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GRDC GROWNOTES™

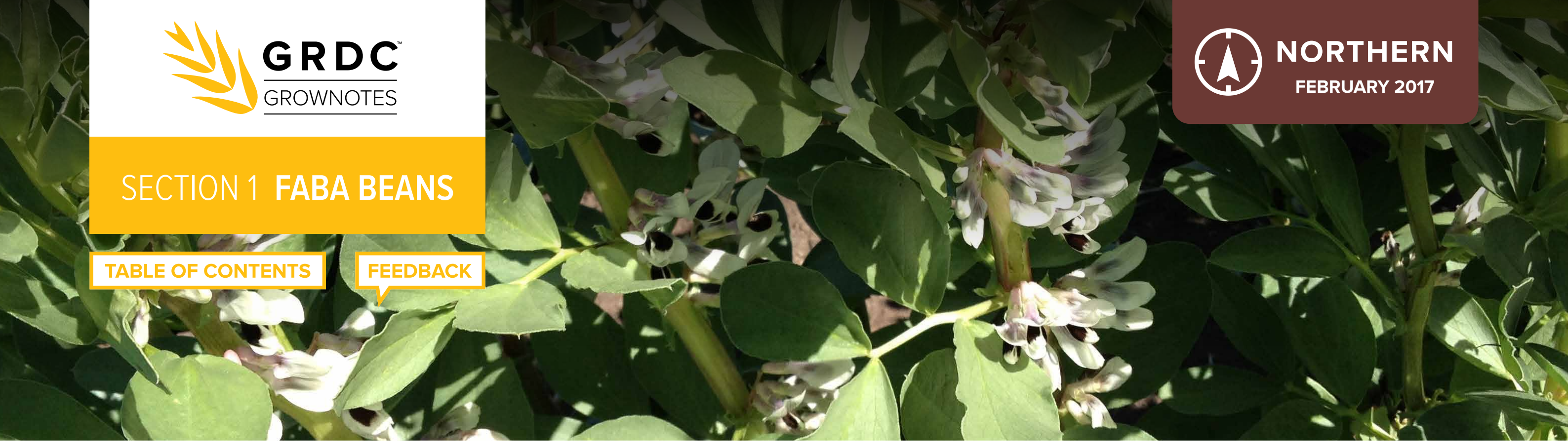
GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

FABA BEAN

SECTION 1

PLANNING AND PADDOCK PREPARATION

PADDOCK SELECTION AND GROUND PREPARATION | KEY REQUIREMENTS FOR FABA BEANS | PADDOCK ROTATION AND HISTORY | BENEFITS OF FABA BEANS AS A ROTATION CROP | DISADVANTAGES OF FABA BEANS AS A ROTATION CROP | FALLOW MANAGEMENT | SEEDBED REQUIREMENTS | SOIL MOISTURE | HERBICIDE RESIDUES IN SOIL | YIELD AND TARGETS | NEMATODE STATUS OF THE PADDOCK



Planning/Paddock preparation

1.1 Paddock selection and ground preparation

Uniformity of soil type, paddock topography, and surface condition of the paddock are important criteria in assessing whether country is suitable for faba bean production.

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 low cutting height. The smoother the paddocks the better is the harvesting result, particularly when using headers with wide fronts. Small variations in paddock topography can lead to large variations in cutting height across a wide front and subsequent harvest losses.

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

If growing irrigated faba beans, select fields with good irrigation layout and tail-water drainage. Beds or hills are preferred if flood-irrigating; however, border-check layout has been successful with grades steeper than 1 : 800 or with short runs that can be watered quickly (<8 h). There is a greater risk of irrigating after flowering with border-check, whereas beds and hills are satisfactory and sprinkler irrigation is the safest method overall.

Paddocks that have even soil types are easier to manage, and are preferred for faba beans. [1]

1.1.1 Avoid major variations in soil types

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. Disease concerns in the northern region include chocolate spot and rust.

Selecting a paddock with minimal variation in soil type will help to provide even maturity and ripening of the crop. This will enable harvesting at the earliest possible time, increase quality, and minimise harvest losses. The overall result is usually a more profitable crop.

The best soils for faba beans are deep, neutral to alkaline, well-structured soils with high clay content (Figure 1). In northern New South Wales (NSW)/southern Queensland, grey clays, black earths and brigalow clay loams are ideal. The crop will also grow well on red earth clay soils.

MORE INFORMATION

GRDC Update Paper: Impact of soil acidity on crop yield and management in Central Western NSW

1 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Figure 1: *The best soils for faba bean are deep, neutral to alkaline, well-structured soils with high clay content. In northern New South Wales/southern Queensland, grey clays, black earths and brigalow clay loams are ideal.*

Photo: NSW DPI

MORE INFORMATION

Ground Cover: Soil acidity holds back pulse potential

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($CaCl_2$) <5.2 at 20–30 cm depth.

Good yields have been achieved in Victoria in paddocks with pH as low as 4.6 where Al and Mn levels are low (Al <20 µg/g and/or Mn <50 µg/g). [2]

Soil sodicity should also be checked, and soils with high exchangeable sodium percentages (ESP) avoided (Figure 2). This is particularly relevant for some of the grey clay soils in the northern region.

2 DEPI (2013) Growing faba bean. AG0083. Update May 2013. Department of Environment and Primary Industries, http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/growing-faba-bean

Figure 2: *Soils with high exchangeable sodium percentages (ESP) should be avoided.*

Photo: Drew Penberthy, Penagcon

The crop can handle wet soil conditions better than other pulses and grows very well under furrow irrigation. It is common for dry seedbeds to be pre-watered before sowing, or for dry-sown crops to be watered up. Strategic irrigation during flowering and pod-filling is desirable to maintain high crop growth rates and to maximise pod development.

Paddocks for faba beans can be prepared using conventional or minimum cultivation, as for other winter crops, but the use of no-till or direct-drill methods is preferred and recommended in NSW. However, some soils in central NSW may require cultivation prior to sowing to remove the hardpans that reduce healthy root development.

Management of the fallow after wheat or barley should start when the cereal is harvested, ensuring that straw is left at ~30 cm height and kept as intact as possible by restricting access to support traffic such as chaser bins. Repeated in-fallow herbicide applications should be done on tramlines to minimise damage to stubble. [3]

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.

Check any soil tests and/or grower records, paying particular attention to the following soil characteristics:

- pH 5.2–8.0
- soil type—loams to self-mulching clays
- sodicity
- salinity/chloride
- bulk density
- potential waterlogging problems
- amount of stored soil moisture and received rainfall, and their potential impact on herbicide residues

Understand the crop management and harvest problems created by unlevelled paddocks and paddock obstacles such as sticks and stones.

