 /t
Per tonne costs	
Levies	$3 /t
Cartage	$12 /t
Receival fee	$11 /t
Freight to Port	$22 /t
Total per tonne costs	$48 /t
Cost of production Port track equiv	$259.20
Target profit (ie 20%)	$52.00
Target price (port equiv)	**$311.20**

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

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

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

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

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

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

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

Figure 5: *An example of how to estimate the costs of production.*

Income requirements

Understanding farm business cash-flow requirements and peak cash debt enables growers to time grain sales 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.

Typical cash-flow to grow a crop are illustrated below (Figures 6 and 7). Costs are incurred up front and during the growing season, with peak working capital debt incurred at or before harvest. Patterns will vary depending on circumstance and enterprise mix. The second figure demonstrates how managing sales can change the farm's cash balance.

MORE INFORMATION

GRDC's manual Farming the Business also provides a cost-of-production template and tips on grain selling *v.* grain marketing.

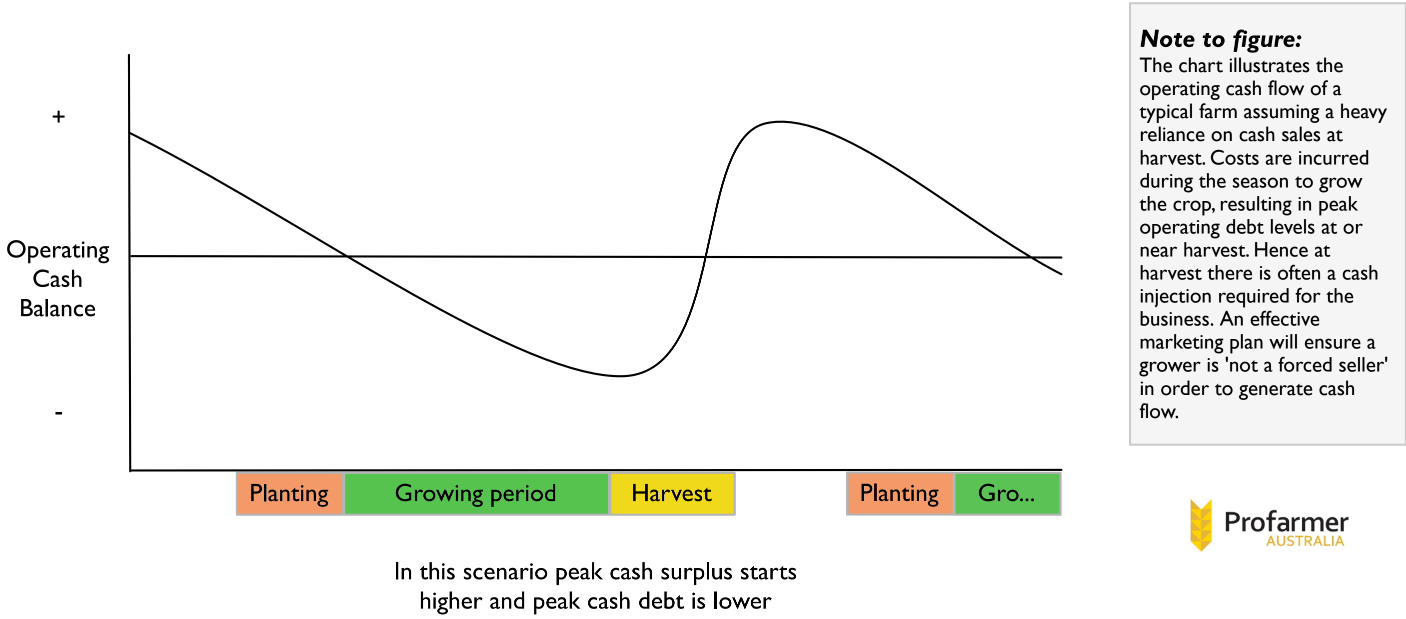


Figure 6: *A typical operating cash balance when relying on cash sales at harvest.*

Source: Profarmer Australia

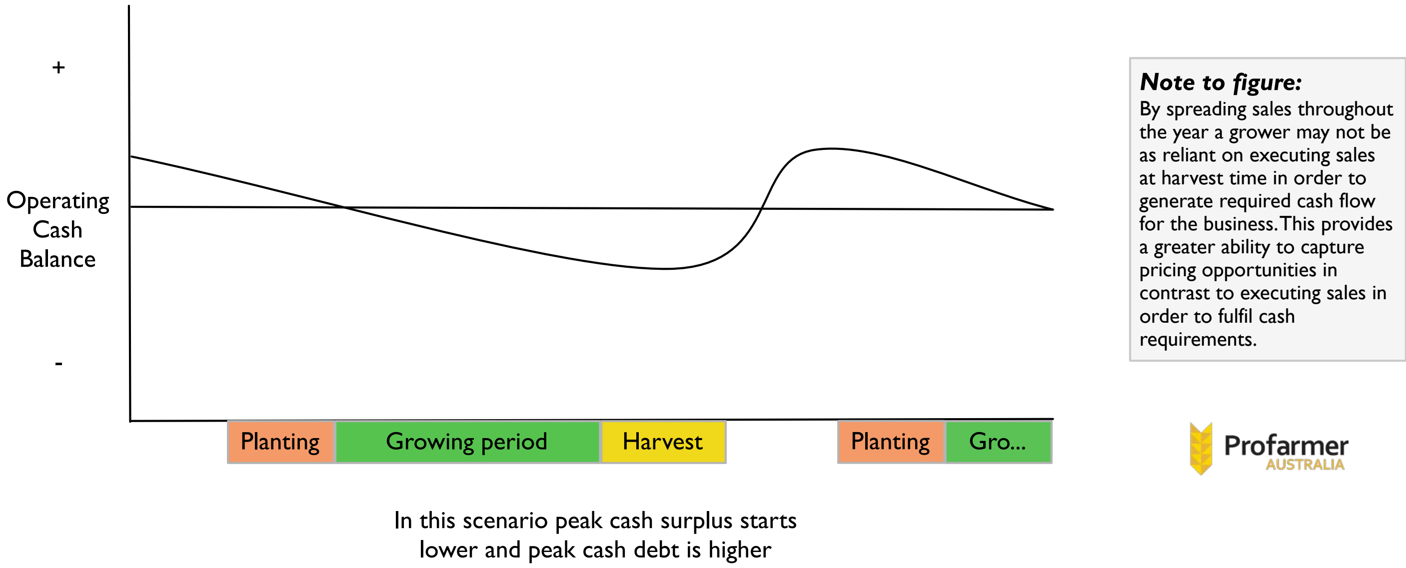


Figure 7: *Typical operating cash balance when crop sales are spread over the year.*

Source: Profarmer Australia

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

15.1.3 Managing your price

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

The second part of the strategy, managing your price, addresses how to sell your crop.

Methods of price management

Pricing products provide varying levels of price risk coverage, but not all products are available for all crops (Table 1).

Table 1: *Pricing methods and how they are used for different crops.*

	Description	Wheat	Barley	Canola	Oats	Lupins	Field Peas	Chick Peas
Fixed price products	Provides the most price certainty	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash	Cash	Cash	Cash
Floor price products	Limits price downside but provides exposure to future price upside	Options on futures, floor price pools	Options on futures	Options on futures	none	none	none	none
Floating price products	Subject to both price upside and downside	Pools	Pools	Pools	Pools	Pools	Pools	Pools

Figure 9 summarises how the different methods of price management are suited to the majority of farm businesses.

