

GROWNOTES™

FIELD PEA

INTRODUCTION

PLANNING & PADDOCK PREPARATION

PRE-PLANTING

PLANTING

PLANT GROWTH AND PHYSIOLOGY

NUTRITION AND FERTILISER

WEED CONTROL

PEST MANAGEMENT

DISEASES

PRE-HARVEST TREATMENTS

HARVEST

STORAGE

ENVIRONMENTAL ISSUES

MARKETING

CURRENT RESEARCH

KEY CONTACTS

Start here for answers to your immediate field pea crop management issues



What variety should I grow?



What paddock conditions suit field pea?



What weed control options are there for field pea?



What is the best approach for managing Ascochyta blight?



What are the essentials before and during harvest?



How do I manage the impact of frost on field pea?

FIELD PEA

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FEEDBACK

Field pea production



Not <7°C – Establishment
25°C and less during
critical reproductive phases

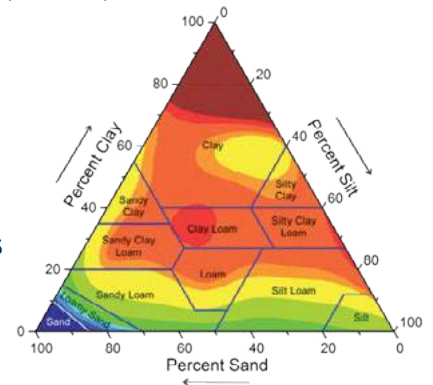


RAINFALL
300–750 mm



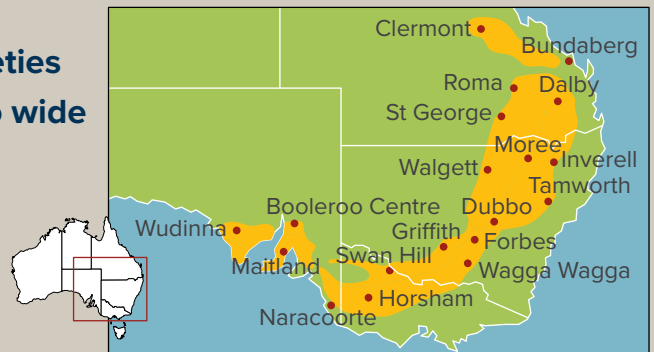
LOW SALINITY
pH 6–9 (water)

Wide adaptation to
soil types
sandy loams – heavy clays



FIVE TYPES

Many varieties
adapted to wide
range of
conditions



Source: Pulse Australia (2015) – Pulse Australia website

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ISBN: 978-1-921779-25-1

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Introduction

Key points

- There are five field pea types, based on seed coat or kernel colour, size and shape.
- Most (70–90%) field pea grown in Australia is for human consumption.
- More than 90% of Australian field pea grown are dun type, with 85% of these now a 'Kaspa' type.
- Two types of plant growth habit: conventional trailing types and semi-leafless types with thicker stems and leaves modified into tendrils to produce better standing ability.
- Field pea has a role in whole farming systems and crop rotations, as a cash crop, in weed control, in soil nitrogen fixation and for a disease break.

1.1 Field pea types

Major field pea (*Pisum sativum*) types are based on seed coat or kernel (cotyledon) colour, size and shape. Varieties range in growth habit from trailing to erect at maturity. Trailing types can be difficult to harvest but the semi-leafless forms, with leaves modified into tendrils, can have a better standing ability, aiding harvestability. Field pea varieties grown in Australia can be divided into five groups:

- **Dun:** greenish-brown (dun) coloured seed with yellow cotyledons. Traditionally dimpled, but rounded types exist now. Used for human consumption and stockfeed.
- **White:** cream-coloured seed with yellow cotyledons and rounded seed. Large whites are used for human consumption (split and flour).
- **Maple:** brown, smooth or dimpled, mottled or speckled seed with yellow cotyledons. Used for stockfeed and birdfeed.
- **Blue:** translucent seed coat, green cotyledons, rounded seed. Used for human consumption. Seed shape and cotyledon colour suited to specialised uses such as canning.
- **Marrowfat:** very large wrinkled blue seed with green cotyledons used for canning.¹

The individual varieties have different coloured flowers ranging from all white to pink and white, to purple and pink.



Photo 1: White flowers of PBA Pearl[®], a semi-leafless field pea.

Photo: Emma Leonard 2016

¹ GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>



Photo 2: The purple flower of PBA Coogee[®], a conventional leaf-type field pea.

Photo: Emma Leonard, 2016



Photo 3: The white and pink flower of Kaspas[®], a semi-leafless field pea.

Photo: Felicity Pritchard

1.2 Field pea history of use

Field pea (*Pisum sativum* L.) has been an important grain legume crop for millennia; seeds showing domesticated characteristics dating from at least 7,000 years ago have been found in archaeological sites in Turkey. The seed is used both as animal feed and for human consumption. It is closely related to the garden pea, the immature pods and seeds of which are used throughout the world as green vegetables.²

Australian field pea for human consumption is commonly used split for dahl, in pre-prepared soups, fermented foods and noodles, as a snack food, whole for green peas for pies, mushy peas and other dishes, and for sprouts.

Research, industry and breeding programs target market specifications for whole and split grain size, shape and colour, whole grain milling properties and grain canning qualities.

Australia produces mostly dun-type field pea (including 'Kaspa' types), with some minor production of blue and white types.

Field pea is grown in the winter cropping areas of Australia. The crop is sown late autumn to mid (late) winter and harvested in spring. The southern region (South Australia, Victoria and Tasmania) grows

² | Pritchard (2015) Growing field pea. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/1755>

161,000 hectares and 204,000 tonnes (five-year average to 2016-17).³ NSW planted 50,000 ha and produced 68,000 tonnes during the same period.

Most field pea are grown for grain, however, some varieties are also being used for green/brown manure, forage or hay.⁴

The high-quality seed is exported for human consumption in Asia and the sub-continent. Between 2010 and 2014 about 60% of pulses produced in Australia were exported, the majority used for human consumption.⁵ Field pea comprises 10–15% of the annual Australian pulse crop, with about 55% exported.⁶

The Australian Export Grains Innovation Centre (AEGIC) estimated a total of 150,000 tonnes of field pea, valued at \$72 million, was exported to South-East Asian markets for human consumption (average over 4 years up to 2015), see Figure 1.⁷

Australia is the major exporter of dun-type peas. Canada and France dominate world export markets and produce mainly white peas. These specialist-type peas are not grown widely in Australia.⁸



Figure 1: Major export markets for Australian field pea.

Source: AEGIC, <http://aegic.org.au/wp-content/uploads/2016/08/Major-markets-for-Australian-field-peas.pdf>

1.3 Why plant field pea?

Field pea offers flexibility and provides many benefit to growers. The crop can be grown for grain, used as a green or brown manure crop, made into hay or silage, or even grazed, depending on seasonal conditions and market prospects.⁹

Field pea has a role in a well-considered rotation. They are a cash crop in their own right and also a valuable part of the whole farming system, especially for weed control, soil nitrogen fixation and for disease break. Field pea benefit from stubble retention for erosion protection and moisture retention, giving the crop structural support for the plant to climb on and greater standability at harvest. Seeding

³ ABARE (2017) Australian Crop Report, No. 183, September 2017, http://data.daff.gov.au/data/warehouse/aucrpd9abcc003/aucrpd9aba_20170912_vGQh0/AustCropRrt20170912_v1.0.0.pdf

⁴ Pulse Australia (2010) Northern Region Field Pea Management Guide, https://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

⁵ AEGIC (2016) Pulses, <http://aegic.org.au/about/australian-grains/pulses/>

⁶ AEGIC (2016) Australian Grain Note: Pulses, <http://aegic.org.au/wp-content/uploads/2016/08/AEGIC-Pulses.pdf>

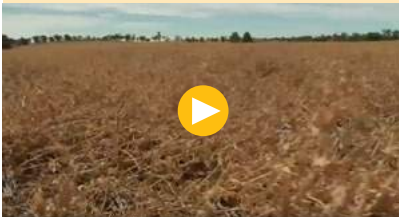
⁷ AEGIC (2016) Major markets for Australian field peas, <http://aegic.org.au/major-markets-for-australian-field-peas/>

⁸ I Pritchard (2015) Growing field pea. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/1755>

⁹ Pulse Australia (2010) Northern Region Field Pea Management Guide, https://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

VIDEO

Watch Video GCTV 9: Southern Pulse for the benefits of growing field pea <https://youtu.be/ZfbW40oPOSJ>



machinery used in no-till or minimum-tillage systems can handle stubble retention to allow pulse crops to be sown after a cereal.

The benefits of growing pulses include:

- crop diversity in a rotation, which is important for continuous cropping systems;
- handling, or delaying the onset of, herbicide-resistant weeds, by varying herbicide options and timings for weed control;
- providing a pest and disease break;
- spreading the timing of farm operations;
- spreading risk across commodities; and
- minimising the impact of increased nitrogen fertiliser and fuel costs.¹⁰

In addition to these benefits and in comparison to the other pulses, field pea has more post-emergent herbicide options and can be grown on a wider variety of soil types.¹¹

1.4 How field pea can benefit the farming operation

Field pea is the most adaptable and least demanding of all the pulse crops. It is suited to a wide range of soils, acid or alkaline pH, sodic soils, and both medium and low-rainfall environments see [Section 2 Planning and paddock preparation](#).¹² Field pea has unique farming system advantages because it can be sown later than most other annual crops. This allows weeds to germinate, with adequate time left for control by either mechanical means, or with non-selective herbicides, before sowing.

The early maturity of some field pea varieties also makes it ideally suited to crop-topping to prevent seedset of surviving in-crop weeds. The reduced reliance on selective herbicides provides a very useful tool in the battle against herbicide-resistant weeds. The late sowing and early harvest means the planting and harvest windows of the cropping program as a whole can be widened, allowing more efficient labour and machinery use.

Field pea provides substantial rotational benefits to subsequent cereal and oilseed crops. The three main benefits are: weed management, a disease break for root and foliar diseases and fixation of nitrogen in the soil.¹³

¹⁰ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 1-2016

¹¹ Pulse Australia (2010) Northern Region Field Pea Management Guide, https://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

¹² Pulse Australia (2010) Northern Region Field Pea Management Guide, https://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

¹³ I Pritchard (2015) Growing field pea. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/1755>

Planning and paddock preparation

Key points

- Field pea has the widest adaptation to soil types of all pulse crops, from sandy loams through to heavy clays, although prefers friable, well-draining soils (not hard-setting as they are prone to waterlogging).
- Field pea tolerates a wide range of pH, from 6.0–9.0 (water).
- Field pea is best grown in districts with 300–750 mm annual rainfall. It is the best adapted pulse to lower rainfall areas, but prone to frost and heat stress during flowering and podding.
- Field pea benefits from no-till with retained stubble, giving the crop structural support and greater standability at harvest.
- Field pea provide benefits in cropping rotations such as weed control, disease control, residual nitrogen and flexibility in timing of farm operations.
- A number of tools are available to estimate potential yield of field pea to manage inputs effectively.