3 P Matthews, 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

Aim to direct-drill faba beans into standing cereal stubble. Crops reliably yield 10% higher when established this way. [4]

1.1.2 Avoid deep gilgai or heavily contoured country

Contoured country and undulating country with gilgais present two problems. First, uneven crop maturity occurs because of variation in soil-water supply. Melon-holes usually store more water than the mounds, and the crop in wetter areas often continues flowering and podding when the rest of the crop is already drying down. Similarly, contour banks retain more moisture after rain, and prolong crop maturity relative to the rest of the crop late in the crop cycle.

Second, high harvest losses occur and there is increased risk of dirt contamination in the header sample. Many dryland faba bean crops require the header front to be set close to ground level, and even small variations in paddock topography can cause large variations in cutting height across the header front and significant harvest losses. Contamination of the harvested sample with dirt and clods is difficult to avoid in undulating, gilgai country, and can cause a significant increase in grading losses and costs.

Foreign material must not exceed 3% by weight, of which ≤0.3% must be un-millable material (soil, stones and on-vegetable matter).

If faba beans are delivered that do not meet this export standard, they will need to be graded at a cost of A$15–25/t. [5]

1.1.3 Sticks, stones, clods of soil, ridged soil surface

Stones and sticks are a concern in either poorly or recently cleared country. Harvest losses increase dramatically if the front needs to be raised to avoid serious mechanical damage to the header. Small stones and wood fragments can also contaminate the seed sample and downgrade quality.

Cloddy or badly ridged paddocks are likely to cause contamination of the faba bean sample during harvest. Level the soil surface as much as possible, either during ground preparation or at sowing. Use of a roller after sowing can be helpful where you need to level the soil surface, and push clods of soil and small stones down level with the surface (Figure 3). [6]

Figure 3: *Stones can be a harvest hazard in beans, even in tall crops, unless the ground is rolled after sowing.*

Photo: W. Hawthorne, Pulse Australia

4 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

5 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

6 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

1.1.4 Bunching and clumping of stubble

Stubble bunching or clumping can occur when sowing into retained stubble, as a result of blockages during sowing. These mounds of stubble are often picked up in the header front, causing mechanical blockages and contamination of the sample if they contain excessive amounts of soil.

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 (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. [7]
- Kelly discs are often used immediately after sowing to level the paddock prior to applying the residual herbicides. [8]
- Planting between standing cereal stubble protects the young faba plants from early frosts and helps to prevent spread of viruses from thrips and aphids (Figure 4).

Figure 4: *Planting between standing cereal stubble protects the young faba bean plants from early frosts and helps to prevent spread of viruses from thrips and aphids.*

Photo: Drew Penberthy, Penagcon

1.1.5 Disease and paddock selection

Avoid sowing adjacent to faba bean stubble, particularly downwind. If possible, aim to separate the current faba bean crop from last year's bean stubble by a minimum of 500 m.

A break of at least 4 years between faba bean crops is recommended.

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 breakdown of disease resistance and production of mixed seed types that are difficult to market.

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 bean. If this is

7 Northern Faba Bean—Best Management Practices Training Course, Pulse Australia 2014.

8 G Onus. Fababean Growing Program. Landmark Moree.

not possible, employ a management strategy appropriate for situations where there is a high risk of disease.

Ensure that the maximum plant-back periods for herbicides are adhered to, particularly for sulfonylurea and clopyralid. Herbicide residue may cause significant crop damage and weaken the plant's resistance to disease. [9]

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 will not grow as well in light or acidic soils. They can grow in areas prone to waterlogging, and are the pulse most tolerant of waterlogging (Figure 5). However, they must be well nodulated and have foliar diseases controlled to survive prolonged, waterlogged conditions. There is a limit to their tolerance, and their growth is affected by waterlogging. Avoid stony ground, because the plants need to be harvested close to the ground.

Figure 5: *Faba beans prefer well-draining loam to clay soils but are considered the pulse most tolerant to waterlogging.*

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

Tolerance to sodicity in the root-zone (to 90 cm) is: <5% ESP on the surface and <10% ESP in the subsoil (Mullen 2004) (see 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), Mn and perhaps iron (Fe) may be needed where deficiencies of these micronutrients are known to occur. [10]

9 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

10 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

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)
Lupin, narrow leaf	Sandy loams	4.2–6.0	20% tolerant	Sensitive (2)	<1 surface <3 subsoil
Lupin, albus	Sandy loams–clay loams	4.6–7.0	Up to 8%	Very sensitive (1)	<1 surface <3 subsoil
Field pea	Sandy loams–clays	4.6–8.0	Up to 5–10%	Tolerant (3)	<5 surface <8 subsoil
Chickpea	Loams–self mulching clay loams	5.2–8.0	Nil	Very sensitive (1)	<1 surface <5 subsoil
Faba bean	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 Paddock rotation and history

Implementation of the most suitable cereal–pulse–oilseed rotation requires careful planning. There are no set rules and a separate rotation should be devised for each cropping paddock.

The main aims should be sustainability and the highest possible overall profit. To achieve this, the rotation must be flexible enough to cope with key management strategies such as maintaining soil fertility and structure, controlling crop diseases, and controlling weeds and their seed-set.

The same pulse should not be grown in succession. Extreme care must be taken if growing the same crop in the same paddock without a spell of at least 3 years. Successive cropping with the same pulse is likely to result in rapid build-up of root and foliar diseases as well as weeds. Where possible, alternate different pulse crops in a continuous rotation with cereals.

Some farmers have adopted a pulse–wheat–barley sequence for their basic rotation. However, where a pulse and other crops can be grown, farmers are increasingly adopting a continuous pulse–cereal–oilseed–cereal rotation, e.g. beans–wheat–canola–barley. [11]

MORE INFORMATION

Ground Cover: Faba bean potential as southern rotation option

1.4 Benefits of faba beans as a rotation crop

1.4.1 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). They may also include two recently discovered processes. One is growth stimulation following hydrogen gas released into the soil by the

11 GRDC (2008) Grain Legume Handbook. Update 7 February 2008. Grains Research & Development Corporation, https://grdc.com.au/uploads/documents/Index.pdf

legume–rhizobial symbiosis. The other is a drain on assimilates when its roots are strongly colonised by the hyphae of arbuscular mycorrhizal fungi (AMF) built up by a previous colonised host crop. (AMFs have also been known as vesicular arbuscular mycorrhizal or VAM.)