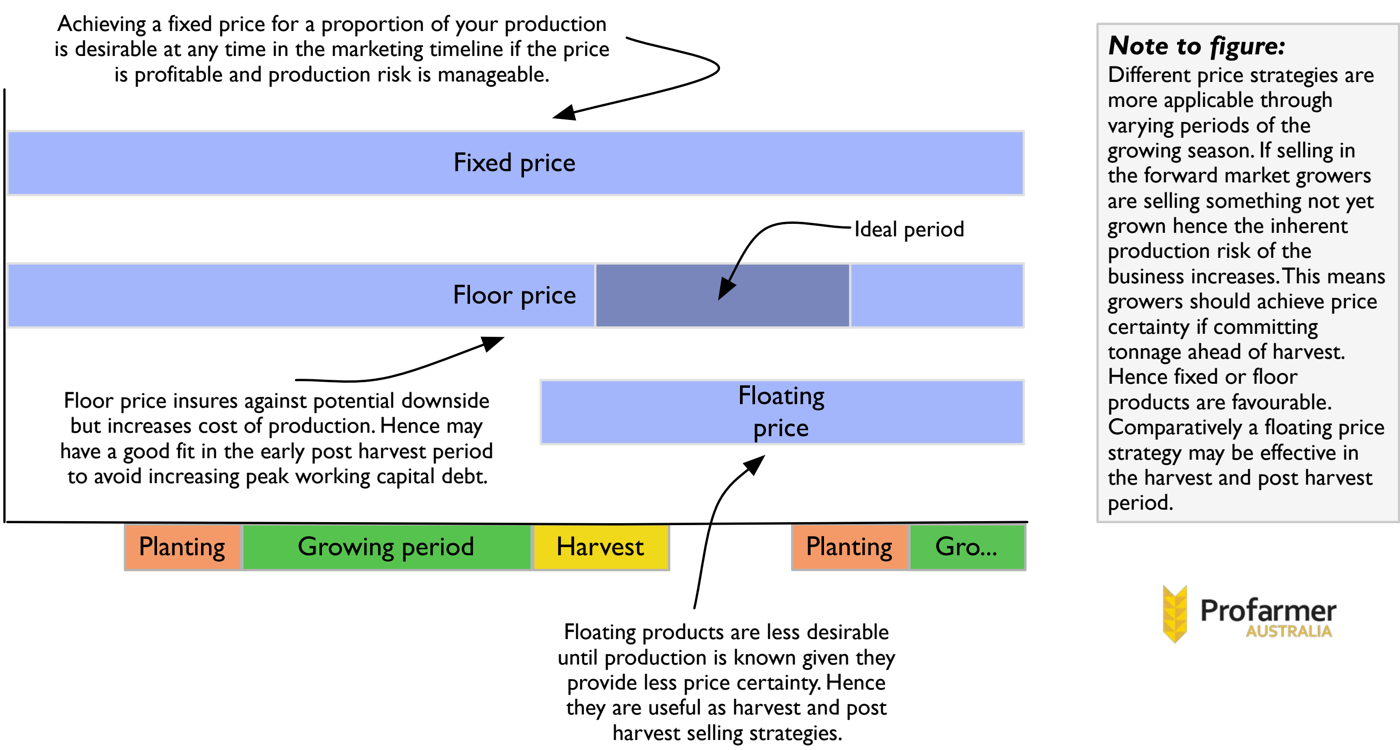


Figure 8: *Price strategy timeline, summarising the suitability for most farm businesses of different methods of price management for different phases of production.*

Source: Profarmer Australia

Principle: If increasing production risk, take price risk off the table.

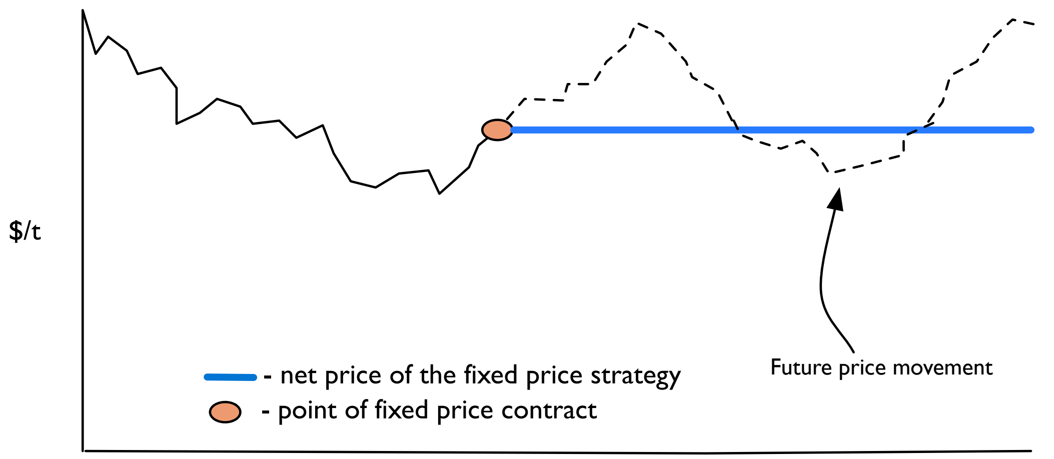
When committing to unknown production, price certainty should be achieved to avoid increasing overall business risk.

Principle: Separate the pricing decision from the delivery decision.

Most commodities can be sold at any time with delivery timeframes being negotiable, hence price management is not determined by delivery.

Fixed price

A fixed price is achieved via cash sales and/or selling a futures position (swaps) (Figure 9). It provides some certainty around expected revenue from a sale as the price is largely a known factor, except when there is a floating component in the price, e.g. a multi-grade cash contract with floating spreads or a floating-basis component on futures positions.



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

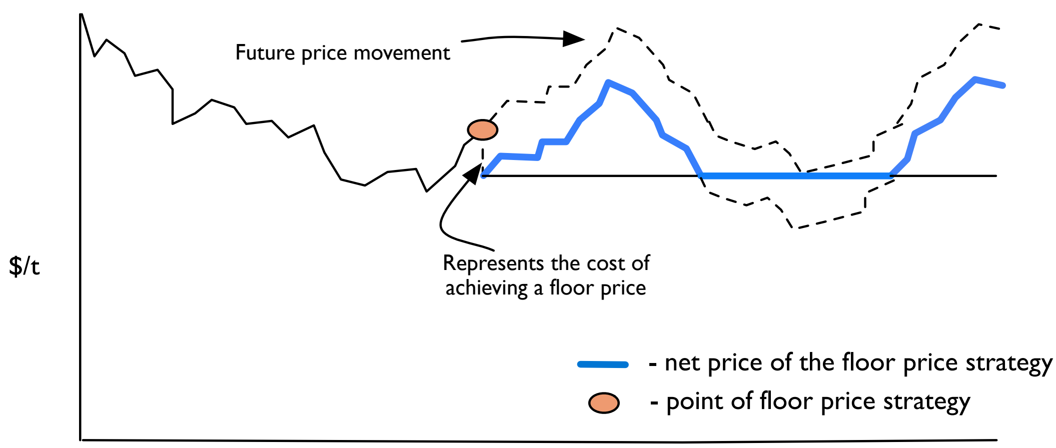
Profarmer AUSTRALIA

Figure 9: *Fixed price strategy.*

Source: Profarmer Australia

Floor price

Floor-price strategies (Figure 10) can be achieved by utilising options on a relevant futures exchange (if one exists), or via a managed-sales program (i.e. a pool with a defined floor-price strategy) offered by a third party. This pricing method protects against potential future downside while capturing any upside. The disadvantage is that this kind of price 'insurance' has a cost, which adds to the farm's cost of production.



Note to figure:
A floor price strategy insures against potential future downside in price while allowing price gains in the event of future price rallies.

Profarmer AUSTRALIA

Figure 10: *Floor price strategy.*

Source: Profarmer Australia

3. Floating price

Many of the pools or managed-sales programs are a floating price, where the net price received will move up and down with the future movement in price (Figure 11). Floating-price products provide the least price certainty and are best suited for use at or after harvest rather than before harvest.