Pulses have a role in a well-considered rotation. They are a cash crop in their own right and also a valuable part of the whole farming system, especially for weed control, nitrogen fixation and for a disease break. Field pea benefits from stubble retention for erosion protection and moisture retention, giving the crop structural support for the plant to climb on and greater standability at harvest. Seeding machinery used in no-till or minimum-tillage systems can now handle stubble retention to allow pulse crops to be sown after a cereal.

Diversity of crops in a rotation is important for continuous cropping systems to:

- handle herbicide-resistant weeds, or delay the onset by varying herbicide options and timings for weed control;
- control crop diseases in the rotation;
- spread the timing of farm operations;
- spread risk across commodities; and
- minimise the impact of increased nitrogen fertiliser and fuel costs.¹

2.1 Paddock selection: summary

A suitable soil type, paddock surface condition and paddock topography are all important criteria in assessing whether country is suitable for field pea 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 holes' or 'crab holes') will prevent headers operating at low cutting height. The more level paddocks are the better, particularly when using headers with wide fronts. Small variations in paddock topography can lead to big variations in cutting height across a wide front and a subsequent increase in harvest losses.

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 timing of some operations, such as the timing of herbicide applications.

Field pea crops should be separated from a previous year's crop by at least 500 metres and up to 1 kilometre in areas where old stubble is prone to movement, i.e. down slope and on flood plains. This helps to reduce the spread of *Ascochyta* blight (both foliar and stubble), bacterial blight and downy mildew diseases. (See [Section 9 Diseases](#))

Avoid paddocks with high weed burdens, as field pea is poorly competitive against weeds. Be aware of those difficult-to-control weeds, particularly tares, wild radish, bedstraw, bifora and herbicide-resistant ryegrass. (See [Section 7 Weed control](#))

Review herbicide use over the previous two seasons and assess any potential herbicide residue problems prior to sowing. (See [Section 7 Weed control](#))

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

- soil type – loams to self-mulching clays
- pH 6.0–9.0 (water)
- sodicity
- salinity/chloride
- bulk density
- potential waterlogging problems
- amount of stored soil moisture and received rainfall, noting their potential impact on herbicide residues.²

¹ GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>

² GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>

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Over the Fence South: Chook poo breaks through clay soil's grip on crops
<https://youtu.be/KKOTV3r6DtI>



Photo 1: Field pea needs to be rolled to minimise the impact of stones at harvest.

Photo: P. Gibbs; Pulse Australia

2.1.1 Soil types

Field pea has the widest adaptation to soil types of all pulse crops, from sandy loams through to heavy clays (Table 1). Soils may be slightly acid to alkaline (pH water 6.0–9.0). Like all pulse crops, field pea is less productive on soils with a hard-setting surface or with heavy clay subsoils that drain poorly, but is the best suited of all the pulses to grow on these hard-setting soils.

Field pea grows on a wide range of soil types, but best results can be expected from those with a heavier texture.

Table 1: Conditions suited to pulses with winter-dominant rainfall.³

Crop	Soil type					Clayed sand (free lime)	Water-logging tolerance	Optimum soil pH (H ₂ O)	Lower rainfall limit (mm)
	Clay	Loam	Sand	Light sand	Clayed sand (low lime)				
Bean									
Faba	excellent	excellent	poor	very poor	medium	medium	good	6.5–9.0	400
Broad	excellent	excellent	poor	very poor	poor	poor	good	6.5–9.0	450
Chickpea									
Desi	excellent	excellent	fair	poor	fair–good	fair–good	poor	6.0–9.0	350
Kabuli	excellent	excellent	fair	poor	fair	fair	poor	6.0–9.0	425
Lentils	good	good	fair	poor	medium	medium	very poor	6.5–9.0	400
Lupin									
N.L	fair	excellent	fair	excellent	fair–excellent	very poor	poor	4.5–7.5	375
Albus	excellent	excellent	poor	very poor	fair	fair	very poor	4.5–7.5	400
Yellow	poor	medium	good	good	medium	poor	good	4.0–7.0	400
Pea	excellent	excellent	fair	poor	medium	medium	fair	6.0–9.0	350
Vetch	excellent	excellent	fair	fair	excellent	excellent	poor	5.5–9.0	250

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

³ J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

Field pea do not tolerate extended periods of waterlogging, particularly when just sown or at the seedling stage. Well-drained soils are therefore important for successful crop establishment and growth.

Field pea can be sensitive to high levels of exchangeable aluminum in acid soils.

Level paddocks are preferred. Paddocks with gilgais, rocks or sticks, and hard-pans should be avoided as they can create issues at harvest time with contamination of the sample, damage to machinery or prevent collection/harvesting of the whole crop up.⁴

Field pea is best grown in districts with 300–750 mm annual rainfall. It is the best adapted pulse to lower rainfall areas, but prone to frost and heat stress during flowering and podding.

Checklist for field pea paddock selection:

- Research variety choice and specific variety management packages.
- Rainfall >300 mm/year.
- Soil is friable, free draining, not prone to waterlogging, surface not hard-setting and pH (water) is 6.0–9.0.
- Soil surface flat and free of undulations. Rolling will flatten clods, rocks and stones.
- Pea not sown in the previous 4 years and paddock not downwind of last year's pea stubble to avoid black spot.
- Few problem weeds like herbicide-resistant ryegrass, medics, vetch and tares.
- Maximum herbicide plant-back periods satisfied (e.g. Group Bs, clorpyralid, triazines).
- Stubble able to be sown into without leaving clumps.⁵

2.1.2 Soil pH

The ideal pH range for field pea is (water) 6.0–9.0. Field pea can be sensitive to high levels of exchangeable aluminium (Al) in acid soils. They will tolerate levels of 5–10% exchangeable aluminium. Acid soils can significantly reduce production and profitability before paddock symptoms are noticed.

Danger levels for crops are when soil pH is <6.0 (water). Monitor changes in soil pH by regular soil testing. If severe acidity is allowed to develop, then irreversible soil damage can occur. Prevention is better than cure, so apply lime regularly to acidic soils. The most effective liming sources have a high neutralising value and have a high proportion of material with particle size <0.25 mm. More lime is required to raise pH in clays than in sands. Liming can induce manganese deficiency where soil manganese levels are marginal.

Low soil pH often leads to poor or ineffective nodulation in pulses because acid soil conditions affect rhizobia survival in the soil. Field pea, faba bean, lentil and chickpea are vulnerable, as is vetch. Lupin is an exception because its rhizobia (Group G) are acid-tolerant. Granular inoculants seem to provide greater protection to rhizobia in acid soil conditions.⁶ (See [Section 4 Planting](#).)

2.1.3 Sodicty

Soils high in sodium are structurally unstable, with clay particles dispersing when wet. This subsequently blocks soil pores, reduces water infiltration and aeration, and retards root growth. On drying, a sodic soil becomes dense and forms a hard surface crust up to 10 mm thick. This can also restrict seedling emergence and damage or break root structures.

4 GRDC (2009) Field peas: The Ute Guide, Southern region, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

5 GRDC (2009) Field peas: The Ute Guide, Southern region, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

6 GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>

Some indicators of surface sodicity include:

- soils prone to crusting and sealing up;
- ongoing problems with poor plant establishment; and
- presence of scalded areas in adjoining pasture.

Exchangeable sodium percentage (ESP) is the measure for sodicity:

- ESP <3 – non-sodic soils
- ESP 3–14 – sodic soil
- ESP >15 – strongly sodic.⁷

Field pea can tolerate subsoil sodicity up to approximately 5 ESP in the surface layer and 8 ESP in the subsoil.⁸

Sodicity adversely affects cool-season pulses by reducing germination and seedling establishment with increasing ESP (15–20).

Soils with sodic topsoils have the greatest impact on crop performance. Sodic layers deeper in the soil profile are not as great a concern, but can still affect yields by restricting root development and water extraction from depth.

2.1.4 Salinity

Salinity is the presence of dissolved salts in soil and water. It causes iron toxicity in plants and impedes the plants' ability to absorb water.

Saline soils are defined as those with electrical conductivity (EC) of the saturated soil extract >4 deciSiemens per metre (dS/m) and sodic soils are those with a sodium adsorption ratio (SAR) >15. Winter pulses, particularly field pea and lentil, are relatively salt-sensitive compared to cereal crops. Yield reduction of about 20% has been reported in field pea at an EC of 2 dS/m) and 90–100% at an EC of 3 dS/m.⁹

Field peas are sensitive to waterlogging and moderately sensitive to soil salinity. Soil salinity affects plant growth by reducing the roots' ability to extract water from the soil. Soil salinity damage varies from season to season due to variations in the soil salt concentration. Waterlogging increases salinity damage.

⁷ GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>

⁸ C Mullen (2004) The right pulse in the right paddock at the right time. NSW Agriculture, <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/general-information/right-pulse>

⁹ GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>



Photo 2: *Salinity damage: marginal necrosis of older leaves that progresses up the plant, older leaf yellowing.*

Photo: DPIRD (2015). <https://www.agric.wa.gov.au/mycrop/diagnosing-salinity-damage-field-peas>

Glasshouse studies and field observations suggest that field pea and lentil may have greater salinity tolerance than faba bean and chickpea. Salinity tolerance of field pea and lentil are comparable to wheat, but less than that of barley.¹⁰

A glasshouse study in Western Australia to determine the influence of salinity (0 and 6 dS/m) and boron (5 and 20 milligrams per kilogram) and the combined effects of both on the early growth of two field pea varieties, Kaspera[®] and Parafield, found salinity to be the main inhibitor of plant growth in both varieties, reducing plant height, root length and the number of nodes on the main stem.

No interaction was observed between the combined effects of salinity and boron toxic soils. Kaspera[®] was more tolerant of boron toxic soils than Parafield, with no significant difference between low and high boron soils. In Parafield, boron significantly reduced plant growth under low saline conditions.¹¹

¹⁰ K Siddique, Abiotic stresses of cool season pulses in Australia, University of Western Australia, http://www.bcg.org.au/members/download_trial.php?trial_id=295

¹¹ S Bennett (2012) Early growth of field peas under saline and boron toxic soils. Department of Environment and Agriculture, Curtin University, http://www.regional.org.au/au/asa/2012/nutrition/7946_bennettsl.htm



Photo 3: Poor weed and pea germination due to salinity and waterlogging.

Photo: DPIRD (2015). <https://www.agric.wa.gov.au/mycrop/diagnosing-salinity-damage-field-peas>

2.2 Paddock history and rotation

Field pea, like other pulses, play an important, complementary role in cropping sequences by enabling better management of weeds, diseases, herbicide residues and soil nitrogen.

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

To achieve these, the sequence must be flexible enough to cope with key strategies such as maintaining soil fertility and structure, controlling crop diseases, and controlling weeds and their seedset.¹²

Recent research in Victoria and southern NSW showed that canola and pulse crops were frequently as profitable, and in some cases, considerably more profitable, than wheat. Furthermore, wheat following break crops was consistently more profitable than wheat after wheat.¹³

Some farmers have adopted a pulse–wheat–barley sequence for their basic rotation.

However, where a pulse can be grown with other crops, farmers are increasingly adopting a pulse–cereal–oilseed–cereal rotation, e.g. bean–wheat–canola–barley. Peas can be grown in place of beans in the next sequence. A hay cut is often also included for weed control, as preventing weed seedset is a major priority.