Pulses fix their own N_2, 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. The amount of N 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; hence, high soil nitrate means low N_2 fixation.

Numerous trials have clearly demonstrated the yield increases possible when pulses are included in a cropping rotation (see Tables 2, 3 and 4)

Some of the most significant early trial results came from Tarlee, South Australia, where intensive cropping rotations including pulses were continued for >10 years until herbicide resistance became a problem (see Table 2).

Much of the yield increase was directly associated with the control of cereal root diseases, including cereal cyst nematode and take-all. The weed-control measures used in the pulses successfully reduced grass populations, which also act as host to many cereal root diseases. However, herbicide resistance developed, highlighting the fact that sustainability requires more than improving soil fertility and disease control. [12]

Table 2: *Tarlee rotation trial (soil type: red brown earth).*

Rotation	Wheat yields (t/ha) (5-year average)
Fallow–wheat	2.20
Continuous cereal + nitrogen[A]	1.82
Pulse–wheat	2.45
Sown pasture–wheat	2.23
Volunteer pasture–wheat	1.99

Pulses grown were field pea, lupin and faba bean

[A] Nitrogen was applied at 40 kg/ha.

Source: Grain Legume Handbook.

Table 3: *Coonalpyn rotation trial (soil type: sand over shallow clay).*

Pulses were field pea, lupin and faba bean

Rotation	Wheat yields (t/ha)
Continuous wheat + nitrogen[A]	3.0
Volunteer pasture–wheat	2.2
Sown pasture–wheat	2.2
Pulse–wheat	3.7

A Nitrogen was applied at 30 kg/ha.

Source: Grain Legume Handbook.

12 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Table 4: *Mundulla rotation trial (soil type: brown clay loam).*

Pulses were lupin (narrow leaf and albus), field pea and faba bean

Initial crop type	Second-year wheat yields			Third-year wheat yields		
	Rate of nitrogen (kg/ha):			Rate of nitrogen (kg/ha):		
	0	25	50	0	25	50
Pulse	4.75	4.95	4.99	2.71	3.23	3.48
Fallow	4.71	4.91	4.82	2.88	3.30	3.37
Pasture	3.69	4.22	4.27	2.85	3.21	3.28
Cereal	3.65	4.20	4.40	2.70	2.95	3.02

Source: Grain Legume Handbook.

1.4.2 Disease management and nitrogen benefits

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. Major cereal diseases in the northern grains region are shown in Table 5.

Table 5: *Major cereal diseases of the northern grains region and effectiveness of legumes as break-crops.*

Cereal disease	Causal agent	Crop legumes (chickpeas, faba beans, mungbeans, soybeans) as disease breaks
Crown rot	*Fusarium pseudograminearum*	Effective
Common root rot	*Bipolaris sorokiniana*	Effective
Yellow leaf spot	*Pyrenophora triticirepentis*	Effective
Take-all	*Gaeumannomyces graminis*	Effective
Fusarium head blight	*Fusarium graminearum*	Effective
Root lesion nematode	*Pratylenchus thornei, Pratylenchus neglectus*	Not particularly effective - all four crop legumes susceptible to *P. thornei*

From: D Herridge (2013) Managing legume and fertiliser N for northern grains cropping (GRDC)

All of the cereal diseases in Table 5, except root-lesion nematode (RLN), are caused by fungi. Soil-borne cereal pathogens reduce the health of the roots, subcrown internodes and crowns of plants, resulting in diminished ability of the plant to transport water and nutrients from the roots to the rest of the plant.

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

Wildermuth *et al.* (1997) suggested wheat yield losses of 10–20% from crown rot in the northern grainbelt. Other diseases, such as common root rot, yellow leaf spot and RLN, will add to that loss, with RLN alone estimated to cost northern grains region farmers about $50 million annually.

A reasonable estimate for the average disease-break effect of legumes in the northern grainbelt is 0.5 t/ha, equivalent to ~20% of average yield.

The combined N and disease-break effects of legumes are shown in a hypothetical set of data that describe wheat yields following either wheat or a legume, all grown in a relatively low-nitrate soil (Figure 6).

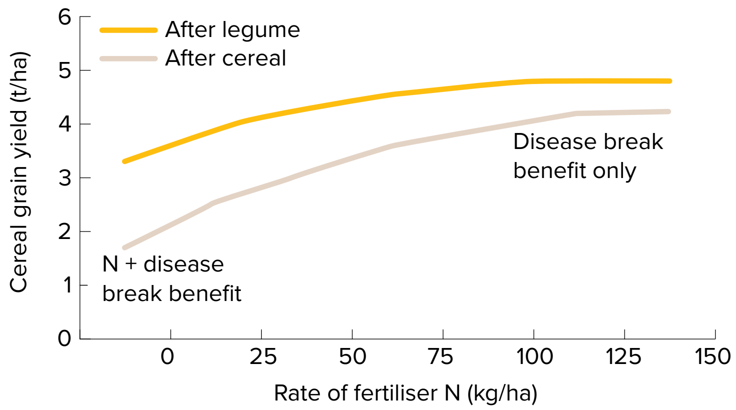


Figure 6: *Cereal yields following either a cereal or a grain legume, at increasing rates of fertiliser nitrogen (N). In this scenario, the yield differences are made up of a disease-break effect (0.5 t/ha) and an N effect, the latter ranging from zero at the highest rate of fertiliser N to 1.1 t/ha at nil fertiliser N.*

From: D Herridge (2013) Managing legume and fertiliser N for northern grains cropping. p. 35. GRDC

The wheat is fertilised with different rates of N to determine the fertiliser N equivalence, that is, how much additional fertiliser N is required for wheat after wheat compared with wheat after legume. At nil fertiliser N, the increased wheat yield after the legume is a combination of the N and disease-break effects. As the rate of fertiliser N is increased, the N benefit of the legume diminishes and the disease-break effect remains constant. At the high rates of fertiliser N, the rotational benefit of the legume may be entirely due to the disease-break effect.

In this hypothetical scenario, the fertiliser N equivalence of the legume benefit is about 60 kg N/ha. [13]

1.4.3 Controlling cereal root disease

Crown rot

Crown rot caused by the fungal pathogen *Fusarium pseudograminearum* is a major constraint to winter cereal production (wheat, barley and triticale) in Australia. The crown rot pathogen is stubble-borne and survives as mycelium (cottony growth) inside cereal and grass weed residues.

The starting levels of crown rot inoculum and the season in which break-crops are grown will influence their effectiveness. Hence, rotation to non-host winter pulse (chickpea, faba bean, field pea, lupin) or oilseed (canola or mustard) crops or to summer crops (sorghum, cotton, sunflowers, mungbean etc.) is a crucial component of an integrated disease management system (Figure 7). Break-crops allow natural microbial decomposition of cereal residues, which harbour the crown rot fungus.