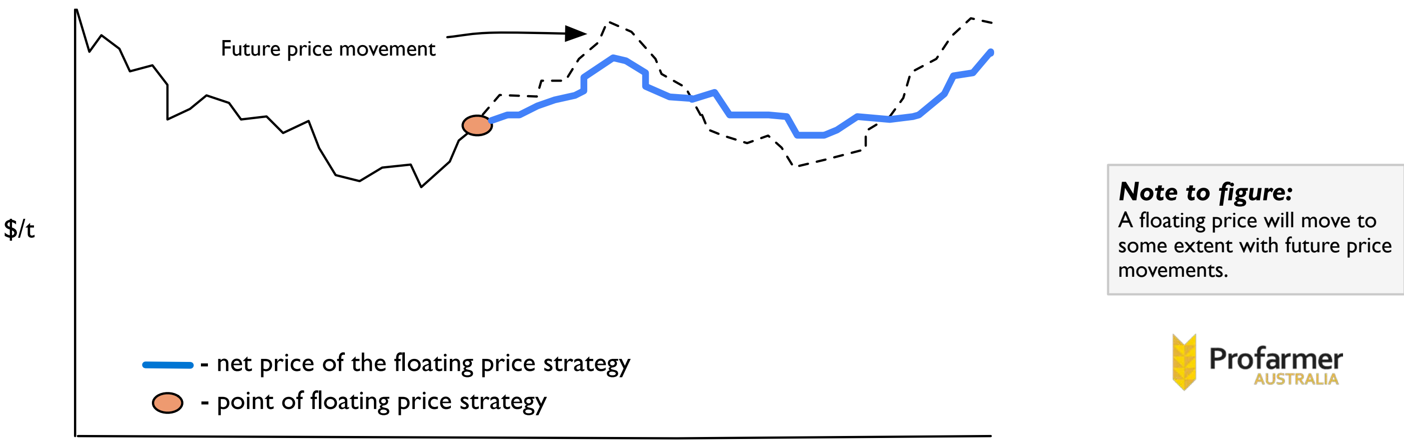


Figure 11: *Floating price strategy.*

Source: Profarmer Australia

Having considered the variables of production for the crop to be sold, and how these fit against the different pricing mechanisms, the farmer may revise their selling strategy, taking the risks associated with each mechanism into account.

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

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

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

15.1.4 Ensuring access to markets

Once the questions of when and how to sell are sorted out, planning moves to the storage and delivery of commodities to ensure timely access to markets and execution of sales. Planning where to store the commodity is an important component of ensuring the type of access to the market that is likely to yield the highest return (Figure 13).

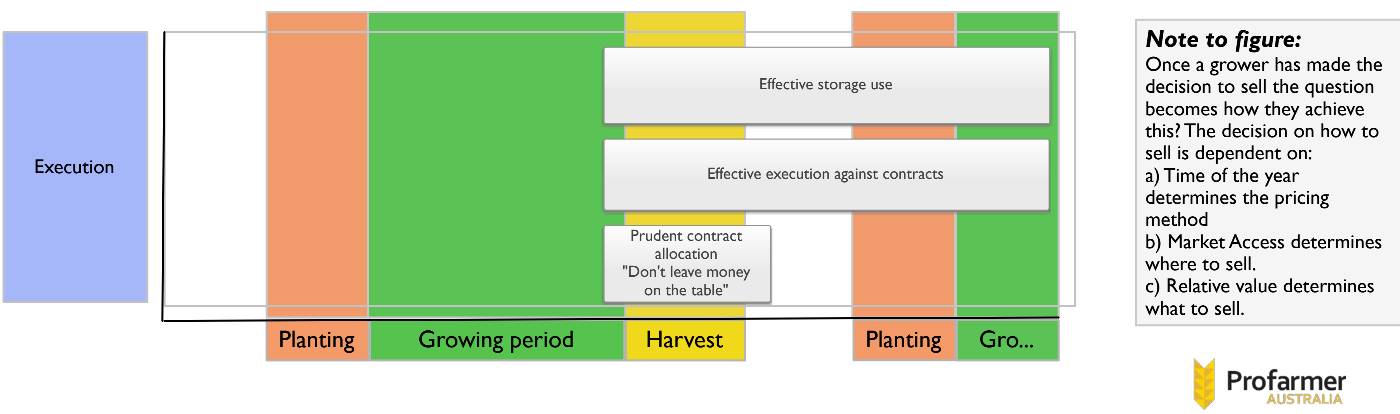


Figure 12: *Storage decisions are influenced by selling decisions and the timing of all farming activities.*

Source: Profarmer Australia

Storage and logistics

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

Storage alternatives include variations of bulk handling, private off-farm storage, and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity (Figure 13).

Principle: Harvest is the first priority.

During harvest, getting the crop into the bin is the most critical aspect of business success; hence storage, sale and delivery of grain should be planned well ahead of harvest to allow the grower to focus on the harvest itself.

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

Storing commodities on the farm requires prudent quality management to ensure that the grain is delivered to the agreed specifications. If not well planned and carried out, it can expose the business to high risk. Penalties for out-of-specification grain arriving at a buyer's weighbridge can be expensive, as the buyer has no obligation to accept it. This means the grower may have to incur the cost of taking the load elsewhere, and may also have to find a new buyer.

On-farm storage also requires that delivery is managed to ensure that the buyer receives the commodities on time and with appropriate weighbridge and sampling tickets.

Principle: Storage is all about market access.

Storage decisions depend on quality management and expected markets.

MORE INFORMATION

For more information on on-farm storage alternatives and economics refer to Section 13: Grain Storage.

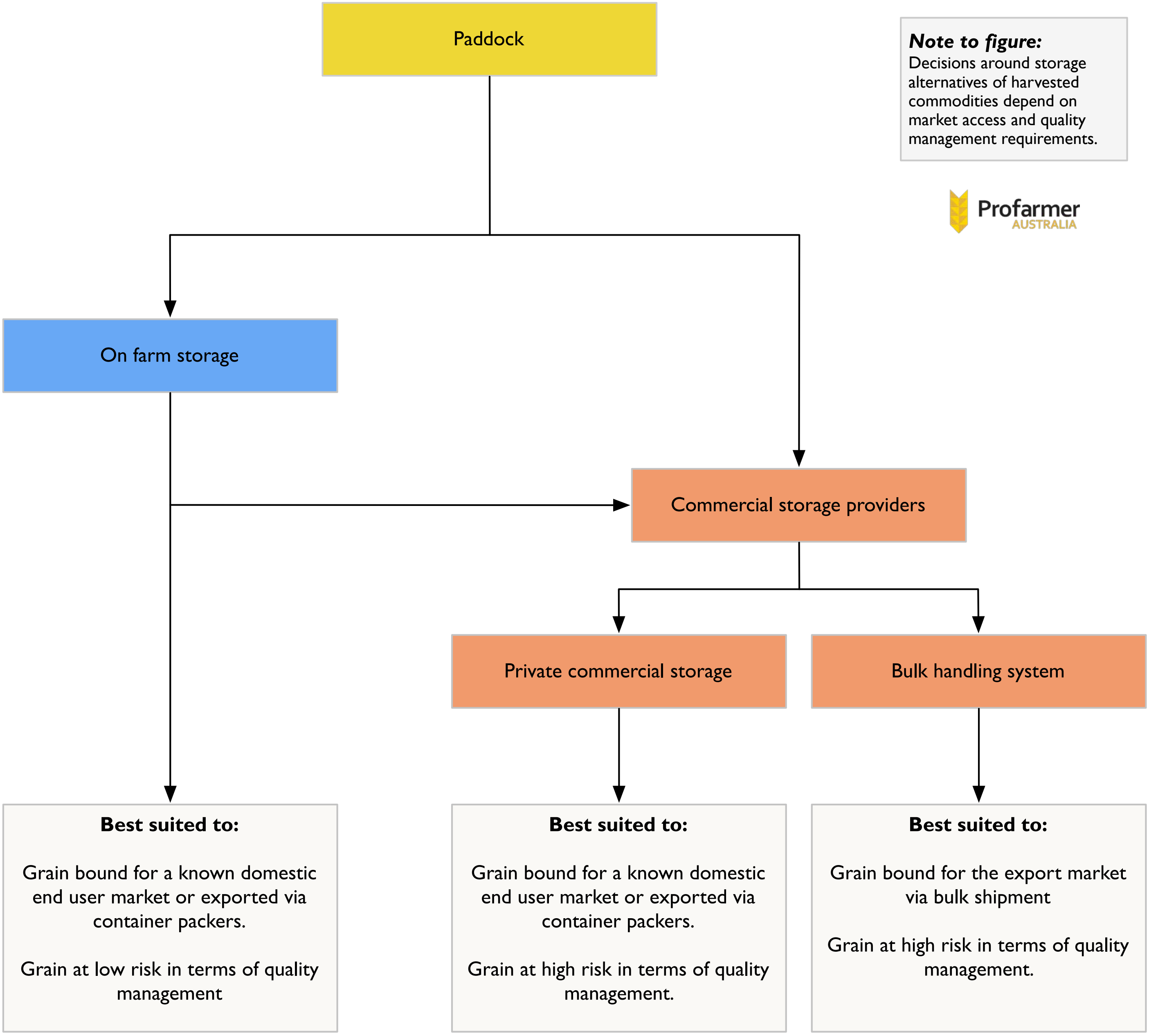


Figure 13: *Grain storage decision-making.*

Source: Profarmer Australia

Cost of carrying grain

Storing grain to access sales opportunities post-harvest invokes a cost to 'carry', or hold, the grain (Figure 15). Price targets for carried grain need to account for the cost of carrying it. Carrying costs are typically $3–4/t per month and consist of:

- Monthly storage fee charged by a commercial provider (typically ~$1.50–2.00/t).
- Monthly interest associated with having wealth tied up in grain rather than available as cash or for paying off debt (~$1.50–$2.00/t, depending on the price of the commodity and interest rates).