Successive cropping with the same pulse is likely to result in rapid build-up of root and foliar diseases and weeds. Take extreme care if growing the same crop in the same paddock without a break of at least three years. Where possible, alternate different pulse crops in a continuous rotation with cereals.¹⁴

Field pea is well-suited to no-till systems. The previous crop should preferably have been a cereal, resulting in low soil nitrogen and disease levels for pulses. This

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

¹³ M Peoples, T Swan, L Goward, J Hunt, A Glover, I Trevethan (2105) Key outcomes arising from the crop sequence project. GRDC Grains Research Update, Corowa, 19 February 2015

¹⁴ J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

i MORE INFORMATION

GroundCover™ Issue 115 – Profitable pulses and pastures,
<https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures?pg=2&all=0>

GRDC Update: Key outcomes arising from the crop sequence project

<https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/key-outcomes-arising-from-the-crop-sequence-project>

▶ VIDEO

Growing profitable pulses.
<https://youtu.be/6kuoiCmzMco>



▶ VIDEO

Crop Sequencing in the Mallee
<https://youtu.be/OCGQ9mskxz8>



maximises nitrogen fixation and helps minimise disease. Standing cereal stubble also inhibits aphid activity, providing a physical barrier that inhibits the insect flying through the crop. Aphid presence itself can be a problem to field pea, especially because they can transmit viruses. Cereal stubble also provides architectural support for the growing pea crop.

Broadleaf weed pressure should be low and the weed seedbank should have been reduced in previous crops. Avoid problem weed paddocks, considering both weeds that are difficult to control and weeds that may contaminate the grain sample.

Herbicide residues and herbicide history must also be considered. For example, herbicide residues of the Group B sulfonylurea herbicides, such as chlorsulfuron (e.g. Glean®) and metsulfuron methyl (e.g. Ally®), can be very damaging, particularly in alkaline soils after extended dry periods, and can stunt field peas.¹⁵

2.2.1 Rotational benefits of field pea

A survey of scientific research from across the world has revealed mean yield benefits to wheat production after a break crop to be 20% or more.

The reasons for this include:

- improved weed control;
- improved residual water and nitrogen supply;
- cereal root disease control;
- effects on soil biology and structure; and possibly
- allelopathy (the chemical inhibition of one plant by another).¹⁶

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

A weedy, low-yielding pulse or canola crop is not really a ‘break’ crop, as weeds will host cereal diseases and set seeds that emerge in subsequent cereal crops. Nitrogen fixation by the legumes will also be poor.¹⁷

Yield gains in subsequent crops

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

When compared with wheat on wheat, wheat yields increased, on average, by:

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

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

This ‘break-crop effect’ often extended to a second wheat crop in the sequence, especially following legumes (a benefit of 0.2–0.3 t/ha), but rarely to a third crop, except under dry conditions.¹⁸

The individual factors contributing to the yield gains in cereal crops after break crops have been assessed. The most important components were found to be the suppression of the cereal disease take-all and the contribution of soil nitrogen by

15 L Jenkins, P Matthews, B Haskins, K Hertel, G Brooke, E Armstrong, D McCaffery, G Lane (2005) Field Pea: Western NSW Planting Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0007/157507/field-pea-western-nsw-planting-guide.pdf

16 J Kirkegaard, O Christen, J Krupinsky, D Layzell (2008) Break crop benefits in temperate wheat production, Field Crops Research, 107, 185–195. <http://www.sciencedirect.com/science/article/pii/S0378429008000385>

17 J Kirkegaard (2015) Grain legumes can deliver an extra 1t/ha yield to wheat crops, Ground Cover™ Supplement: Profitable Pulses and pastures. Ground Cover™ Issue 115, <https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Grain-legumes-can-deliver-an-extra-1t/ha-yield-to-wheat-crops>

18 J Kirkegaard (2015) Grain legumes can deliver an extra 1t/ha yield to wheat crops, Ground Cover™ Supplement: Profitable Pulses and pastures. Ground Cover™ Issue 115, <https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Grain-legumes-can-deliver-an-extra-1t/ha-yield-to-wheat-crops>

legume crops. These two factors were each estimated to increase the yield of a 4 t/ha wheat crop by 0.5 t/ha.¹⁹

Financial benefits over the rotation

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

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

Another important benefit of break crops is having a diversified income to manage price variations.²⁰

Managing weeds including herbicide-resistant weeds

Break crops such as field pea can be used for weed control, by providing additional herbicide group options to reduce the potential development of herbicide resistance. They are one of the best weed competitors of all the pulses and have more chemical options for broadleaf weed control than chickpea or lentil.

The prevalence of herbicide-resistant weeds (especially annual ryegrass) due to intensive cereal production with selective herbicides now dictates crop sequence decisions for many growers.²¹ One of the main reasons for southern region growers to switch from a cereal to a break crop is the availability of more herbicide options to manage grass weeds.²²

For more information, go to [Section 7.7 Herbicide types](#), [Section 7.7.2 Knockdown herbicides](#), [Section 7.7.3 Pre-emergent herbicides](#), [Section 7.7.4 Post-emergent herbicides](#) and [Section 7.7.6 Crop-topping](#).

Random sampling of paddocks in southern NSW, South Australia and Victoria has revealed widespread resistance or partial resistance of some grasses and broadleaf weeds to a broad range of herbicide groups (up to 70–80%) of samples in some areas.²³

Nitrogen fixation

Pulses (and pasture legumes) play an essential role in the nitrogen (N) supply chain of field crops, especially since soil nitrogen is one of the most limited plant nutrients worldwide. By fixing their own nitrogen during growth, pulses become independent of soil mineral nitrogen and thereby conserve or spare it. When combined, these two sources (fixed and spared N) produce large amounts of residual nitrogen for following crops, boosting their grain yield and grain protein.²⁴

A well nodulated field pea crop with good weed control can provide nitrogen to the crop rotation by means of fixing nitrogen through rhizobia and from nitrogen released from crop residues. Larger benefits to the following crop in the rotation are more likely where soil fertility is low to medium, because in the presence of available nitrogen field pea will be 'lazy' and use this nitrogen as opposed to producing their own via their symbiotic relationship with the rhizobia. The better the field pea crop,

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

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

21 J Kirkegaard (2015) Grain legumes can deliver an extra 1t/ha yield to wheat crops, Ground Cover™ Supplement: Profitable Pulses and pastures. Ground Cover™ Issue 115, <https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Grain-legumes-can-deliver-an-extra-1t/ha-yield-to-wheat-crops>

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

23 C Preston *et al.* (2013) Maintaining the best options with herbicides. NSW GRDC Grains Research Update for Advisers 2013, Temora, NSW, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Maintaining-the-best-options-with-herbicides>

24 E Armstrong, D Holding (2015) Pulses: putting life into the farming system. NSW Government Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/558958/Pulses-putting-life-into-the-farming-system.pdf

i.e. one that has a thick plant stand, healthy plants with good nodulation and good bulk, the greater the amount of N that will be fixed.

A 10-year study researching the contributions to farming systems of eastern Australia of nitrogen fixed by legume crops found that where southern pulse crops followed several years of cereal cropping, concentrations of mineral N at sowing were generally low and legume reliance upon N fixation was consistently high. Therefore, the amounts of N fixed were closely linked to biomass production, with around 20–25 kg of shoot N being fixed for every tonne of legume shoot of dry matter (DM) accumulated.²⁵

The availability of nitrogen following a field pea crop depends on seasonal conditions, as moisture and warm temperatures are required to convert the organic nitrogen in the legume residues to nitrate. Most of the short-term nitrogen benefit following field pea comes from spared mineral nitrogen and the breakdown of fine roots and nodules.

The nitrogen benefit from field pea is typified by two experiments in central-west NSW that measured the amount of nitrogen fixed by field pea, the effect of management on nitrogen cycling and the response of two subsequent wheat crops (Tables 2 and 3).

Table 2: First and second year wheat yields and protein responses to crop types and management at Parkes, NSW.

Treatment in 1997	Wheat in 1998		Wheat in 1999	
	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)	Protein (%)
Oats – grain	2.83	2.80	11.6	
Oats – hay	3.58	3.36	12.0	
Pea – grain	3.78	3.43	12.3	
Pea – hay	3.70	3.21	11.9	
Pea – ploughed in	4.15	3.56	12.2	
Pea – sprayed out	4.09	3.44	12.2	

Source: GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>, chapter 1, p 8

Table 3: First and second year wheat yields and protein responses to crop types and management at Condobolin, NSW.

Treatment in 1998	Wheat in 1999		Wheat in 2000	
	Yield (t/ha)	Protein (%)	Yield (t/ha)	Protein (%)
Oats – grain	2.63	12.2	2.02	9.2
Pea – grain	3.05	13.1	2.33	10.4
Pea – hay	3.15	13.4	2.38	10.5
Pea – ploughed in	3.41	13.6	2.53	10.9
Pea – sprayed out	3.20	13.7	2.48	10.7

Source: GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>, chapter 1, p 8

Field pea crops resulted in higher wheat yield and protein in each of two following crops than after oats, and this was related to higher soil mineral nitrogen levels. Green or brown manuring by either ploughing in or spraying the crop out gave the highest yield, but this advantage over harvesting the pulses for grain was less than expected.

²⁵ M Peoples, R Gault, D Herridge, M McCallum, K McCormick, R Norton, G Scammell, G Schwenke, H Hauggaard-Nielsen (2001) Contributions of Fixed Nitrogen by Crop Legumes to Farming System of Eastern Australia. Australian Agronomy Conference 2001, <http://www.regional.org.au/au/asa/2001/1/c/peoples.htm>

The higher yield after green manuring needs to be balanced against the income from hay or harvested legume grain. Additional benefits from making hay or manuring could include the prevention of weed seedset in and the storage of additional soil moisture for the following crop. Above-average growing-season rainfall in both 1998 and 1999 minimised this ‘fallow’ effect in these trials.²⁶

Soil conditioning

Field pea roots are small and fibrous and upon breakdown can create a more friable soil for the following year’s crop; that is, they condition the soil or improve soil tilth.

Versatility – soil type & soil pH, temperature, rainfall, management & harvest

Field pea is the most versatile pulse with regard to soil type and soil pH. It will grow on soils from sand through to heavy clays, medium and low-rainfall environments, and from pH (water) 6.0–9.0.

Field pea has unique farming system advantages because it can be sown later than most other annual crops. This allows weeds to germinate, with adequate time left for control by either mechanical means or with non-selective herbicides before sowing.

The early maturity of some field pea varieties also makes them ideally suited to crop-topping to prevent seedset of surviving in-crop weeds. The reduced reliance on selective herbicides provides a very useful tool in the battle against herbicide-resistant weeds. Late sowing and early harvest also mean the planting and harvest windows of the cropping program as a whole can be widened, thus allowing more efficient labour and machinery use.²⁷

Cereal disease management

Grass-free pulse crops are generally effective disease breaks, usually more so than pastures due to the potential of grasses to host root diseases.

Field pea is a pulse break crop that can be used in rotations to effectively break the life cycle of cereal root diseases like take-all, crown rot, root-lesion nematode and cereal cyst nematode.²⁸

Take-all

All grass-free pulse and oilseed crops can provide a disease break from take-all. Remove grass weeds from field pea before the end of July (or the end of June in the Mallee) to prevent the fungus multiplying and being carried into the next crop.²⁹

Crown rot

For crown rot, a two-year break with a non-susceptible crop such as field pea or canola can reduce the severity of crown rot in subsequent wheat or barley crops.³⁰ Break crops allow for the natural decomposition of cereal residues that harbour the crown rot fungus.