The row spacing at which break-crops are sown likely influences their effectiveness in controlling crown rot. Research indicates that break-crops grown on row spacings of 30 or 38 cm rather than 50 or 100 cm provide more groundcover and will be more effective in reducing the inoculum of the crown rot fungus. [14]

Trials in the northern region have indicated that faba beans and canola are better break crops for crown rot than chickpeas.

MORE INFORMATION

Ground Cover: Fusarium head blight in the north

GRDC Update Paper: Managing crown rot through crop sequencing and row placement

GRDC Update Paper: Crown rot an update on latest research

13 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

14 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

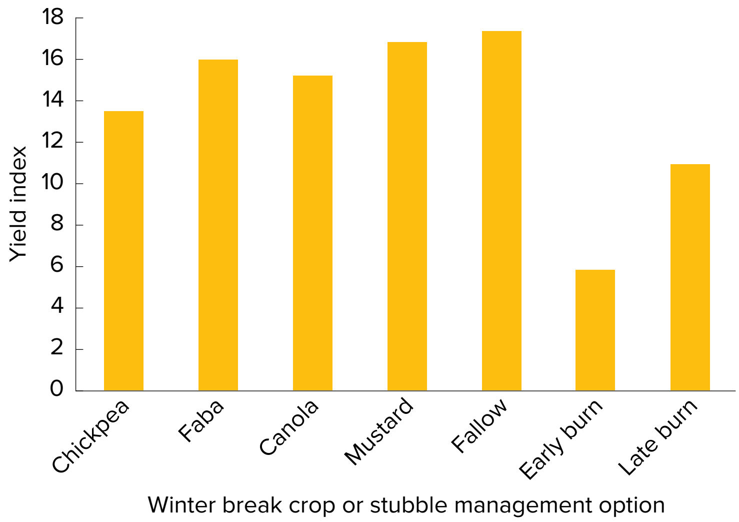


Figure 7: *Winter break-crop or stubble management options—yield indexed to continuous wheat.*

Source: NSW DPI. Crown rot management strategies, http://www.pulseaus.com.au/storage/app/media/crops/2006_Pulses-crown-rot-management.pdf

MORE INFORMATION

NSW DPI: Crown rot management strategies: http://www.pulseaus.com.au/storage/app/media/crops/2006_Pulses-crown-rot-management.pdf

MORE INFORMATION

GRDC Update Paper: Key outcomes arising from the crop sequence project

MORE INFORMATION

Ground Cover: New varieties and rotations rescue lost potential

1.4.4 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.

Break-crops improve the yield of subsequent wheat crops. For a 4 t/ha wheat crop, the additional yield after pulses was ranged from 1.81 t/ha (for lupin) to 1.10 t/ha (for field pea). For an oats break-crop it was 0.47 t/ha, and after canola and linseed it was 0.85 t/ha.

Data suggest that control of take-all and residual N after legumes are the largest benefits from break-crops (Table 6).

Table 6: *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 lupin, chickpeas, field peas and faba beans 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%. [15]

1.4.5 Nitrogen fixation

A pulse crop does not necessarily add large quantities of N to the soil. The amount of 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 in the grain when crops are harvested.

Soil N levels following a pulse crop usually remain undepleted, so it is the available N that is high (see Table 7).

Where a pulse crop grows well but produces a poor yield, i.e. low harvest Index, the net result 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 (see Table 7). In low-yielding cereal–pulse rotations, the pulse may provide enough N for the following crop. [16]

Quantifying nitrogen fixation

Turpin *et al* (2002) found that faba beans are more reliant on N_2 fixation than are chickpeas when grown under the same conditions of soil N supply. Early in crop growth, when soil N supply was high, faba beans maintained a higher dependence on N_2 fixation than chickpeas (45% v's 12%), fixed greater amounts of N_2 (57 *v.* 16 kg/ha), and used substantially less soil N (69 *v.* 118 kg/ha) (Figure 8).

In that study, soil-N sparing was observed. However, despite these differences in N_2 fixation and soil nitrate interactions, at the end of the growing season, there were no differences in soil nitrate levels between the chickpea, faba bean, and wheat plots. Grain yields of the two pulses were unaffected by soil-N supply (i.e. fertiliser N treatment).

Under the starting soil nitrate levels typical of many cropping soils (11–86 kg N/ha), faba bean and chickpea crops with high biomass will not spare significant amounts of soil N. With higher soil nitrate and/or smaller biomass crops with less N demand, nitrate sparing may occur, particularly with faba beans.

MORE INFORMATION

GRDC Update Paper: Legume effects on soil N dynamics - comparisons of crop response to legume and fertiliser N (Corowa)

15 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

16 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Overall, Turpin *et al* (2002) found that 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. Values for percentage of the N that had been fixed were 69–88% for faba beans and 64–85% for chickpeas (Figure 9). 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). [17]

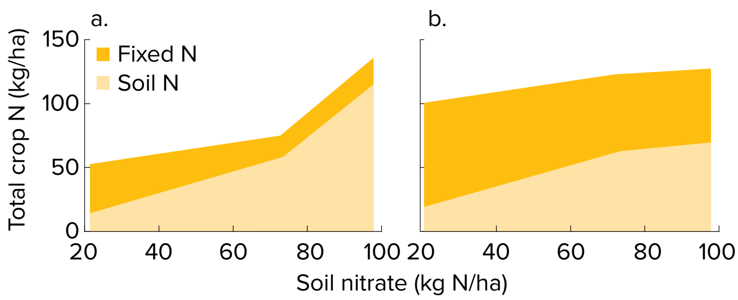


Figure 8: *Effects of soil N supply on soil-N use and N_2 fixation of (a) chickpeas and (b) faba beans for days 0–64 of growth. Soil N supply varied with fertiliser N treatment. These data supports the need for early and effective nodulation in faba bean.*