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

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

Principle: Carrying grain is not free.

The cost of carrying grain needs to be accounted for if holding it for sale after harvest is part of the selling strategy. If selling a cash contract with deferred delivery, a carrying charge can be negotiated into the contract. For example, a March sale for March–June delivery on the buyer's call at $400/t + $3/t carry per month, if delivered in June would generate revenue of $409/t (Figure 14).

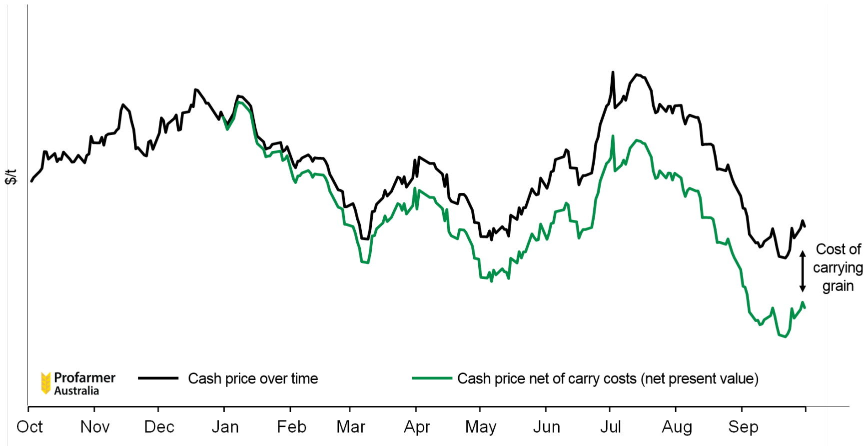


Figure 14: *Cash values compared with cash values adjusted for the cost of carrying.*

Source: Profarmer Australia

Optimising farm-gate returns involves planning the appropriate storage strategy for each commodity so as to improve market access and ensure that carrying costs are covered in the price received.

15.1.5 Converting tonnes into cash

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

Set up the toolbox

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox for converting tonnes of grain into cash includes the following.

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 services and cost structures vary considerably. An effective grain-selling professional will put their clients' best interests first by not having conflicts of interest and by investing time in the relationship. A better return on investment for the farm business is achieved through higher farm-gate prices, which are obtained by accessing timely information, and being able to exploit the seller's greater market knowledge and greater market access.

3. Futures account and a bank-swap facility

MORE INFORMATION

Access to buyers, brokers, agents, products and banks through Grain Trade Australia

Commodity futures brokers

ASX's Find a futures broker

These accounts provide access to global futures markets. Hedging futures markets is not for everyone; however, strategies which utilise exchanges such as the Chicago Board of Trade (CBOT) can add significant value.

How to sell for cash

Like any market transaction, a cash–grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components, with each component requiring a level of risk management (Figure 15):

- Price—future price is largely unpredictable, so devising a selling plan to put current prices into the context of the farm business is critical to managing price risk.
- Quantity and quality—when entering a cash contract, you are committing to deliver the nominated amount of grain at the quality specified, so production and quality risks must be managed.
- Delivery terms—the timing of the 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 on the grain to be transferred ahead of payment, so counterparty risk must be managed.

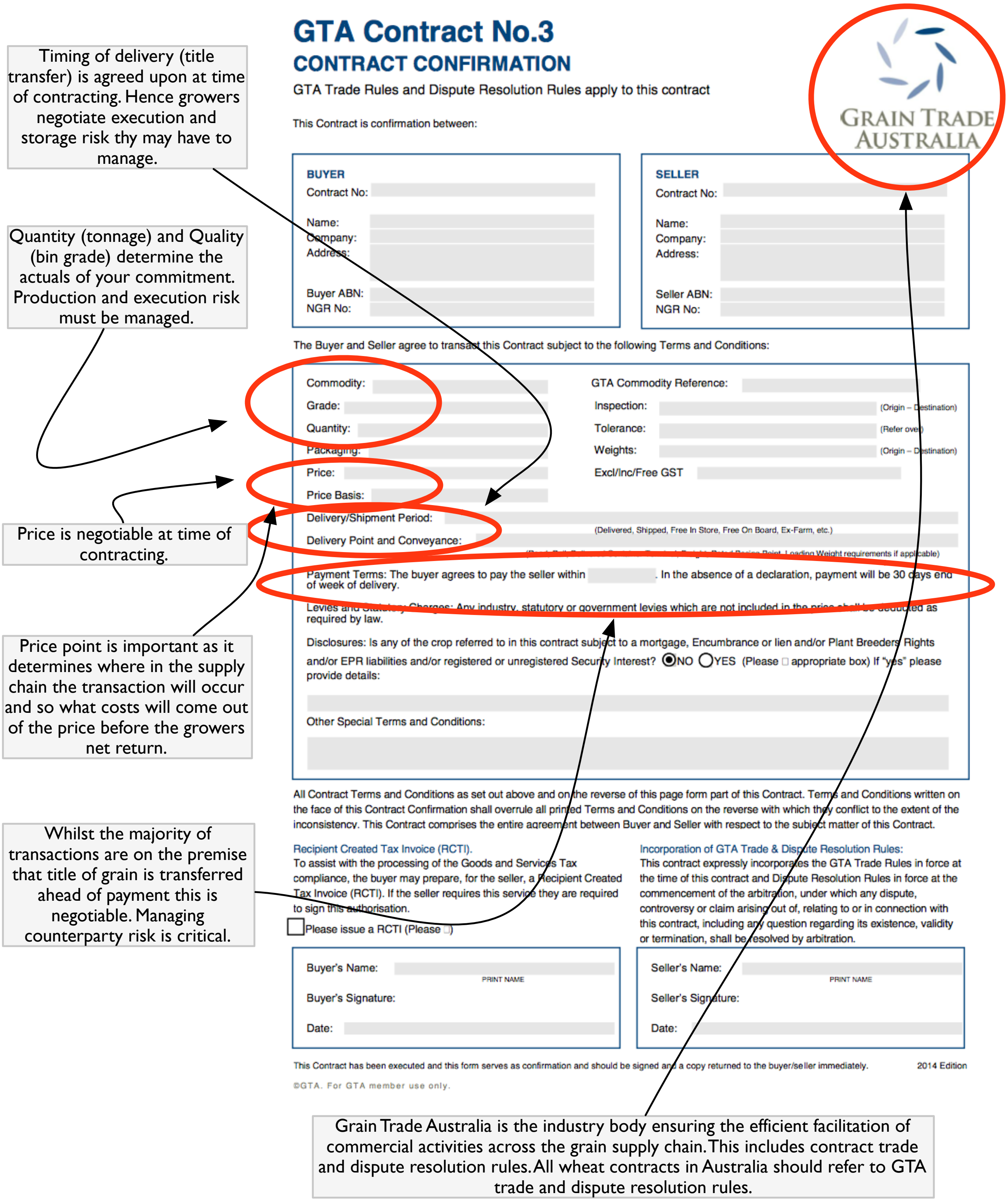


Figure 15: *Typical terms of a cash contract.*

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 16 depicts the terminology used to describe these points and the associated costs to come out of each price before growers receive their net return.