Root-lesion nematode

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

Field pea is a poor host of the two important species that are common in southern region cropping soils: *Pratylenchus neglectus* and *P. thornei* (see [Table 4](#)). The two

26 GRDC (2015). Field Peas Northern Region GrowNotes™, <https://grdc.com.au/Resources/GrowNotes>

27 I Pritchard (2015) Growing field pea. Department of Agriculture and Food Western Australia, <https://agric.wa.gov.au/n/1755>

28 G Holloway (2013) Cereal Root Diseases, Agnote AG0562, June 2013, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases>

29 G Holloway (2013) Cereal Root Diseases, Agnote AG0562, June 2013, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases>

30 G Holloway (2013) Cereal Root Diseases, Agnote AG0562, June 2013, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases>

species often occur together. Rotations are the best way of controlling RLN. Resistant crops can potentially halve nematode populations each year. A 2-year break (or more) from susceptible crops may be necessary to minimise yield loss if nematode numbers were high to begin with.³¹ For more information on nematode status for paddock selection, go to [Section 2.8.3 Nematode status of paddock](#).

Table 4: Field pea is a poor host of the two important root-lesion nematode species, making it particularly useful crop in rotations.³²

Crop	<i>P. thornei</i>	<i>P. neglectus</i>
Wheat	Intermediate – good*	Intermediate – good
Faba bean	Poor	Poor
Barley	Poor – intermediate	Poor – intermediate
Canola	Intermediate	Good
Field pea	Poor	Poor
Lentil	Poor	Poor
Vetch	Good	–

* In some crops the hosting ability varies between varieties.

Source: G Holloway (2013) Cereal Root Diseases. Agnote AG0562, June 2013, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases>

Cereal foliar disease

Break crops such as field pea can also play a role in cereal foliar disease management such as yellow leaf spot or tan spot (*Pyrenophora tritici-repentis*). For example, reducing the number of susceptible crops grown in a district will reduce inoculum load from season to season.³³

2.2.2 Rotational disadvantages of field pea

As a crop field pea has few disadvantages but it is worth considering the following:

- Compared to cereals, field pea provides little groundcover over the summer period. Being weak-stemmed with fragile surface roots, they leave little stubble after harvest to hold the soil. If grown on erosion-susceptible soils, pea stubble should either not be grazed or carefully grazed to ensure adequate stubble cover is maintained.³⁴
- Like other crops, self-sown field pea plants can emerge after harvest.
- Field pea is less productive on soils with a hard-setting surface, or heavy clay subsoils.
- Among the pulses field pea seems to be the most susceptible to frost injury during the reproductive stages.
- Field pea does not tolerate waterlogging at sowing or at the seedling phase.
- Field pea is susceptible to hostile subsoils, with boron toxicity, sodicity and salinity.
- Field pea is susceptible to insect attack, especially native budworm.
- Sand blasting by wind can severely damage seedling crops.
- Crops can lodge prior to harvest.

31 G Holloway (2013) Cereal Root Diseases. Agnote AG0562, June 2013, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases>

32 G Holloway (2013) Cereal Root Diseases. Agnote AG0562, June 2013, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases>

33 G Holloway (2014) Yellow Leaf Spot of Wheat. Agnote AG1114 May 2014, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/yellow-leaf-spot-of-wheat>

34 I Pritchard (2015) Field pea stubble: wind erosion control and grazing management. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/402>

- Weed control, particularly of broadleaf weeds, can be an issue, especially for weeds such as medic and clover.
- Harvest can be slow and expensive.
- Marketing of the crop can be challenging but some new avenues have emerged in the past few years.
- Field pea is susceptible to fungal diseases such as Ascochyta blight and chocolate spot.
- Volunteer field pea, particularly if a traditional dun type, can be a weed in subsequent crops and contaminate harvested grain with pea seed, which may contain pea weevil.

2.3 Seedbed requirements

Sowing depth of pulse seeds needs to be varied to take into account the crop type, soil type (Table 1), soil residual herbicide used, diseases likely to be present and soil temperature at sowing time, i.e. how long the crop will take to emerge. Lighter-textured soils can be more prone to herbicide leaching in wet winters, hence deeper sowing in sandier soils is recommended if applying a pre-emergent herbicide. The deepest sowings tend to be in sandy soil with warm soil temperatures and if dry sowing, while the shallowest sowings will be in heavy soils with cold soil temperatures or late sowing – however, there are exceptions.

The maximum depth at which the pulse crop can be safely sown to avoid poor establishment and lower seedling vigour is shown in Table 5. Sowing seed outside the suggested range may delay emergence and slow seedling growth. Actual sowing depth should be shallower on clay soils and hard-setting soils and deeper on sands. Lupin, with its epigeal emergence, is the pulse least tolerant of deep sowing; crops with hypogeal emergence (lentil, field pea, chickpea and vetch) are intermediate; and faba bean (also hypogeal emergence) is the most tolerant.

Table 5: Sowing depth ranges (in centimetres).³⁵

Crop	General recommended sowing depth range*
Chickpea	3–5 cm
Faba bean	5–8 cm
Lentil	2–6 cm
Lupin	1–3 cm
Pea	3–5 cm
Vetch	3–5 cm

* Note: if applying a pre-emergent herbicide, the deeper depth should be used.
 Source: J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

Burying seed too deep to chase seedbed moisture for early sowing is not recommended, particularly as weed control, establishment and possibly nodulation is more likely to be poor. Deeper sowing may be needed in some districts to reduce the damage caused by birds and mice.³⁶

If sowing deep to chase seedbed moisture, adopting a practice of ‘sow deep, cover shallow’ may be required, bearing in mind the risk of herbicide wash into seed furrows after rainfall.

³⁵ J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

³⁶ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 4-2016

Sowing depth and herbicide interaction

Pulses can be more tolerant of some soil residual herbicides if not sown shallow. For example, field pea is less affected by metribuzin applied either pre-sowing or post-sowing pre-emergent if they are sown deeper.

The actual depth of sowing will depend on the soil type. Herbicides leach deeper in sands than in clay soils. Some herbicides leach more than others. Heavy rain onto a dry soil surface, particularly on a sand, makes leaching worse.

Leaving the soil ridged increases the risk of a post-sowing pre-emergent herbicide washing into the furrow, especially on sands. As pre-sowing applications of herbicide may be less effective in the furrows, a split herbicide application is suggested to ensure effective weed control while avoiding the risk of herbicide damage.

Rolling

- Leaving a flat, firm soil surface free of sticks, stones and clumps is essential when growing most pulse crops. Rolling field pea after sowing to aid harvestability is required where height to bottom pods is often low, particularly in lower-rainfall areas or late-sown crops.
- Another reason for rolling soils is to leave a flat soil surface for post-sowing herbicide application to prevent herbicides washing and accumulating in furrows. 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 rolled their pulses post-emergence. This is particularly common in peas and lentils but has also been used in other crops, although more sparingly and dependent upon soil type and conditions.³⁷
- Field pea can be rolled post-emergent when it is best, between the 3 and 10 node stages. The disadvantage of this technique is that it could increase foliar disease, especially bacterial blight, and it requires a second pass over the paddock during a labour-intensive period. Most southern region field pea growers would consider a roller as a most essential piece of equipment. New growers may not possess this piece of machinery.³⁸



Photo 4: *Rollers being used on an emerging lentil crop.*

Photo: Pulse Australia (2016)

³⁷ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 5

³⁸ GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/Resources/GrowNotes>

Undulating paddocks and gilgai (crab holes) can also cause harvest issues for field pea. This can lead to uneven crop maturity due to a variation in soil water supply across the paddock. Many dryland field pea crops require the header front to be set close to ground level. Small variations in paddock topography can lead to differences in cutting height across the header front, creating significant harvest losses. Cloddy or badly ridged paddocks and sticks and stones can contaminate the harvested grain and downgrade quality. The header may also be damaged.³⁹



Photo 5: Stones in pulse crops are a hazard, so rolling is suggested.

Photo: W. Hawthorne, formerly Pulse Australia

VIDEO

Watch GCTV 5: Manage Summer Fallows:
<https://youtu.be/5Kp5woTOo7c>



2.4 Soil moisture

2.4.1 Dryland/fallow moisture

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. Southern growers have little control over stored soil water, but can help to retain as much as possible through summer weed control and stubble retention. Soil moisture can be measured before planting and long-range forecasts and tools such as the Southern Oscillation Index (SOI) can indicate the likelihood of the season being wet or dry.⁴⁰

Measure stored soil moisture depth

Soil moisture probes can be used to monitor soil water during the growing season.

Plant-available water capacity (PAWC)

PAWC is a measure of the ability of a soil to store water for later crop production. Figure 1 shows the water components that are measured to determine a soil's PAWC, or as it is often called, 'the size of its water bucket'. The two most important are the drained upper limit (DUL), which is related solely to the physical properties of the soil,

³⁹ Pulse Australia (2014) Northern Faba Bean – Best Management Practices Training Course

⁴⁰ J Wish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Papers 23 July 2013, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW>

and the crop lower limit (CLL), which is related both to soil physical properties and to the ability of the particular crop to extract water from the soil.

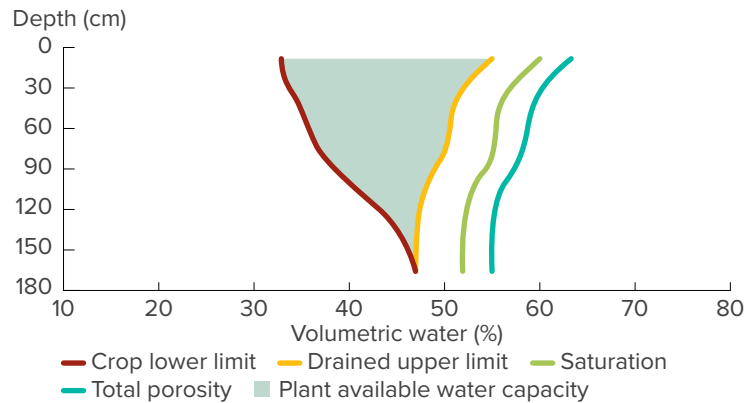


Figure 1: A typical storage profile for a heavy-textured clay soil showing the potential water storage of the soil (plant-available water capacity, PAWC) as defined by the drained upper limit (DUL, blue shading), crop lower limit (CLL), saturation (SAT) and total porosity (PO).⁴¹

Source: N Dalgliesh (2014) Practical processes for better soil water management. GRDC Update Papers 28 Feb 2014, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Practical-processes-for-better-soil-water-management>

Fallow

Fallowing captures out-of-season rainfall and can increase the amount of water available for crop growth. However, the proportion of rainfall retained by fallowing (also referred to as fallow efficiency) can be small, typically about 20%. Nevertheless, despite the low efficiency of many fallows, storage of moisture can help with managing the risk associated with variable rainfall. Soil mineral nitrogen can also increase under fallows as cultivation stimulates the mineralisation of soil organic matter and yield improvements following fallow can be associated with increases in nitrogen more so than moisture.