Source: Turpin et al. 2002

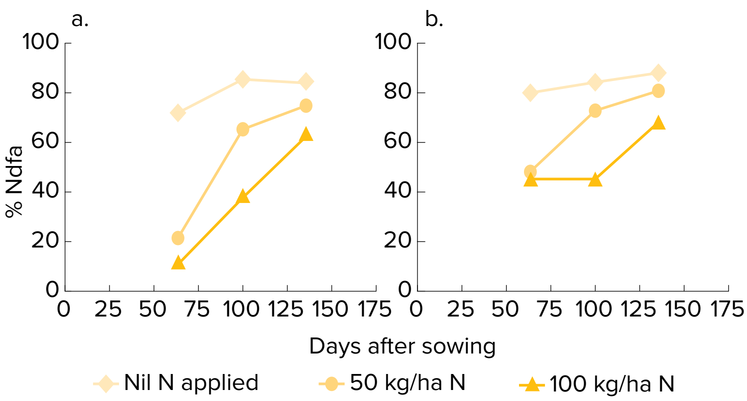


Figure 9: *Effects of available soil nitrogen (applied as N fertiliser) on the percentage of the N that was fixed (i.e. derived from the atmosphere; % Ndfa) over time for (a) chickpea and (b) faba bean.*

Source: Turpin et al. 2002

Nitrate-N benefit for following cereals

The nitrate-N benefit from chickpea and faba bean over a range of grain yields has been calculated from trials in northern Australia (Herridge *et al*. 2003) (Table 8). To understand N budgets for chickpeas and faba beans, it is important to understand the terminology:

17 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

- Total nitrogen fixed. The N fixed in both aboveground (shoots) and belowground (roots and nodules) biomass. With chickpea, 50% of total crop N is belowground; with faba bean, it is ~30%.
- Nitrogen balance. The difference between N inputs to the pulse crop (N_2 fixation + N applied) and N outputs (N harvested in grain or hay + N lost (volatilised) from the crop and soil).
- Nitrate-N benefit. The extra nitrate-N available at sowing in soil that grew a pulse crop in the previous season, compared with soil that grew a cereal crop.
- Harvest index (HI). For different crops, the relationship between shoot dry matter and grain yield (i.e. HI) may vary according to season and management. [18]

Table 7: *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.

MORE INFORMATION

GRDC Update Paper: Fixing more nitrogen in pulse crops

By understanding the development and measurement of crop biomass as well as the factors that influence HI, then better N and rotation management decisions can be made.

1.5 Disadvantages of faba beans 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.

Faba beans also provide limited stubble cover and may have implications for nematode populations.

Faba beans have few disadvantages; however, volunteers can appear after the crop is harvested. Diseases in wet years are also a concern. Spraying with a tow-behind

18 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

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.

1.6 Fallow management

The increased soil-water retention and decreased soil nitrate accumulation that occurs during a summer (pre-crop) fallow has been shown by the NSW Department of Primary Industries (NSW DPI) to improve the productivity and N_2 fixation of chickpeas and faba beans.

In NSW DPI rotation experiments involving faba beans, no-tilled soils contained 38 mm more water than cultivated soils at the end of the summer fallows, and 30 kg N/ha less nitrate. Shoot dry matter, plant N and crop N_2 fixed were, respectively, 5%, 12% and 14% higher in no-till crops. [19]

Paddocks for faba beans can be prepared using conventional or minimum cultivation as for other winter crops, but no-till or direct-drill methods are preferred, and are recommended in NSW. However, some soils may require cultivation prior to sowing to remove hardpans that inhibit healthy root development.

Management of the fallow after wheat or barley should start when the cereal is harvested. Leave straw at ~30 cm height and keep as intact as possible by restricting access to support traffic such as chaser bins. Repeated in-fallow herbicide applications should be done on tramlines to minimise damage to stubble. [20]

1.6.1 Fallow weed 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 select a paddock with low weed burden, or utilise the preceding crop and fallow to reduce weed numbers. Weed control mostly needs to be done in preceding cereal crops, combined with pre-emergent herbicides and vigorous plant stands.

For a list of registered herbicides, the annual NSW Agriculture Weed Control in Winter Crops is a useful guide. Consult the product label before using any herbicide.

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. [21]

1.6.2 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.

Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half of the original amount, what remains can persist for long periods, for example in sulfonylureas such as chlorsulfuron. Herbicides with long residuals can affect subsequent crops, especially if effective at low levels of active ingredient (such as the sulfonylureas). On the label, this will be shown by plant-back periods, which are

19 GRDC (2013) Nitrogen fixation and N benefits of chickpeas and faba beans in northern farming systems. GRDC Nitrogen Fixation Fact Sheet July 2013, http://www.grdc.com.au/Resources/Factsheets/2013/07/Nitrogen-fixation-and-N-benefits-of-chickpeas-and-faba-beans-in-northern-farming-systems

20 P Matthews, 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

21 P Matthews, 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

usually listed under a separate 'Plant-back' heading or under the 'Protection of crops etc.' heading in the 'General Instructions' section of the label. [22]

1.6.3 Herbicide residues in soil

Pulse growers need to be aware of possible herbicide residues because they can affect crop rotation choices or cause crop damage. Herbicide residues are more damaging where rainfall has been low. After a dry season, herbicide residues from previous crops could influence crop choice and rotations more than considerations of disease. The reverse occurs after a wet year.

Weed burden in the new crop will depend on the seed-set from previous year and residual herbicide efficacy.

Pulse crop types differ in their sensitivity to residual herbicides, so check each herbicide used against each pulse type.

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; plants stop growing and eventually die. Beans and vetches are more sensitive to Logran® (triasulfuron) than to Glean® (chlorsulfuron) residues, unlike other pulses. 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 use of any herbicides. Be especially wary under conditions of limited rainfall since herbicide application.

MORE INFORMATION

Australian Pulse Bulletin: Residual herbicides and weed control

Picloram (e.g. Tordon® 75-D) residues 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 (Figures 10 and 11). 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.

In wheat–faba bean rotations, fallow and in-crop residual 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 (Glean®, Lusta®) and Logran® should be avoided in wheat when re-cropping to faba beans. [23]

Figure 10: *Tordon® soil residues affecting faba bean. Note the stem distortion and severe leaf curl.*

Photo: Grain Legume Handbook

22 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

23 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Figure 11: *Previous year's Tordon® spot spray effect. Plants in the affected area are stunted.*

Photo: Grain Legume Handbook

1.7 Seedbed requirements

Rhizobia

Before European settlement, Australian soils lacked the rhizobia (N_2-fixing soil bacteria) needed for the pulse and pasture legumes now commonly grown in farming systems. However, after more than a century of legume cultivation, many soils have developed large and diverse communities of these introduced rhizobia.

Rhizobia become established in soils in several ways. Many were introduced as high-quality inoculants. Others arrived accidently with the movement of dust, soil and seed around the country, and some have evolved via genetic exchange with other bacteria in the soil. Because rhizobia are legume-specific and their persistence is affected by soil characteristics and cultural practices, their diversity, number and N_2-fixation capacity can vary greatly.