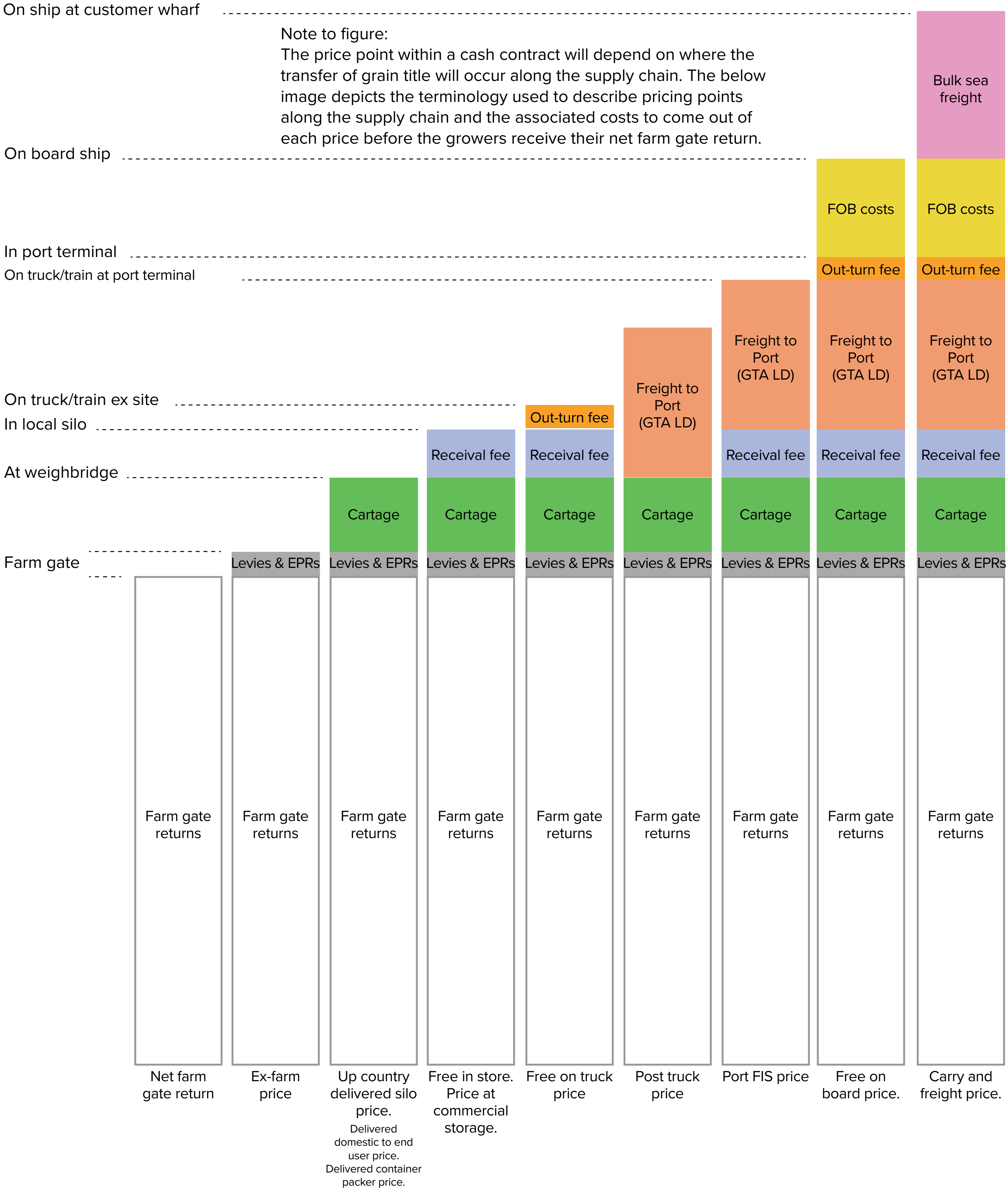


Figure 16: *Cost and pricing points throughout the supply chains.*

Source: Profarmer Australia

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Grain Trade Australia, Trading standards

GrainTransact Resource Centre

GrainFlow

Emerald Grain

Clear Grain Exchange, Getting started

Clear Grain Exchange, Terms and conditions

GTA, Managing counterparty risk

Clear Grain Exchange's title transfer model

GrainGrowers, Managing risk in grain contracts

Leo Delahunty, Counterparty risk: A producer's perspective

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 is 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 option depends on location and commodity.
- Placing an anonymous firm offer—growers can place a firm offer price on a parcel of grain anonymously and expose it to the entire market of buyers, who then bid on it anonymously using the Clear Grain Exchange, which is an independent online exchange. If the offer and bid match, the particulars of the transaction are sent to a secure settlement facility, although the title on the grain does not transfer from the grower until they receive funds from the buyer. The availability of this option depends on location and commodity. Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

Counterparty risk

Most sales involve transferring the title on the grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

Principle: Seller beware.

There is not much point selling for an extra $5/t if you don't get paid.

Counterparty risk management includes:

- Dealing only with known and trusted counterparties.
- Conducting a credit check (banks will do this) before dealing with a buyer they are unsure of.
- Selling only a small amount of grain to unknown counterparties.
- Considering credit insurance or a letter of credit from the buyer.
- Never delivering a second load of grain if payment has not been received for the first.
- Not parting with the title before payment, or requesting and receiving a cash deposit of part of the value ahead of delivery. Payment terms are negotiated at time of contracting. Alternatively, the Clear Grain Exchange provides secure settlement whereby the grower maintains title on the grain until they receive payment, and then title and payment are settled simultaneously.

Above all, act commercially to ensure the time invested in implementing a selling strategy is not wasted by poor management of counterparty risk. Achieving $5/t more on paper and not getting paid is a disastrous outcome.

Relative values

Grain-sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well, and to hold commodities that are not well priced at any given time. That is, give preference to the commodities with the highest relative value. This achieves price protection for the overall revenue of the farm business and enables more flexibility to a grower's selling program while achieving the business goal 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. For example, a farmer with wheat and barley to sell will sell the one that is getting good prices relative to the other, and hold the other for the meantime (see Figure 17).

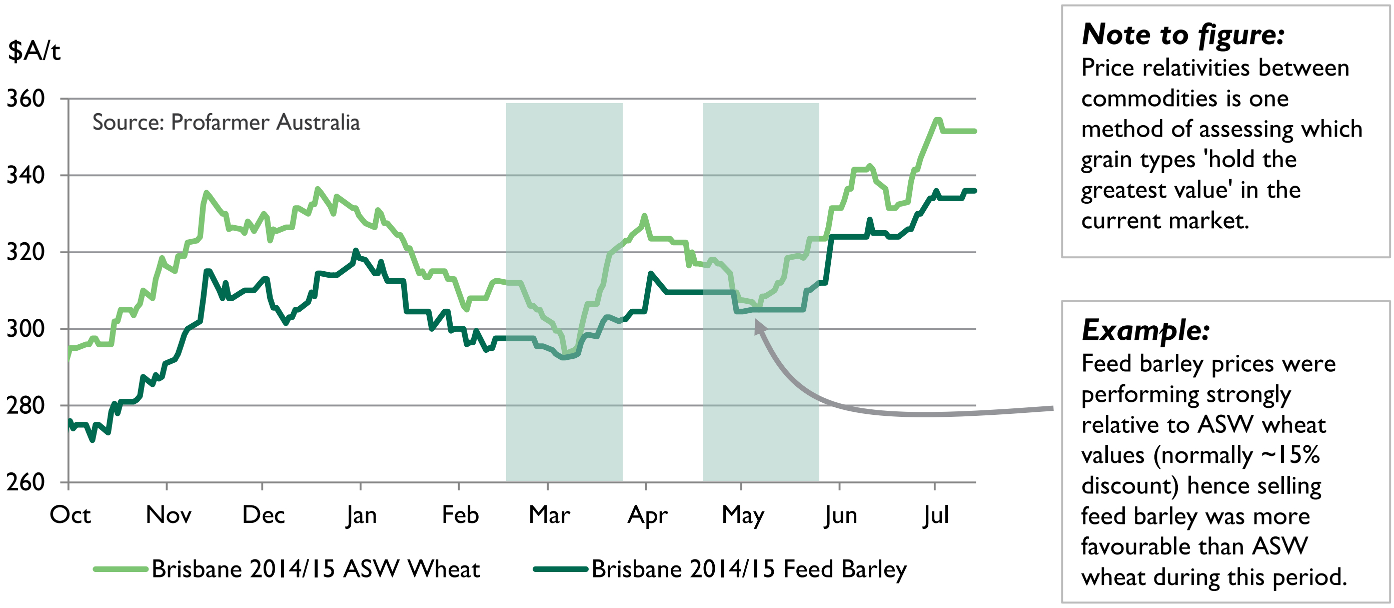


Figure 17: *Brisbane ASW wheat v. feed barley are compared, and the barley held until it is favourable to sell it.*

Source: Profarmer Australia

If the decision has been made to sell wheat, CBOT wheat may be the better choice if the futures market is showing better value than the cash market (Figure 18).