Fallowing is very important for winter crop production in the northern cereal zone where rainfall shows a strong summer incidence. In the southern and western regions fallowing is less important because the accumulation of moisture by fallowing is often much less and yield gains are frequently small over in-crop rainfall. The benefit of fallowing in regions with a winter-dominant rainfall pattern is influenced by the timing of rainfall. In these southern regions very little of the summer (December to March) rainfall is stored and the value of fallowing depends more on rainfall captured and retained from the previous growing season. Control of summer weeds is however very important for retaining as much stored moisture as possible.

Soil texture is also important. In a study in the 1960s in South Australia using cultivated fallows, the average increase in soil moisture after a 9–10 month fallow was only 9 mm (maximum 38 mm) on sandy soils and 38 mm (maximum 125 mm) on fine-textured soils. Each additional millimetre of moisture stored by the fallow increased grain yield by 8 kg/ha. This yield benefit from fallowing was confirmed in a more recent survey of commercial wheat crops in the Mallee region of NSW, Victoria and South Australia. It was found that the initial moisture in the top metre of soil after fallowing was 39 mm higher than after a cereal crop and 15 mm higher than after pasture. However, in both cases yield after fallow was increased by 10 kg/ha per mm of additional soil moisture.

Retaining stubbles on the fallow and controlling summer weeds may help to reduce water loss from the fallow and improve fallow efficiency, although the value of stubble retention appears to vary with soil texture and rainfall. On sandy soils, there may be little benefit from stubble retention on water capture over summer and in some

⁴¹ N Dalgliesh (2014) Practical processes for better soil water management. GRDC Update Papers 28 Feb 2014, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Practical-processes-for-better-soil-water-management>

i MORE INFORMATION

GRDC Water Use Efficiency of Grain Crops in Australia: Principles, Benchmarks and Management, https://grdc.com.au/_data/assets/pdf_file/0030/159186/grdcpublicationwateruseefficiencyofgraincropsinaustraliapdf.pdf.pdf

cases standing stubble may enhance evaporative losses. In contrast, on clay soils in southern Australia fallow efficiencies of up to 40% have been measured with retained stubbles.

The ability to store summer rainfall may also depend on the size of the rainfall events, with the potential benefit of stubble retention being greatest where moderate rainfall is received during the fallow period. Small amounts of rain may evaporate quickly irrespective of the presence of stubble, whereas high rainfall may allow soil moisture to accumulate irrespective of the presence or absence of stubble.⁴²

Fallowing – implications for water use efficiency

While fallowing efficiency is often low, leading to only small increases in available soil moisture and crop water use, the benefits of this moisture can still be high because it is not subject to additional evaporative loss, and is stored at depth and likely to be used during the critical phase of growth immediately prior to flowering and during the grain-filling period.

Work in southern NSW has indicated that the conversion efficiency of subsoil moisture used during grain filling can be up to 60 kg grain/ha/mm compared to a reference 20 kg grain/ha/mm for growing-season rainfall. Thus, small amounts of additional moisture may result in significant improvements in yield.⁴³

2.4.2 Irrigation

Irrigating field pea, with either full or supplementary irrigation, is not widely practiced in Australia, and is considered risky because field pea is very susceptible to waterlogging. Nevertheless irrigating field pea may be economical if grown in an excellent irrigation layout, with good quality water and managed carefully in rotation with other winter and summer crops. Management requirements for irrigated field pea are the same as for dryland crops, with a greater emphasis on disease control as they will have a greater sensitivity to foliar diseases under irrigation. Field pea sensitivity to waterlogging under irrigation must be carefully considered and managed. Even waterlogging for a short time can result in severe losses, particularly if the crop is stressed (from herbicides, disease, moisture, etc). Irrigation type and layout will be critical to success.⁴⁴

2.5 Yields and yield targets

Increasing production costs and increasing supplies of pulses will mean that future success with pulses will depend on greater productivity per hectare and per millimetre of rainfall.

Best management practices for the crop in relation to tillage, time of sowing, weed control and fertilising are needed and there is room for improvement. Under ideal conditions pulse crops should be able to produce 15 kg/ha of grain for every millimetre of growing season rainfall above 130 mm. By comparison wheat can produce up to 25 kg/ha for every millimetre of rainfall above 110 mm.⁴⁵

Australia’s climate, and in particular rainfall, is among the most variable on Earth; consequently, crop yields vary from season to season. In order to remain profitable, crop producers must manage their agronomy, crop inputs, marketing and finance to match each season’s yield potential.⁴⁶

42 V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. Grains Research & Development Corporation, https://grdc.com.au/_data/assets/pdf_file/0030/159186/grdcpublicationwateruseefficiencyofgraincropsinaustraliapdf.pdf.pdf

43 V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. Grains Research & Development Corporation, https://grdc.com.au/_data/assets/pdf_file/0030/159186/grdcpublicationwateruseefficiencyofgraincropsinaustraliapdf.pdf.pdf

44 GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>

45 V Sadras, G McDonald (2012) Water use efficiency of grain crops in Australia: principles, benchmarks and management. Grains Research & Development Corporation, https://grdc.com.au/_data/assets/pdf_file/0030/159186/grdcpublicationwateruseefficiencyofgraincropsinaustraliapdf.pdf.pdf

46 T McClelland (2013) Yield Prophet®-What difference can it make to crop decision making? GRDC Update Papers, 6 February 2013, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Yield-Prophet-What-difference-can-it-make-to-crop-decision-making>

Before planting identify the target yield required to be profitable:

- Do a simple calculation to see how much water you need to achieve this yield.
- Know how much soil water you have (treat this water like money in the bank).
- Think about how much risk your farm can take.
- Consider how this crop fits into your cropping plan – will the longer-term benefits to the system outweigh any short-term losses?⁴⁷

2.5.1 Variety yield comparisons

See the National Variety Trials website (<http://www.nvtonline.com.au>) to compare the performance of current field pea varieties across the southern region. Also see [Section 3.1 Evaluation of yield potential](#) and [Section 3.2.1 Characteristics of field pea varieties for southern Australia](#) for more information.

2.5.2 Seasonal outlook

‘The Break’ newsletter is a good source of climate information for southern regions. It is produced by Agriculture Victoria regularly through the season and reviews climate models and changes to key influences on southern rainfall. To view issues and to subscribe, visit: The Break, The Fast Break and The Very Fast Break Newsletters (<http://agriculture.vic.gov.au/agriculture/weather-and-climate/newsletters>)

For tips on understanding weather and climate drivers including the Southern Oscillation Index (SOI), visit the Climate Kelpie website (<http://www.climatekelpie.com.au/>). Case studies of 43 farmers across Australia recruited as ‘Climate Champions’ as part of the Managing Climate Variability R&D Program can be accessed at: Climate Kelpie MCV Climate Champion program (<http://www.climatekelpie.com.au/farmers-managing-risk/climate-champion-program>).

Australian CliMate (<http://www.australianclimate.net.au/>) is a suite of climate-analysis tools delivered on the web, iPhone, iPad and iPod Touch devices. CliMate allows you to interrogate climate records on questions relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, as well as El Niño/SOI 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/cropmate-varietychooser/id476014848?mt=8> or visit <http://www.australianclimate.net.au>

Season’s progress?

One of the CliMate tools, *Season’s progress?*, uses long-term (1949 to present) weather records to assess the 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 and helps to answer the following questions:

- How is the crop developing relative to previous seasons, based on the heat sum?
- Is there any reason why my crop is not doing as well as usual because of below-average rainfall or radiation?
- Based on *Season’s progress?* (and starting conditions from *How wet?*), should I adjust inputs?

⁴⁷ J Wish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Papers, 23 July 2013, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW#sthash.2h5bo1Tp.dpuf>

Inputs:

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

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.⁴⁸

The Bureau of Meteorology has 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 and monthly outlooks and the forecasting of additional climate variables.⁴⁹

How wet? – a climate analysis tool

How wet? is a climate-analysis tool (from CliMate) that uses records from a nearby weather station to estimate how much plant-available water (PAW) has accumulated in the soil and the amount of organic nitrogen that has been converted to an available nitrate during a fallow. *How wet?* tracks soil moisture, evaporation, runoff and drainage on a daily time-step. Accumulation of available nitrogen in the soil is calculated based on surface soil moisture, temperature and soil organic carbon.

How wet? estimates how much:

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

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

Many grain growers are in regions where stored soil water and nitrate at planting are important in crop-management decisions.

Questions this tool answers:

- How much longer should I fallow? If the soil is nearly 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?

Inputs:

- A selected soil type and weather station.
- An estimate of soil cover and starting soil moisture.
- Rainfall data input by the user for the stand-alone version of *How often?*.

Outputs:

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

⁴⁸ Australian CliMate, Commonwealth of Australia, <http://www.australianclimate.net.au>

⁴⁹ J Sabburg, G Allen (2013) Seasonal climate outlook improvements changes from historical to real time data. GRDC Update Papers 18 July 2013, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Seasonal-climate-outlook-improvements-changes-from-historical-to-real-time-data>

i MORE INFORMATION

For more information visit:
<http://www.australianclimate.net.au/About/HowWetN>

i MORE INFORMATION

Water use efficiency, southern/western regions GRDC Fact Sheet
<http://www.grdc.com.au/GRDC-FS-WaterUseEfficiencySouthWest>

Reliability How wet?

uses standard water-balance algorithms from *How leaky?* and a simplified nitrate mineralisation based on the original version of *How wet?* 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.⁵⁰

2.5.3 Water use efficiency

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

- the soil’s ability to capture and store water;
- the crop’s ability to access water stored in the soil and rainfall during the season;
- the crop’s ability to convert water into biomass; and
- the crop’s ability to convert biomass into grain (harvest index).⁵¹

2.5.4 Setting target yields

French–Schultz model

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

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

The model is:

Potential yield (kg/ha) = (crop water supply (mm) – 110 mm) x 20 kg/ha/mm⁵²

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

For pulses and canola, the typical parameters used are 15 kg/ha/mm for WUE and 130 mm for soil evaporation. Of note, for pulses this could now be less than the original 130 mm given that modern stubble-retention systems retain more soil moisture.⁵³

50 Australian CliMate: HowWet/N? <http://www.australianclimate.net.au/About/HowWetN>

51 GRDC (2009) Water Use Efficiency Fact Sheet, Southern and Western Regions, <https://grdc.com.au/Resources/Factsheets/2010/02/Water-Use-Efficiency-SouthWest>

52 R French, J Schultz (1984) Water use efficiency of wheat in a Mediterranean-type environment. Part I: The relation between yield, water use and climate. *Australian Journal of Agricultural Research*, 35, 743–764

53 W Hawthorne, pers. comm.

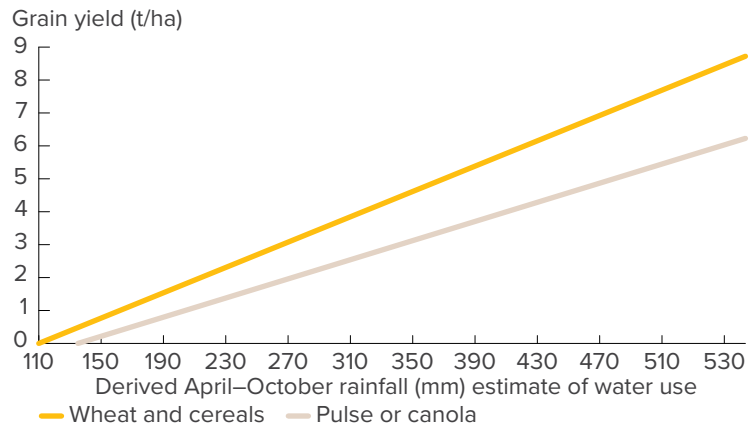


Figure 2: Relationship of grain yield (t/ha) to estimated water use April–October. Pulses, 15 kg/ha/mm water available over 130 mm; cereals, 20 kg/ha/mm available over 110 mm.