The legume history of a soil provides some guide. If a legume species, or one very similar to it, has not been grown in a paddock, it is unlikely that the rhizobia for that legume will be present in the soil in high numbers.

Conversely, where there is a recent history of well-nodulated legumes in a paddock, there is a reasonable chance the rhizobia that nodulated the legume will be in the soil.

Some extension materials suggest that inoculation is not necessary if the legume host has been grown in any of the previous 4 years. This simplistic rule fails to recognise that the level of nodulation of the previous crop can affect the current population of rhizobia in the soil, and that many soils are not conducive to the survival of large numbers of rhizobia because of factors such as extremes of soil pH and low clay content. In addition, the communities of rhizobia that develop under legume cultivation often become less effective N_2 fixers over time. [24]

It is wise to inoculate the faba beans each time they are planted to ensure effective nodulation; it is the cheapest and most effective N supplied into the farming system. Always inoculate the seed with the correct rhizobial strain regardless of paddock history.

Inoculate seed with correct rhizobium (Group F). This comes in various forms including freeze-dried vials, liquid vials and peat-based products. The vial products can be easily pumped and sprayed onto the seed. The peat products are usually mixed into a slurry with water and poured onto the stream of grain as it goes up

24 E Drew et al. (2012) GRDC Inoculating legumes: a practical guide. GRDC, http://www.grdc.com.au/GRDC-Booklet-InoculatingLegumes

MORE INFORMATION

Rhizobial inoculants Fact Sheet

the auger. Inoculation is usually done as the faba beans are augered into the air seeder cart. [25]

1.8 Soil moisture

1.8.1 Dryland

At sowing, faba beans need at least 150 mm of plant-available water (PAW), to a depth of 1 m. The crop requires average annual rainfall of 400 mm, or areas with irrigation. Faba beans have been grown in drier areas (350 mm); however, there are yield penalties.

Eighty mm of PAW is equivalent to about a 50% profile on a deep clay soil, and closer to a 75% profile on a loam soil. Faba beans have good tolerance of sodic and waterlogged soils, providing the sodicity or underlying structural problems do not greatly affect the water-holding capacity of the soil. [26]

1.8.2 Irrigation

Faba beans can be sown into pre-watered beds or hills, or into a dry seedbed. Dry sown seed should be watered-up as soon as possible to maintain the viability of the inoculum applied to the seed. Once watered up, and/or given reasonable rainfall in June and July, the crop may not need watering until early spring. [27]

1.8.3 Seasonal outlook

Growers and advisers now have a readily available online decision tool. CropMate was developed by NSW DPI and can be used in pre-season planning to analyse average temperature, rainfall and evaporation. It provides seasonal forecasts and information about influences on climate, such as the effect of Southern Oscillation Index (SOI) on rainfall. CropMate provides estimates of soil water and N, frost and heat risk, and gross margin analyses of the various cropping options.

Download CropMate from the App Store on iTunes at:
https://itunes.apple.com/au/app/cropmate-varietychooser/id476014848?mt=8

Australian CliMate is a suite of climate analysis tools delivered on the web, and iPhone, iPad and iPod Touch devices. CliMate allows you to interrogate climate records, to ask questions relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, and well as El Niño Southern Oscillation status. It is designed for decision makers such as farmers whose businesses rely on the weather.

Download from the Apple iTunes store at https://itunes.apple.com/au/app/australian-climate/id582572607?mt=8 or visit http://www.australianclimate.net.au

One of the CliMate tools, '*Season's progress?*', uses long-term (1949 to present) weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years. It explores the readily available weather data, compares the current season with the long-term average, and graphically presents the spread of experience from previous seasons.

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

- How is the crop developing compared to previous seasons, based on heat sum?
- Is there any reason why my crop is not doing as well as usual because of below-average rainfall or radiation?

25 G Onus. Fababean Growing Program. Landmark Moree.

26 R Brill (2011) Research reveals how to improve faba results. GRDC Ground Cover Issue 92, May–June 2011, http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-92-May-June-2011/Research-reveals-how-to-improve-faba-results

27 P Matthews, 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

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Seasonal-climate-outlook-improvements-changes-from-historical-to-real-time-data

www.australianclimate.net.au

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW

- Based on season's progress (and starting conditions from HowWet-N?), should I adjust inputs?

For inputs, *Season's progress?* asks for the weather variable to be explored (rainfall, average daily temperature, radiation, heat sum with base temperatures of 0, 5, 10, 15 and 20°C), a start month and a duration.

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. [28]

The Bureau of Meteorology has recently moved from a statistics-based to a physics-based (dynamical) model for its seasonal climate outlooks. The new system has better overall skill, is reliable, allows for incremental improvements in skill over time, and provides a framework for new outlook services including multi-week/monthly outlooks and the forecasting of additional climate variables. [29]

For a growing crop, there are two sources of water: first, the water stored in the soil during the fallow, and second, the water that falls as rain while the crop is growing. As a farmer, you have some control over the stored soil water; you can measure how much you have before planting the crop. Long-range forecasts and tools such as the SOI can indicate the likelihood of the season being wet or dry; however, they cannot guarantee that rain will fall when you need it. [30]

Faba bean varieties should be grown only in areas where the rainfall is >350 mm. Faba beans 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 hot conditions occur. Yield potential is therefore severely penalised by adverse hot and dry conditions during flowering.

Cool conditions are ideal for flowering and pod-set. Cool and wet conditions are more likely to stimulate foliar diseases if protection is not provided, and foliar disease can adversely affect seed-set and yield. Chocolate spot *(Botrytis fabae)* and, in some areas, rust (*Uromyces viciae*) are now 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 bean.

HowWet?

HowWet? is a program that uses records from a nearby weather station to estimate how much PAW has accumulated in the soil and the amount of organic N that has been converted to an available nitrate during a fallow. HowWet? tracks soil moisture, evaporation, runoff and drainage on a daily time-step. Accumulation of available N in the soil is calculated based on surface soil moisture, temperature and soil organic carbon.

HowWet?:

- estimates how much rain has been stored as plant-available soil water during the most recent fallow period;
- estimates the N mineralised as nitrate-N in soil; and
- provides a comparison with previous seasons.

This information aids in the decision about which crop to plant and how much N fertiliser to apply.

28 Australian CliMate. Climate tools for decision makers. Managing Climate Variability R&D Program, www.australianclimate.net.au

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

30 J Whish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Papers 23 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW

Many grain growers are in regions where stored soil water and nitrate at planting are important in crop management decisions. This is particularly so for northern Australian grain growers with clay soils, where stored soil water at planting can constitute a large part of a crop's water supply.