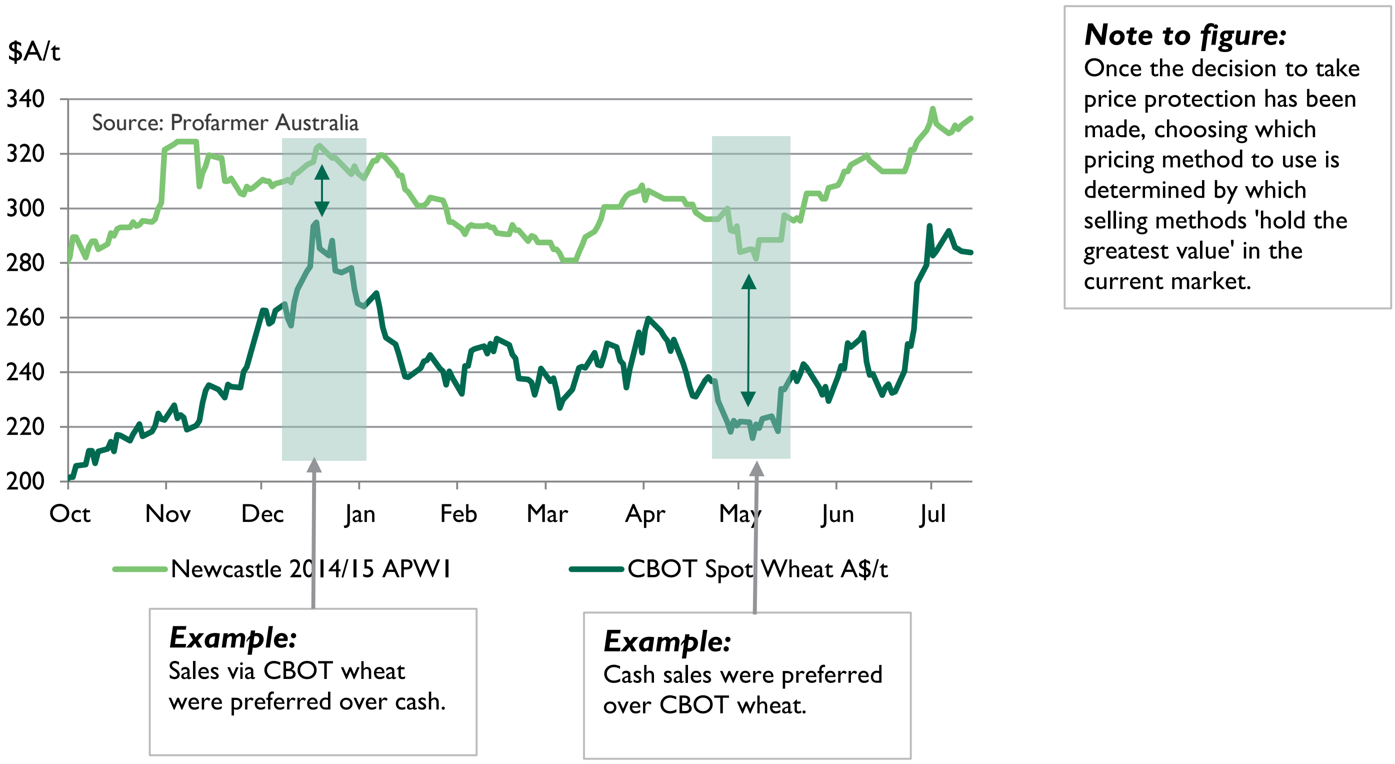


Figure 18: *By comparing prices for Newcastle APWI vs CBOT wheat, the grower can see which market to sell into.*

Contract allocation

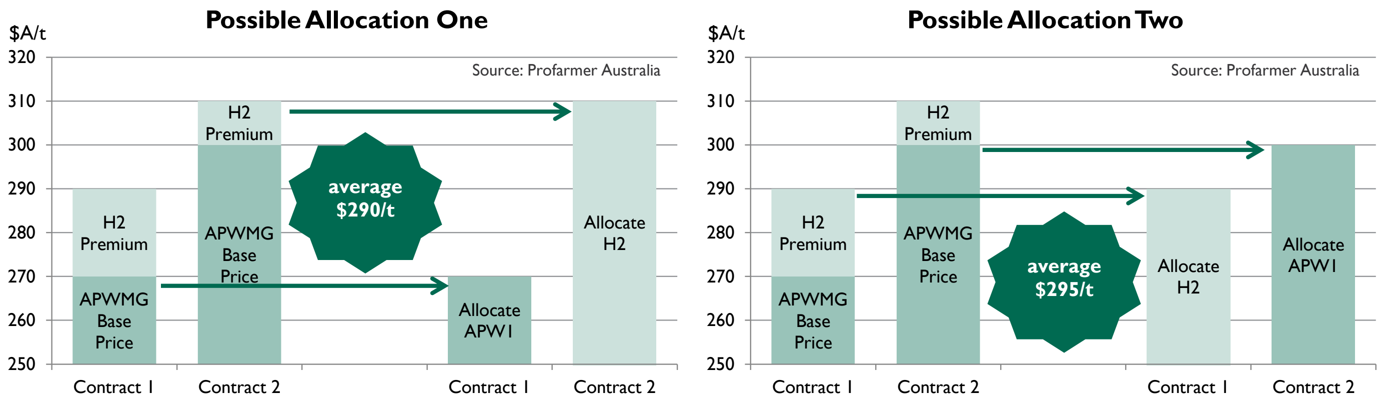
Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (e.g. price, premiums-discounts, oil bonuses), and optimising your allocation reflects immediately on your bottom line.

Principle: Don't leave money on the table.

Contract allocation decisions don't take long, and can be worth thousands of dollars to your bottom line.

To achieve the best average price for their crop growers should:

- Allocate lower grades of grain to contracts with the lowest discounts.
- Allocate higher grades of grain to contracts with the highest premiums (Figure 19).



Note to figure:
In these two examples the only difference between acheiving an average price of $290/t and $295/t is which contracts each parcel was allocated to. Over 400/t that equates to $2,000 which could be lost just in how parcels are allocated to contracts.

Figure 19: *How the crop is allocated across contracts can have an impact of earnings from the crop. Although this example uses wheat, the same principle applies for faba beans.*

Source: Profarmer Australia

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 very interested.

Principle: Sell when there is buyer appetite.

When buyers are chasing grain, growers have more market power to demand the price they want.

Buyer appetite can be monitored by:

- The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate that buyer appetite is strong. However, if one buyer is offering $5/t above the next best bid, it may mean that cash prices are susceptible to falling $5/t as soon as that buyer satisfies their appetite.
- Monitoring actual trades against public indicative bids. When trades are occurring above indicative public bids it may indicate strong appetite from merchants and the ability for growers to offer their grain at price premiums to public bids. The chart below plots actual trade prices on the Clear Grain Exchange against the best public indicative bid on the day.

The selling strategy is converted to maximum business revenue by:

- Ensuring timely access to information, advice and trading facilities.
- Using different cash-market mechanisms when appropriate.
- Minimising counterparty risk by conducting effective due diligence.
- Understanding relative value and selling commodities when they are priced well.
- Thoughtful contract allocation.
- Reading market signals to extract value from the market or to prevent selling at a discount.

15.2 Western faba beans: market dynamics and execution

15.2.1 Price determinants for western faba beans

Faba bean production in Australia has grown to become an important part of the Australian grain 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, and particularly Egypt, are the main export markets for Australian faba beans. The main competitors in to this market are the UK and France. Although China is also a major producer, it is a net importer of faba beans. France and the UK have a freight advantage over Australian product into Middle Eastern and Egyptian markets, because they are so much closer; however, particular pests common in Europe and the United Kingdom, 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.