Source: J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry, Grain Legume Hand Book Committee. <https://grdc.com.au/grainlegumehandbook> from French and Schultz model. <https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook>

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

$$\text{Potential yield (kg/ha)} = (\text{available rainfall}^* - 110 \text{ mm}^{**}) \times \text{WUE}^{***}$$

where

*available rainfall = GSR + 25% summer rainfall

** or 60 mm evaporation for stubble-retained systems

*** WUE = 15 kg/ha/mm

While the French and Schultz model can be used to determine an upper limit of water-limited potential yield, it often overestimates actual yield as it does not account for rainfall distribution, runoff, drainage, or stored soil water.⁵⁴

The different pulses and their systems do differ though in their water-limited yield potential (see Figure 3). Faba bean has the highest yield potential of the pulses at high-yielding locations, whereas field pea has the highest yield potential at low-yielding, water-restricted locations. Newer, earlier-maturing varieties of field pea and lentil will have improved yielding ability in lower-rainfall sites⁵⁵.

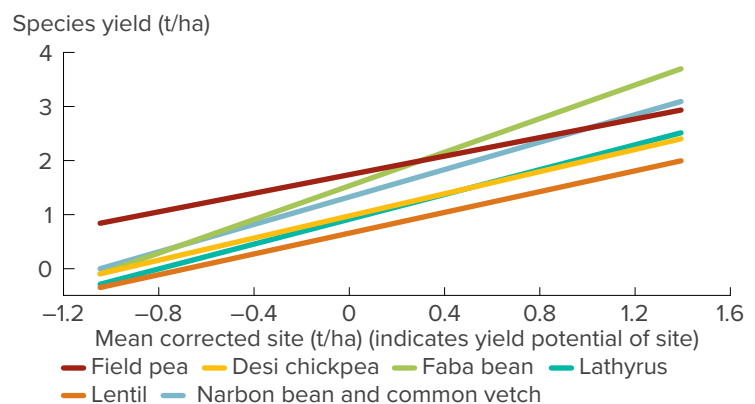


Figure 3: Variation in grain yield of different grain legume species across sites with different yield potential in Western Australia.

Source: K. Siddique (2016)

⁵⁴ Y Oliver, M Robertson, P Stone, A Whitbread (2009) Improving estimates of water-limited yield of wheat by accounting for soil type and within-season rainfall. *Crop & Pasture Science*, 2009, 60, 1137–1146. www.publish.csiro.au/CP/pdf/CP09122

⁵⁵ W Hawthorne, pers. comm.

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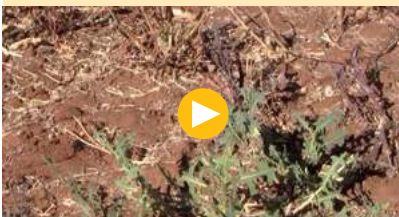
VIDEO

Watch GCTV 12: Water Use Efficiency Initiative
<https://youtu.be/a6QbVs7g3B4>



VIDEO

Over the Fence South: Summer weed control saves moisture for winter crops
<https://youtu.be/97gRnGHP2hM>



VIDEO

Watch GCTV 10: Grazing Stubbles and Water Use Efficiency
<https://youtu.be/GCn7M45gh5k>



APSIM

Sophisticated crop-simulation models such as APSIM (and its commercial interfaces Yield Prophet® and WhopperCropper®) can combine detailed data about soil water-holding capacity, soil moisture at sowing, long-term climate data, weather data, potential crop responses to available moisture and additional inputs in order to estimate potential yield.⁵⁶

2.6 Fallow weed control

Summer weed control stands out as the most effective way to conserve summer rain and soil nitrogen for use by subsequent crops.

Does summer weed control pay?

Trials in the southern and western regions have shown that summer weed control helps conserve soil moisture and/or soil nitrogen, to boost yields in subsequent crops. Economic returns varied but generally the return on investment in herbicides and their application can be positive. In high-rainfall areas or where less summer rainfall is received, the nitrogen benefit can outweigh improved soil moisture conservation.

More than 3–4 t/ha of stubble cover is required to significantly reduce evaporation of moisture from the topsoil. Trials have found that crops producing higher stubble loads have taken more water from the soil, so that by sowing time the balance of used and lost soil water is the same. Retaining stubble does increase infiltration, protect the soil from erosion and slow evaporation of early-sown crops.⁵⁷

Can I control summer weeds with cultivation and conserve soil moisture?

Controlling summer weeds either with herbicides or cultivation has produced similar results in the trials in south-eastern Australia. However, cultivation may leave the soil surface more vulnerable to erosion. If, prior to cultivation, the surface is smooth and has poor stubble cover, cultivation makes the surface rougher and provides some erosion protection.⁵⁸

2.6.1 Double-knock strategies

Double-knock refers to the sequential application of two different weed-control tactics applied in such a way that the second tactic controls any survivors of the first. Most commonly used for pre-sowing weed control, this method can also be applied in-crop.⁵⁹

Double-knock herbicide strategies are useful tools for managing difficult-to-control weeds, including herbicide-resistant ryegrass, but there is no ‘one size fits all’ treatment.

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

56 GRDC (2009) Water Use Efficiency Fact Sheet, Southern and Western regions, <https://grdc.com.au/Resources/Factsheets/2010/02/Water-Use-Efficiency-SouthWest>
 57 GRDC (2012) Making summer weed control a priority Southern Region: Summer Fallow Management Fact sheet. GRDC, https://grdc.com.au/_data/assets/pdf_file/0028/98632/summer-fallow-weed-management-manual.pdf.pdf
 58 GRDC (2012) Making summer weed control a priority Southern Region: Summer Fallow Management Fact sheet. GRDC, <https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/general-information/pre-emergent-herbicides>
 59 C Borger, V Stewart, A Storrie. Herbicides: knockdown herbicides for fallow and pre-sowing control. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/59>

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Watch IWM: Double Knock Applications – Double Knock Strategies for Resistant Weed Populations
<https://youtu.be/bL0sbdQAYK0>

DOUBLE KNOCK APPLICATIONS



VIDEO

IWM: Double Knock Applications – a Grower’s Experience
<https://youtu.be/pEIEGsQDzBg>

DOUBLE KNOCK APPLICATIONS



VIDEO

Glyphosate-resistant weeds
<https://youtu.be/Ke8k1YNQzI8>



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

2.7 Fallow chemical plant-back periods

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of a subsequent crop. Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains that can still cause crop damage can persist for long periods. This is the case with sulfonylureas (SUs, e.g. chlorsulfuron).

Residual persistence and the half-life of common herbicides are shown in [Table 6](#). Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the SUs. On labels this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the heading ‘Protection of crops, etc.’ in the ‘General Instructions’ section of the label.⁶⁰

60 B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/general-information/pre-emergent-herbicides>

Table 6: Half-life of common pre-emergent herbicides and residual persistence from broadacre trials and paddock experiences.⁶¹

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high-pH soils. Weed control commonly drops off within 6 weeks.
Glean® (chlorsulfuron)	28–42	High. Persists longer in high-pH soils. Weed control longer than Logran®
Diuron	90 (range: 1 month–1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Long-lasting activity observed on grass weeds such as black/stink grass (<i>Eragrostis</i> spp.) and to a lesser extent broadleaf weeds such as fleabane
Atrazine	60–100; up to 1 year if dry	High. Long-lasting (>3 months) activity observed on broadleaf weeds such as fleabane
Simazine	60 (range: 28–149)	Medium/high. 1 year of residual in high-pH soils. Long-lasting (> 3 months) activity observed on broadleaf weeds such as fleabane and sow thistle.
Terbyne® X (terbuthlazine)	6.5–139	High. Long-lasting (>6 months) activity observed on broadleaf weeds such as fleabane and sow thistle.
Triflur® (trifluralin)	57–126	High. 6–8 months residual. Higher rates longer. Long-lasting activity observed on grass weeds such as black/stink grass
Stomp® (pendimethalin)	40	Medium. 3–4 months of residual.
Avadex® Xtra (triallate)	56–77	Medium. 3–4 months of residual.
Balance® (isoxaflutole)	1.3 (metabolite: 11.5)	High. Reactivates after each rainfall event. Long-lasting (>6 months) activity observed on broadleaf weeds such as fleabane and sow thistle.
Boxer Gold® (prosulfocarb)	12–49	Medium. Typically quicker to break down than trifluralin, but tends to reactivate after each rainfall event.
Sakura® (pyrozasulfone)	10–35	High. Typically quicker breakdown than trifluralin and Boxer Gold®; however, weed control persists longer than Boxer Gold®.
Ally® (metsulfuron-methyl)	30 (range: 14–180)	Persists longer in high-pH soils and after a dry year.

Source: CDS Tomlinson (ed) (2009) via B Haskins (2012)⁶⁰

2.7.1 Herbicide residues in the soil

Pulse growers need to be aware of possible herbicide residues that may affect crop rotation choices or cause crop damage. Herbicide residue impacts are more pressing where rainfall has been minimal and in many cases where the soil type is heavier. After a dry season, herbicide residues from previous crops could influence choice of crop and rotations more than disease considerations. The opposite occurs after a wet year.

Weed burden in the new crop will depend on the seedset from last 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 Group B herbicides can persist in some soils. These residues can last for several years, especially in more alkaline soils and where there is little summer rainfall. Here the pulses emerge and grow normally for a few weeks, and then start to show signs of stress when they hit the band of residual chemical at depth, leaves become off-colour (often yellow), roots may be clubbed and plants stop growing and eventually die. Photo 6 shows an affected field pea plant. Lentil is

⁶¹ CDS Tomlinson (ed) (2009) The pesticide manual. 15th edn. British Crop Protection Council, Farnham, UK. Extoxnet: <http://extoxnet.orst.edu/>. California Dept Pesticide Regulation Environmental Fate Reviews, <http://www.cdpr.ca.gov/>

among the most sensitive pulses to chlorsulfuron residues in soil and faba bean is one of the least sensitive. Faba bean and vetch are more sensitive than other pulses to Logran® than to Glean® residues.

Refer to the labels for recommendations on plant-back periods for pulses following use of any herbicides. See [Section 7.8 Herbicide residues](#).



Photo 6: (Left) field pea plant affected by sulfonylurea (chlorsulfuron) damage, stunted with reduced root system, and (right) a healthy field pea plant.

Photo: DPIRD (2015) <https://agric.wa.gov.au/n/4467>

Sulfonylurea breakdown occurs by hydrolysis and is favoured by warm, moist conditions in neutral to acid soils. Residues will tend to persist for longer periods under alkaline and/or dry conditions. Persistence of residues is greater for Glean® and Logran® than for Ally® or Harmony®M. Residues are root-absorbed and translocated to the growing points; therefore, both roots and shoots are affected.