Questions this tool answers:

- How much longer should I fallow? If the soil is near full, perhaps the fallow can be shortened.
- Given my soil type and local rainfall to date, what is the relative soil moisture and nitrate-N accumulation over the fallow period compared with most years? Relative changes are more reliable than absolute values.
- Based on estimates of soil water and nitrate-N accumulation over the fallow, what adjustments are needed to the N supply? [31]

Inputs

1. A selected soil type and weather station
2. An estimate of soil cover and starting soil moisture
3. Rainfall data input by the user for the stand-alone version of HowOften?

Outputs

4. A graph showing plant-available soil water for the current year and all other years and a table summarising the recent fallow water balance
5. A graph showing nitrate accumulation for the current year and all other years

Reliability

HowWet? uses standard water-balance algorithms from HowLeaky? and a simplified nitrate mineralisation based on the original version of HowWet? Further calibration is needed before accepting with confidence absolute value estimates.

Soil descriptions are based on generic soil types with standard organic carbon (C) and C/N ratios, and as such should be regarded as indicative only and best used as a measure of relative water accumulation and nitrate mineralisation. [32]

MORE INFORMATION

http://www.australianclimate.net.au/About/HowWetN

1.8.4 Weeds and paddock selection

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 beans in 4 years.
  - » Plant 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 vector viruses).
  - » Consideration also needs to be given to previous crops that may host pathogens such as *Sclerotinia, Rhizoctonia* and *Phoma medicaginis*.
  - » *Ascochyta fabae* and *Botrytis fabae* are faba bean specific, whereas *Botrytis cinerea* has a wide host range including chickpeas.
  - » *Phoma medicaginis* var. *pinodella* can be hosted by lucerne, clover, field peas, lupins and chickpeas as well as *Phaseolus* spp.
- History of bean diseases
  - » 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.
  - » Plant at least 500 m (preferably more) distance from previous year's bean crop.

31 Australian CliMate. How Wet/N. Managing Climate Variability R&D Program, http://www.australianclimate.net.au/About/HowWetN

32 Australian CliMate. How Wet/N. Managing Climate Variability R&D Program, http://www.australianclimate.net.au/About/HowWetN

- 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
  - Have 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 soil may cause crop damage and thus confusion over in-field disease diagnosis. [33]

1.9 Herbicide residues in soil

Residues from herbicides used in the current or previous crop could influence subsequent crop choice in rotations. Crop damage could occur if residues are ignored, particularly where rainfall has been minimal.

Pulse and other crop types differ in their sensitivity to residual herbicides, so check each herbicide used against each crop type. Choice of herbicide in cereal and oilseed crops may have to accommodate the planning of a pulse crop next in the rotation sequence. For example, 10 months may need to elapse before a chickpea crop can be grown after use of an imidazolinone ('imi') herbicide, and likewise, >24 months after chlorsulfuron has been applied on high pH soils.

Soil erosion

Pulses have slow early growth and consequently leave the soil more susceptible to the effects of wind and water erosion than do cereals. This highlights the benefits of stubble retention and limited tillage with pulses in the farming system.

Poor emergence is more likely with pulses on hard-setting soils. This can lead to a greater potential for soil erosion. Rolling after sowing a pulse crop can also leave some soils prone to erosion, and in these situations, post-emergent rolling is preferred if possible. [34]

1.10 Yield and targets

1.10.1 Yields

Constantly increasing production costs and increasing supplies of pulses mean that future success with these crops will depend on greater productivity per ha and per mm of rainfall.

It will be necessary to find and adopt the best management practices for the crop in relation to tillage, time of sowing, weed control and fertilising.

There is much room for improvement in these areas. 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 12).

Different pulses have varying yield potentials under different yielding situations, based on yield potential under adequate moisture or drought tolerance (Figure13).

33 Northern Faba Bean—Best Management Practices Training Course, Pulse Australia 2014.

34 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

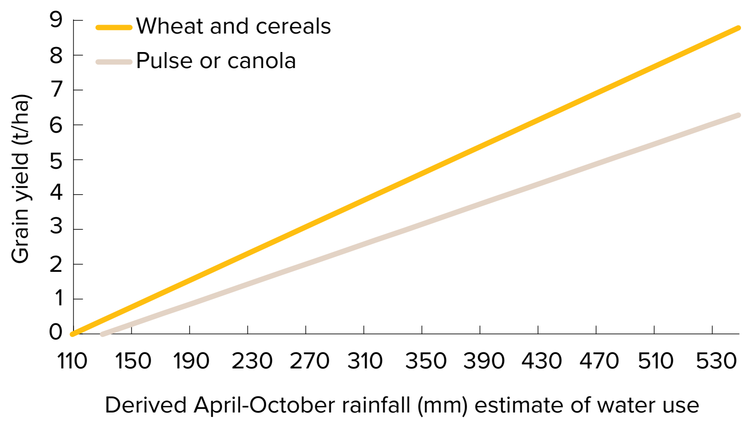


Figure 12: *Relationship of grain yield (t/ha) to estimated water use April–October. Pulses, 15 kg/ha.mm water available over 130 mm; cereals, 20 kg/ha.mm available over 110 mm.*

Source: Grain Legume Handbook, from French and Schultz model

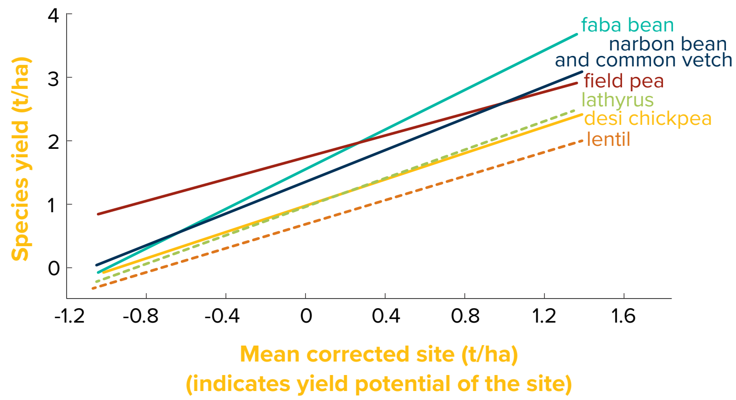


Figure 13: *Variation in grain yield of different grain legume species across sites with different yield potential in Western Australia.*

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.

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 pod-set.

Temperature minimum for pod-set ranges from –1.5°C to 15°C depending on crop species. 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°

required by chickpeas. Sunlight, and hence photosynthesis, is critical for pod-set 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 bean 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 chickpea 30°C.