The major price determinants for faba beans are:

- global supply and demand
- the quality of the global crop
- the timing of Australian exports

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.

When the Australian faba bean crop is sown (from late April to the end of June for most areas), the areas planted and predicted yields for France and United Kingdom should already be known. The sowing intentions in Egypt and Chinese southern production (mainly broad beans) should also be evident (Figure 20).

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 demand for the Australian crop, and this will feed into bean prices achievable and how Australian farmers time marketing and selling. French and UK harvest yields and quality expectations have the most impact on demand for Australian beans.

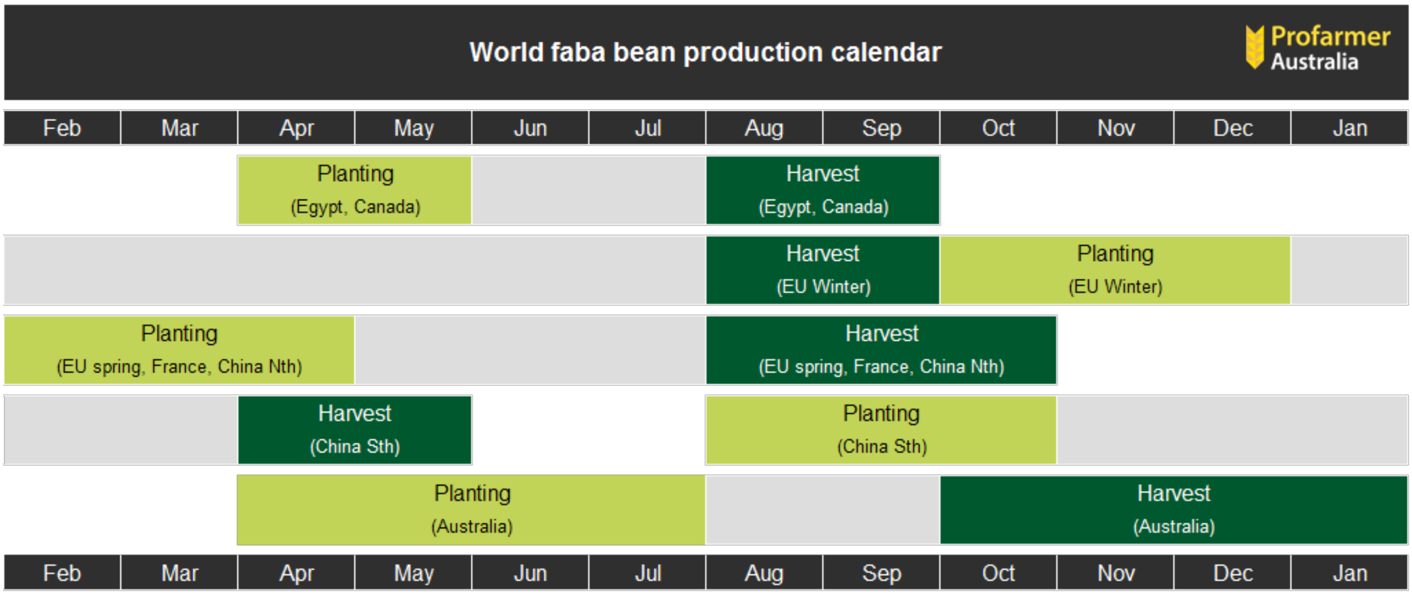


Figure 20: *Global faba bean production calendar.*

Source: Profarmer Australia

The pace of Australian faba bean exports is typically strongest shortly after our harvest (see Figure 21) as buyers seek to move crop ahead of the next Egyptian planting season and as supplies from the last northern hemisphere crop become more scarce.

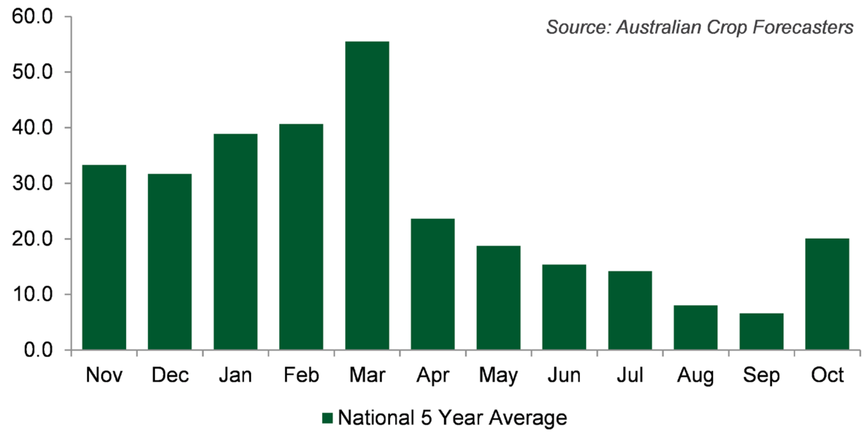


Figure 21: *Average monthly export pace ('000 t) of Australian faba beans and broad beans, averaged over five years.*

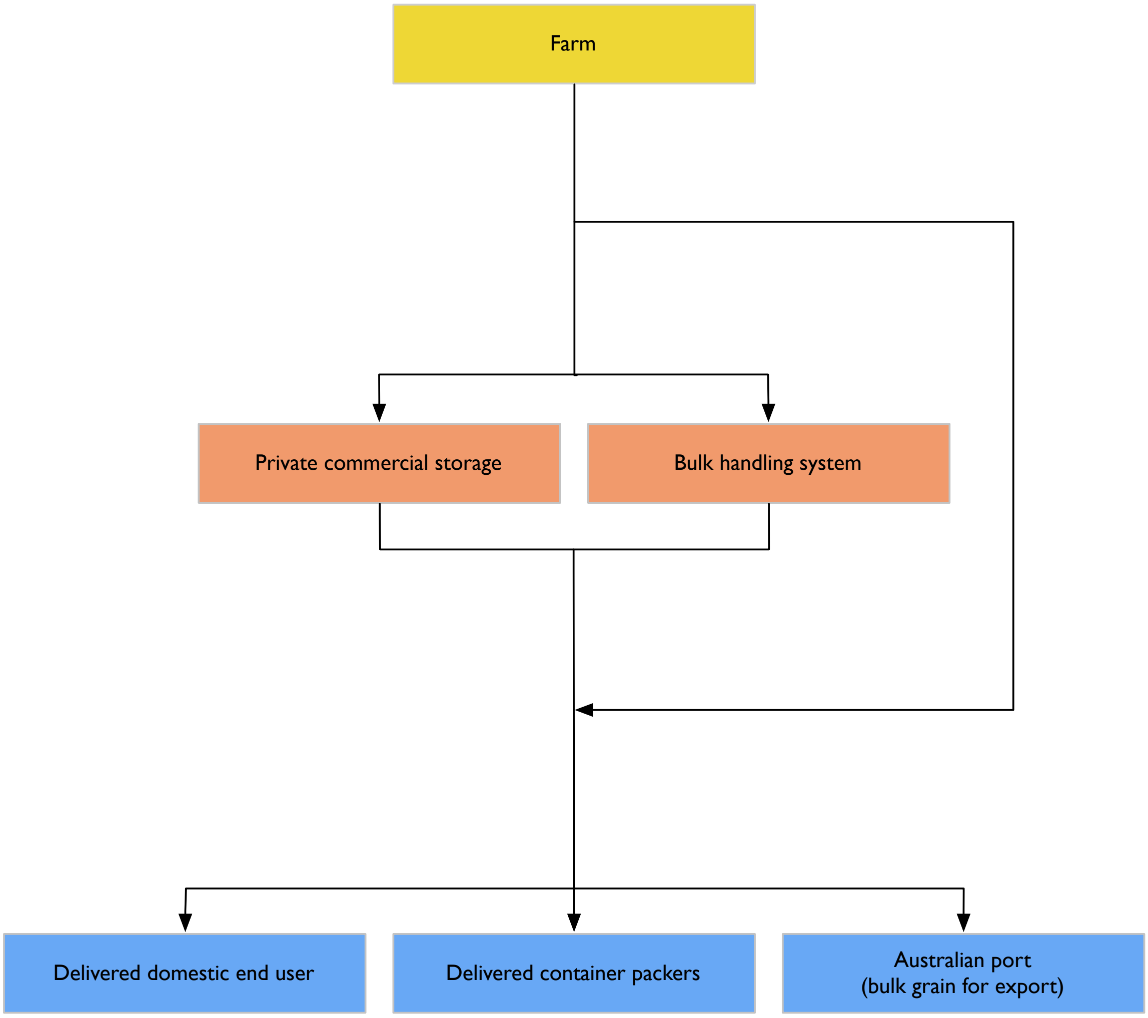
Source: Australian Crop Forecasters)Ensuring market access for western faba beans

The major food markets for faba beans are in the Middle East and Egypt, with the latter 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 beans along with France and the UK.