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 bean, where plants are twisted and leaves shrunken. In more severe cases, bare areas are left in the crop where this herbicide had been used, in some instances more than 5 years ago. This

i MORE INFORMATION

For more information on diseases see [Section 9 Diseases](#) and [Section 10 Pre-harvest treatments](#)

damage is usually over a small area or patches in the paddock that can relate either to soil type or spray patterns from the year before.^{62 63}

In wheat–field pea rotations the use of fallow and in-crop residual herbicides such as Broadstrike®, Eclipse®, Flame®, Grazon®DS, Lontrel®, metsulfuron (Ally®, Associate®, Lynx®) and Harmony®M should 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® in wheat should be avoided when re-cropping to field peas.⁶⁴

2.8 Reducing disease risk

Disease risk can be greatly reduced by making some informed management decisions around paddock and seed selection.

Paddock selection

Selecting the paddock with the lowest disease risk:

1. Paddock history

Determine the time since the last crop of the same species was planted. Spores of several fungal pathogens can survive in the soil for many years. These include those that cause black spot in field pea. Leave at least 4 years between pulse crops to allow fungal spore numbers to decline.

2. Paddock position

Avoid sowing this year’s crop in a paddock adjacent to last year’s pulse. Fungal spores can be carried into adjacent paddocks on infected trash and dust, even if a pulse has never been grown in the paddock before. Disease pressure can be increased two or three fold simply by poor paddock position. Take note of the wind direction when harvesting adjacent paddocks of field pea, the previous year as spores will travel on the prevailing winds. Spores of some pathogens can also be carried on pea residues in water; therefore, floodwater can be a source of the contaminant.

3. Soil structure

Look at the condition of the soil. Most pulses do not tolerate waterlogging or hard-setting, crusting soils, which can result in poor crop growth and promote infection from pathogens.

4. Stubble retention

Cereal stubble should be retained when sowing pulses. Stubble presence reduces rain splash of soil-borne spores onto plant foliage, and so helps to reduce foliar disease and its spread.

In field pea, cereal straw acts as a trellis allowing plants to grow up off the ground, reducing disease and soil contamination of the seed sample.

The straw layer helps conserve soil moisture by acting as a mulch for all pulses.

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

63 GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>

64 GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>

Seed management

High quality seed is the first step towards a successful crop and to minimise disease risk.

1. Consider testing seed for disease – bacterial blight in field pea, Cucumber mosaic virus (CMV) in lupin, Ascochyta blight in chickpea and Ascochyta in faba bean are all seed-borne.
2. Grading removes small, damaged seeds from the seed lot. These seeds often produce poor seedlings, which die from pathogen attack first. Grading also removes scleroties (fruiting bodies of the fungus that causes Sclerotinia), which would otherwise be sown with the seed.
3. Treat seed with fungicide prior to sowing. Seedlings will be protected from a number of fungal pathogens for the first 4–6 weeks after sowing. Seed treatment used with stubble retention greatly reduces blackspot infection in field pea.⁶⁵

Black spot (also known as Ascochyta blight of field pea) is the most common and often most damaging foliar disease of field pea. The disease is caused by a complex of four fungi, which between them can survive on seed, stubble and in soil (see [Section 9 Diseases](#) and [Section 10 Pre-harvest treatments](#)). Management options include crop rotation, paddock selection, sowing time (avoidance of ascospore showers early in the season from old stubble), fungicide seed dressing and foliar fungicides.⁶⁶

2.8.1 Soil testing for disease

PreDicta® B (B = broadacre) is a DNA-based soil-testing service for identifying which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding.

It has been developed for cropping regions in southern Australia and includes tests for:

- Cereal cyst nematode CCN (*Heterodera avenae*)
- Take-all (caused by *Gaeumannomyces graminis* var. *tritici* (Ggt) and *G. graminis* var. *avenae* (Gga))
- Rhizoctonia bare patch (caused by *Rhizoctonia solani* AG8)
- RLN (*Pratylenchus neglectus* and *P. thornei*)
- Crown rot (caused by *Fusarium pseudograminearum* and *F. culmorum*)
- Stem nematode (*Ditylenchus dipsaci*)
- Blackspot of peas (*Mycosphaerella pinodes*, *Phoma medicaginis* var. *pinodella* and *Phoma koolunga*).

Grain producers can access PreDicta® B sampling kits from accredited agronomists and from Primary Industries and Regions SA/the South Australian Research and Development Institute. Samples are processed weekly from February to mid-May (prior to crops being sown) to assist with planning the cropping program.

In some cases, PreDicta® B can be used for in-crop diagnosis, although in most cases this is best achieved by sending samples of affected plants to your local plant pathology laboratory.

2.8.2 Cropping history effects

The general rule of thumb is to have a 4-year interval between pulse crops, regardless of the pulse species. Many of the pulse diseases, such as Sclerotinia, are not host-specific and will infect a wide range of pulse species as well as canola. Ideally, do not plant a pulse crop adjacent to a previous year's pulse paddock.

MORE INFORMATION

For more information on PreDicta® B visit:
http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

65 K Lindbeck (1999) Pulse Point 7: Reducing disease risk. NSW Agriculture, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/157144/pulse-point-07.pdf

66 K Lindbeck (2016) Pulse disease the watch outs for 2016. GRDC Update Papers 16 February 2016, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Pulse-diseases-the-watch-outs-for-2016>

2.8.3 Nematode status of paddock

It is important to have paddocks diagnosed for plant parasitic nematodes so that optimal management strategies can be implemented. Testing will tell:

- if nematodes are present in paddocks and at what density; and
- what species are present.

It is important to know what species are present because some crop-management options are species-specific. If a particular species is present in high numbers, it is important to make immediate decisions to avoid losses in the next crop to be grown. With low numbers it is important to take decisions to safeguard future crops. Learning that a paddock has low nematode numbers is valuable information because it may be possible to take steps and avoid future contamination of that field.⁶⁷

Testing both soil samples taken before a crop is sown or while the crop is in the ground provides valuable information.

2.8.4 Effects of cropping history on nematode status

Root-lesion nematode (RLN) numbers build up steadily under susceptible crops and cause decreasing yields over several years. The amount of damage caused will depend on:

- the numbers of nematodes in the soil at sowing (Table 7);
- the tolerance of the variety of the crop being grown (Table 8);
- the environmental conditions; and
- in-season management decisions.

See Table 9 for a summary of the disease risk interactions pertaining to *Pratylenchus* species.

Table 7: Yield loss risk categories – southern region.

Risk rating*	<i>Pratylenchus thornei</i> /g soil	<i>Pratylenchus neglectus</i> /g soil	% Yield loss
Below detection	<1	<1	<2
Low	1–20	1–20	0–10
Medium	20–60	20–60	5–20
High	>60	>60	10–40

* Use risk categories as a guide only, seasonal condition and variety tolerance influence yield loss.

Source: A McKay, D Roget, R J Hannam, K Ophel Keller (2015) Root Disease, Risk Management, Resource Manual, SARDI, Version 7.2

Yield losses caused by RLN are correlated with the population of these nematodes present in the soil at sowing, the tolerance of the wheat variety and the date of sowing. The root-lesion nematodes *Pratylenchus neglectus* and *P. thornei* are common in broadacre field crops of southern Australia and can cause damage of up to 40% if populations are high and intolerant varieties are sown late, but most losses are less than 15%.⁶⁸

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

The main means of controlling nematodes is growing resistant crops. In the case of susceptible crops, such as wheat or chickpea, choose the most tolerant variety available and rotate with resistant crops like field pea to keep nematode numbers at low levels. Information on the responses of crop varieties to RLN is regularly updated

67 Queensland Primary Industries and Fisheries (2009) Root lesion nematodes: management of root-lesion nematodes in the northern grain region. Queensland Government, https://www.daf.qld.gov.au/_data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

68 A McKay, D Roget, R J Hannam, K Ophel Keller (2015) Root Disease, Risk Management, Resource Manual, SARDI, Version 7.2

in grower planting guides. Note that crops and varieties have different levels of tolerance and resistance to *P. thornei* and *P. neglectus* (Table 8).⁶⁹

For more detail see Section 3 [Table 3 Disease resistance characteristics of field pea varieties.](#)

Table 8: Susceptibility and resistance of various crops to root-lesion nematodes.⁷⁰

RLN species	Susceptible	Intermediate	Resistant
<i>P. thornei</i>	Wheat, chickpea, faba bean, barley, mungbean, navy bean, soybean, cowpea	Canola, mustard, triticale, durum wheat, maize, sunflower	Canary seed, linseed, oats, sorghum, millet, cotton, field pea
<i>P. neglectus</i>	Wheat, canola, chickpea, mustard, sorghum (grain), sorghum (forage)	Barley, oat, canary seed, durum wheat, maize, navy bean	Linseed, field pea, faba bean, triticale, mungbean, soybean

Source: K Owen et al. (2013)

Table 9: Summary of disease risk interactions – *Pratylenchus* species.⁷¹

Lower		Higher
Early break Good growing season rainfall Soft finish to season	Environment	Late break, cold soil Light soils, low fertility Low rainfall year Hard finish to season
Early sowing Adequate nutrition Good summer/autumn weed control Break with non-host crop/pastures	Management	High frequency of susceptible crops Poor control of summer/autumn weed Inadequate fertiliser
Tolerant crop to reduce yield loss Resistance to reduce multiplication	Crop variety	Intolerant crop varieties Susceptible crops and varieties increase populations
Below detection – low	Pathogen level	High High level of other soil/stubble-borne pathogens

Source: A McKay, D Roget, R J Hannam, K Ophel Keller (2015) Root Disease, Risk Management, Resource Manual, SARDI, Version 7.2

For more information, download GRDC Tips and Tactics Root-lesion nematodes and see [Section 9.19 Root-lesion nematodes \(RLN\) \(*Pratylenchus neglectus* and *P. thornei*\)](#)

2.9 Pest status of paddock

2.9.1 Insect sampling of soil

Soil-dwelling insect pests can seriously reduce plant establishment, early growth and subsequent yield potential. 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 moist/dry soil interface.

Soil insects include:

- **black field cricket**, <http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/black-field-cricket>

69 K Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes. GRDC Update Papers, https://www.daf.qld.gov.au/_data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

70 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>

71 A McKay, D Roget, R J Hannam, K Ophel Keller (2015) Root Disease, Risk Management, Resource Manual, SARDI, Version 7.2

- **black scarab beetles**, <https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/black-sunflower-scarab>
- **cut worm**, <http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Cutworm>
- **slaters**, <http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/slaters>
- **false wireworms and true wireworms**, <http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2011/pestfacts-issue-no-4-10th-june-2011/false-wireworms-and-true-wireworms/>

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.
- High stubble levels on the soil surface can promote some soil insects due to 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 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. Methods used to detect soil insects present include using a spade – which can be laborious, time-consuming and difficult in heavy clay or wet soil – or using a seed bait technique.