The different pulse crops also need different amounts of time and cumulative temperature to go through various growth stages. Pulse crops will produce higher yields if they are sown early enough to allow them to finish flowering before the week of critical average daily maximum temperature.

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 (French *et al* 1979). Table 8 presents CMDTs that different crops need from sowing to reach flowering and harvest.

These dates can also be calculated from thermal units (also known as heat units, day-degrees, growing degree-days or GDD). The difference is that thermal unit degree-days are calculated by adding mean daily temperatures, and so use the average of daily minimum and maximum temperatures, whereas CMDT uses only the maximum temperature in its calculation.

Table 8: *Cumulative maximum daily temperatures (CMDT) from sowing to various crop growth stages.*

	Beginning of flowering	End of flowering	Harvest
Faba bean	1300	2200	3300
Field pea	1600	2400	3300
Lupin	1600	2400	3600
Chickpea and lentil			
Early cultivars	1600	2400	3200
Late cultivars	2000	2800	3400
Wheat	1900	2200	3300

Source: Grain Legume Handbook.

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 30°C for chickpea (20°C for other pulses) 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 (Table 8).

Use of thermal units

Thermal unit data are used overseas for comparison between broadacre crops or varieties of their heat requirements to achieve particular growth stages. Thermal unit data are not commonly published or used in Australia for broadacre crops. However, thermal units are used in Australia in entomology and in weed management, for example. Thermal unit maps are published on the web for Canada and USA so that growers can know how the current season is progressing relative to average. Perhaps the concept should be more widely used in Australia.

1.10.2 Water Use Efficiency

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

Water Use Efficiency relies on:

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

Water is the principal limiting factor in rain-fed cropping systems in northern Australia. The objective of rain-fed cropping systems is to maximise the proportion of rainfall that crops use, and minimise water lost through runoff, drainage and evaporation from the soil surface and to weeds.

Rainfall is more summer-dominant in the northern region, and both summer and winter crops are grown. However, rainfall is highly variable and can range, during each cropping season, from little or no rain to major rain events that result in waterlogging or flooding.

Storing water in fallows between crops is the grower's most effective tool to manage the risk of rainfall variability, as in-season rainfall alone, in either summer or winter, is rarely enough to produce a profitable crop, especially with high levels of plant transpiration and evaporation. [35]

MORE INFORMATION

http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

1.11 Nematode status of the paddock

The primary RLN species, Pratylenchus thornei, costs the wheat industry A$38 million annually. [36] Including the secondary species, *P. neglectus*, RLN is found in three-quarters of paddocks tested. [37]

MORE INFORMATION

https://www.grdc.com.au/~/media/B4063ED6F63C4A968B3D7601E9E3FA38.pdf

http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

1.11.1 Nematode testing of soil

Paddocks should be diagnosed for plant parasitic nematodes so that optimal management strategies can be implemented. Testing your farm will tell you:

- whether nematodes are present in your paddocks and at what density; and
- which species are present.

It is important to know which species are present because some crop-management options are species-specific. If a particular species is present in high numbers, immediate decisions must be made to avoid losses in the next crop to be grown. With low numbers, plans can be made to safeguard future crops. Learning that a paddock is free of these nematodes is valuable information because steps may be taken to avoid contamination. [38]

MORE INFORMATION

vGround Cover Supplement: Predicta B an identity kit for soil borne pathogens

Testing of soil samples taken before a crop is sown or while the crop is in the ground provides valuable information. Because there is a great deal of spatial variation in

MORE INFORMATION

Ground Cover: Single test improves stubble-borne disease management

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35 GRDC (2009) Northern Region. Converting rainfall to grain. GRDC Water Use Efficiency Fact Sheet, http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

36 GM Murray, JP Brennan (2009) The current and potential costs from diseases of wheat in Australia. GRDC Report, https://www.grdc.com.au/~/media/B4063ED6F63C4A968B3D7601E9E3FA38.pdf

37 K Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

38 Queensland Primary Industries and Fisheries (2009) Root lesion nematodes—management of root-lesion nematodes in the northern grain region. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

nematode populations within paddocks, it is important to follow sampling guidelines to ensure accurate results.

1.11.2 Effects of cropping history on nematode status

Root-lesion nematode numbers build up steadily under susceptible crops and cause decreasing 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

Generally, a population density of 2000 RLN/kg soil anywhere in the soil profile has the potential to reduce the grain yield of intolerant wheat varieties.

A tolerant crop yields well when high populations of RLN are present (the opposite is intolerance). A resistant crop does not allow RLN to reproduce and increase in number (the opposite is susceptibility).

Growing resistant crops is the main tool for managing nematodes. In the case of crops such as wheat or chickpea, choose the most tolerant variety available and rotate with resistant crops to keep nematode numbers at low levels. Information on the responses of crop varieties to RLN is regularly updated in grower and Department of Agriculture, Fisheries and Forestry Queensland planting guides. Note that crops and varieties have different levels of tolerance and resistance to *P. thornei* and *P. neglectus*. In the northern region, faba bean is resistant to *P. neglectus* and susceptible to *P. thornei*. [39]

Summer crops have an important role in management of RLN. Research shows when *P. thornei* is present in high numbers, two or more resistant crops in sequence are needed to reduce populations to low enough levels to avoid yield loss in the following intolerant, susceptible wheat crops. [40]

1.11.3 Faba beans and RLN

Preliminary results from Northern Grower Alliance (NGA) trials show there is no evidence of yield loss due to *Pratylenchus thornei* in faba beans.

Faba beans are broadly similar to chickpeas and bread wheat in building-up *Pratylenchus thornei* populations with all three crops rated as susceptible. To date, varietal differences in resistance have been minor but PBA Warda⍉ may be marginally less susceptible than Cairo⍉ and Doza⍉. In contrast, in both wheat and chickpeas there is a large varietal range in susceptibility. [41]

MORE INFORMATION

https://sites.google.com/site/crownanalyticalservices/home

http://www.sardi.sa.gov.au/products__and__services/entomology/diagnostic_services/predicta_b

http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

MORE INFORMATION

'Management of root-lesion nematodes in the northern grain region':
http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

MORE INFORMATION

GRDC Update Paper: Impact of crop varieties on RLN multiplication

39 GRDC (2009) Northern region. Root lesion nematode dominates in the north. GRDC Plant Parasitic Nematodes Fact Sheet, http://www.grdc.com.au/uploads/documents/GRDC_NematodesFS_North_4pp.pdf

40 K Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes. GRDC Update Papers 16 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

41 R Daniel, Northern Grower Alliance pers comms 3014