The timing of Ramadan can also influence appetite for faba beans. 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 beans 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. Although the bulk-handling system can be cheaper for product destined for bulk export, storage on the farm and delivery direct to the end-user is likely to be cheaper and also more flexible in the domestic and container-export markets.

Most human consumption markets prefer faba beans that are >8 mm in size. Smaller faba beans and broken beans (kibble) may be sold for the production of bean flour or stockfeed. Tolerances for seed discolouration are also much lower for human-consumption markets, especially for canning beans.



Note to figure:
Storage decisions should be determined by assessing market access. In Western Australia the large majority of wheat is exported in bulk. Hence the bulk handling system should provide efficiencies to market. Alternatively on-farm and private commercial storage may be a more reasonable method of accessing the container and end user markets.

Profarmer AUSTRALIA

Figure 22: *Australian supply-chain.*

Source: Profarmer Australia

15.2.2 Converting tonnes into cash for western faba beans

Given the volatile nature of faba bean prices, setting a target price using knowledge of the market outlined in section 15.2.2 will minimise the farmer's risk of having to accept an unprofitable price or of holding out for an unrealistically high price that may not eventuate.

There are some forward-price mechanisms available for faba beans, including area contracts and traditional fixed-volume forward contracts. Area-based contracts tend to price at a discount compared to fixed-volume contracts, but this needs to be weighed up against the level of production risk inherent in each contract.

As with all sales, minimising counterparty risk and having an understanding the contract of sale is essential. Counterparty risk 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, a lack of appropriate price-risk tools (such as futures), and the visual and subjective nature of determining quality. These can place extra risk on Australian traders endeavouring to find buyers for their product.

With the majority of Western Australia's container packing facilities being located in or around Perth, WA growers looking to market faba beans should consider their access to these facilities as part of their overall marketing plan.

If targeting buyers in domestic stockfeed markets, it is important to explore how strong and where the appetite is before planting a faba bean crop for the first time.

Price discovery for faba beans in the west can be difficult given the small size of the market, particularly relative to other grains produced. Hence South Australian markets, which have much greater market depth, can be an important source of price discovery, especially for those looking to understand export values (Figures 23 and 24).

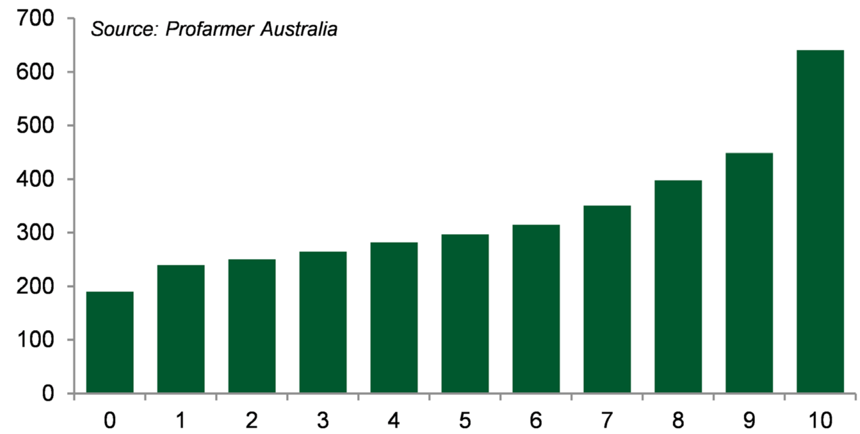


Figure 23: *Port Adelaide faba bean deciles. Deciles provide an indication of price performance relative to historical values. Decile 1 indicates values in the bottom 10% of historical observations, and a decile 9 indicates the top 10%.*

Source: Profarmer Australia

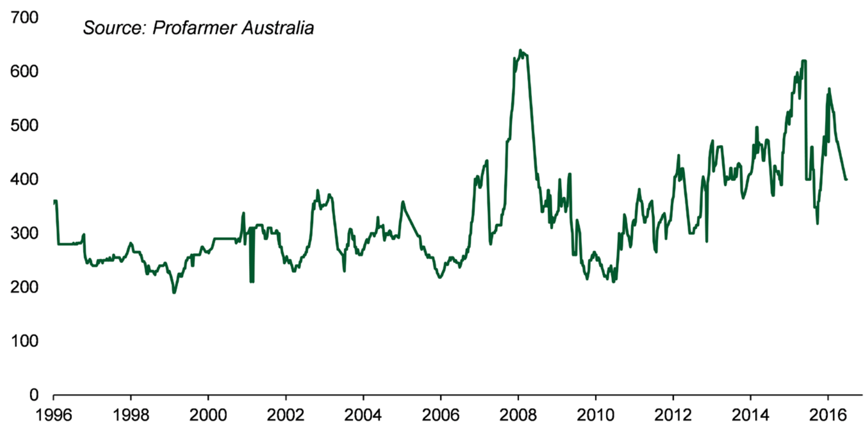


Figure 24: *Long-term Port Adelaide faba bean prices.*

Source: Profarmer Australia

MORE INFORMATION

[World pulse production calendar, in Pulses: Understanding global markets]

Australian pulse traders

Faba beans, in Understanding global markets

Lentil production: southern region

AEGIC's Australian pulses

Agriculture Victoria's ag note, Growing faba bean

DAFWA, Growing broad beans in Western Australia

Current and past research

Project Summaries www.grdc.com.au/ProjectSummaries

As part of a continuous investment cycle each year the Grains Research and Development Corporation (GRDC) invests in several hundred research, development and extension and capacity building projects. To raise awareness of these investments the GRDC has made available summaries of these projects.

These project summaries have been compiled by GRDC's research partners with the aim of raising awareness of the research activities each project investment.

The GRDC's project summaries portfolio is dynamic: presenting information on current projects, projects that have concluded and new projects which have commenced. It is updated on a regular basis.

The search function allows project summaries to be searched by keywords, project title, project number, theme or by GRDC region (i.e. Northern, Southern or Western Region).

Where a project has been completed and a final report has been submitted and approved a link to a summary of the project's final report appears at the top of the page.

The link to Project Summaries is www.grdc.com.au/ProjectSummaries

Final Report Summaries http://finalreports.grdc.com.au/final_reports

In the interests of raising awareness of GRDC's investments among growers, advisers and other stakeholders, the GRDC has available final reports summaries of projects.

These reports are written by GRDC research partners and are intended to communicate a useful summary as well as present findings of the research activities from each project investment.

The GRDC's project portfolio is dynamic with projects concluding on a regular basis.

In the final report summaries there is a search function that allows the summaries to be searched by keywords, project title, project number, theme or GRDC Regions. The advanced options also enables a report to be searched by recently added, most popular, map or just browse by agro-ecological zones.

The link to the Final Report Summaries is http://finalreports.grdc.com.au/final_reports

Online Farm Trials http://www.farmtrials.com.au/

The Online Farm Trials project brings national grains research data and information directly to the grower, agronomist, researcher and grain industry community through innovative online technology. Online Farm Trials is designed to provide growers with the information they need to improve the productivity and sustainability of their farming enterprises.

Using specifically developed research applications, users are able to search the Online Farm Trials database to find a wide range of individual trial reports, project summary reports and other relevant trial research documents produced and supplied by Online Farm Trials contributors.

The Online Farm Trials website collaborates closely with grower groups, regional farming networks, research organisations and industry to bring a wide range of crop research datasets and literature into a fully accessible and open online digital repository.

Individual trial reports can also be accessed in the trial project information via the Trial Explorer.

The link to the Online Farm Trials is http://www.farmtrials.com.au/

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