2.9.2 Key pests of field pea

The key pests of field pea in southern Australia are native budworm (*Helicoverpa punctigera*), pea weevil (*Bruchus pisorum*), snail, slugs, aphids, mites, lucerne flea and lucerne seed web moth (*Etiella behrii*). (See [Section 8 Pest management](#).) [Table 10](#) shows the timing of damaging effects of the key and other pests in field pea crops.

SECTION 2 FIELD PEA

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Table 10: Incidence of insect pests in field pea.

	Crop stage				
	Emergence/ Seedling	Vegetative	Flowering	Podding	Grain fill
Earth mites	Damaging	Present	Present		
Lucerne flea	Damaging	Present			
Cutworms	Damaging				
Slugs and snails*	Damaging	Damaging			
Aphids	Damaging	Damaging	Present	Present	
Thrips		Present	Present		
Pea weevil		Present	Damaging	Damaging	Damaging
Helicoverpa		Present	Damaging	Damaging	Damaging
Etiella		Present	Present	Damaging	Damaging

Present = Present in crop but generally not damaging Damaging = Crop susceptible to damage and loss

Source: NIPI & field pea IPM, <http://ipmguidelinesforgrains.com.au/crops/winter-pulses/field-peas/>

MORE INFORMATION

For more information, see [Section 8.3](#)
[Key pests of field pea](#)

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Pre-planting

Key points

- When selecting a variety, consider seed type (white, dun, blue), marketability, seed size with reference to sowing or cleaning machinery, varietal maturity and sowing date, disease resistance, standing ability, seed-shattering resistance, ease of harvest, yield in your region, market outlets and seed availability.
- Good quality, undamaged seed is essential to ensure the best start for the crop. Use seed with greater than 80% germination.
- Testing of seed for germination and disease is highly desirable.

When a paddock is to be sown to a pulse crop, broadleaf weed pressure should be low and the weed seedbank should have been reduced in previous crops. Avoid problem-weed paddocks, considering both weeds that are difficult to control and weeds which may contaminate the grain sample.

Herbicide history must also be considered and paddock records reviewed. Residues of Group B herbicides that have been applied in the previous crop can be very damaging to following pulse crops including field pea, particularly in alkaline soils after extended dry periods. Examples of these products include sulfonylurea herbicides, such as chlorsulfuron (e.g. Glean®) and metsulfuron methyl (e.g. Ally®), as well as metosulam (Eclipse®), triasulfuron (Logran®) and imazapic + imazapyr (OnDuty®).

Common spikes used in pre-plant knockdown sprays (e.g. 2,4-D products and dicamba) have plant-back restrictions. These range from 7–21 days, depending upon product and rate. When applied to dry soil, at least 15 mm of rainfall is required prior to the commencement of the plant-back period. Always consult the product label and follow the recommended plant-back periods.¹

3.1 Evaluation of yield potential

Productivity of the grains industry depends on the continued adoption and deployment of new technologies, including the adoption of new varieties with superior yield and useful disease resistance. When considering a new variety, growers should compare the grain yield, grain quality and disease resistances of the new variety with currently grown varieties.² (See [Section 1.1 Field pea types](#) for more information.)

The most accurate predictor of a variety's performance is a stable yield in many locations over several years. Yield results are available from the National Variety Trials (NVT) website (<http://www.nvtonline.com.au>), as well as from specific Pulse Variety Management Package (VMP) brochure (<https://grdc.com.au/research/trials-programs-and-initiatives/pba/link3.aspx>).³

Individual NVT trial results provide only a snapshot in time and may lead to an unsuitable varietal choice. Combining data across trials (and years), using a current long-term analysis based on geographic region, enhances the chance of selecting appropriate varieties. A new method of analysis forms environment groups from 'similar' trials rather than geographic regions and will provide the most accurate prediction of relative yield performance of varieties for an environment.⁴

1 Northern Region Field Pea Management Guide (2010). Pulse Australia, http://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

2 NVT (2013) Queensland 2013 wheat varieties. GRDC/Queensland Department of Agriculture and Fisheries, <https://grdc.com.au/NVT-QLD-WheatVarietyGuide>

3 G Cumming (2014) Chickpea varieties selecting horses for courses. GRDC Update Papers 5 March 2014, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Chickpea-varieties-selecting-horses-for-courses>

4 A Kelly, A Smith, B Cullis (2013) Which variety should I grow? New statistical methods for NVT allow for better decision making. GRDC Update Papers, 12 March 2013, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Kelly-Alison-What-should-I-grow>

NVT long-term-yield report

As examples, [Table 1](#) shows the long-term (2011–15) NVT results for field pea in South Australia’s Mid North region and [Figure 1](#) shows the long-term (2011–15) NVT results for field pea in the Victorian Mallee.

Table 1: Field pea variety trials example – Mid North, South Australia.

Variety	Predicted average yield (t/ha)	Total number of trials
PBA Pearl ^{db}	2.221	32
PBA Wharton ^{db}	2.167	32
PBA Oura ^{db}	2.098	32
Yarrum	2.088	8
Sturt	2.084	15
PBA Gonyah ^{db}	2.069	29
PBA Percy ^{db}	2.053	25
PBA Twilight ^{db}	2.043	29
Kaspa ^{db}	1.993	32
Morgan ^{db}	1.901	3
Excell	1.889	3
Parafield	1.804	20

Source: <http://www.nvtonline.com.au/nvt-results-reports/?nocollapseomatic=1#filterYear=2015&filterCrop=fp&filterSubcrop=&postcode=3551>

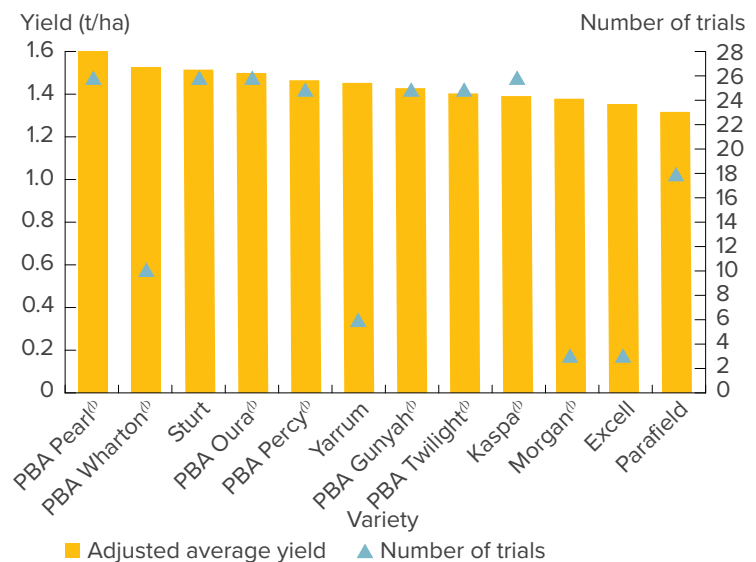


Figure 1: Field pea yield responses, 2011–15, Mallee, Victoria.

Source: <http://www.nvtonline.com.au/nvt-results-reports/?nocollapseomatic=1#filterYear=2015&filterCrop=fp&filterSubcrop=&postcode=3551>

MORE INFORMATION

More information on PBA varieties and brochures

<https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures>

MORE INFORMATION

Online Farm Trials

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

PBA and NVT

Pulse Breeding Australia (PBA) and its commercial seed partners launch new varieties at targeted pulse field days during the spring field days. This gives growers and advisers the opportunity to view and assess the varieties in their growing regions prior to their availability.

A Variety Management Package (VMP) is released with each new PBA variety (<http://www.seednet.com.au/pulses-101.html>). These brochures provide information about appropriate agronomic and disease management, and disease ratings for each variety. The information in the brochures is compiled from agronomic and disease management projects with investment from the Grains Research and Development Corporation (GRDC) in conjunction with the PBA partner agencies, combined with yield data from variety trials conducted by both PBA and NVT.

3.2 Selecting a variety

When choosing a field pea variety a number of factors need to be considered:

- What market am I aiming for – human consumption or stockfeed?
- What am I producing field pea for – grain, hay, green/brown manure?
- What disease traits are required?
- What is my sowing date?
- Harvesting equipment – can I handle a variety that falls over or does it need to be erect at harvest?

To achieve maximum returns, best agronomic practice needs to be employed according to the variety. These practices include careful paddock selection, planting of high quality seed and suitable crop protection measures, including weed, disease and insect management, followed by careful harvest, handling and storage practices.

Consideration of market access and options, even prior to crop establishment, can also have a significant impact on the crop's value and profitability.⁵

When selecting a variety consider seed type (white, dun, blue), seed size with reference to sowing or cleaning machinery, varietal maturity and sowing date, disease resistance, standing ability, seed-shattering resistance, ease of harvest, yield in your region, market outlets and seed availability. A large number of varieties are available, with a wide range of characteristics; some are only suited to specific growing regions.⁶ Improved tolerance to salinity and boron has also been important in variety selection for some areas (e.g. PBA Wharton⁶).⁷

Trials conducted at Westmere in 2011 and 2012 investigated the adaptability of a range of field pea varieties to varying sowing dates, crop-topping and disease control. (See [Section 10.2.1 Field trial](#).)

3.2.1 Characteristics of field pea varieties for southern Australia

Agronomic characteristics

For detailed information on varieties available in Victoria in 2017 ([Table 2](#)) visit Agriculture Victoria's Victorian winter crop summary (<https://grdc.com.au/resources-and-publications/all-publications/publications/2017/03/nvt-victorian-winter-crop-summary>).

5 G Cumming (2014) Chickpea varieties selecting horses for courses. GRDC Update Papers, 5 March 2014, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Chickpea-varieties-selecting-horses-for-courses>

6 P Matthews, D McCaffery, L Jenkins (2017) Winter crop variety sowing guide, Department of Primary Industries, NSW, <https://www.dpi.nsw.gov.au/about-us/media-centre/releases/2017/2017-winter-crop-variety-sowing-guide-now-available>

7 Pulse Breeding Australia (2015) PBA Wharton⁶ variety management package, http://www.pulseaus.com.au/storage/app/media/crops/2013_VMP-Kfieldpea-PBAWharton.pdf

For detailed information on varieties available in SA in 2017 see SARDI's *Field pea variety sowing guide 2017* (http://www.nvtonline.com.au/wp-content/uploads/2017/01/SA-sowing-guide-2017_lo-res.pdf).

Table 2: Agronomic characteristics of field pea varieties.⁸

Variety	Seed size	Plant habit	Plant vigour, early season	Flowering time	Flowering colour	Maturity time	Plant lodging resistance at maturity	Pod shattering at maturity	Boron tolerance	Salinity tolerance
Yellow or blue pea grain type										
Excell	Me	SD-SL	high	early		early-mid	good	S:NSP	S	S
PBA Hayman ^{db}	Sm	C (multi-branched)	Low-Med	very late	white	very late	poor	MR:NSP	MS	MS
PBA Pearl ^{db}	Me-Lg	SD-SL	moderate	early-mid	white	early-mid	good	MR:NSP	MS	MS
Sturt	M-Sm	C	high	early-mid	white	mid	poor	MR:NSP	S	MS
Kaspa grain type										
Kaspa ^{db}	Me	SD-SL	moderate	late	pink	mid	fair-good	R:SP	S	S
OZP1101		SD-SL	high	mid-late		mid	good	R:SP	S	S
PBA Gonyah ^{db}	Me	SD-SL	high	early-mid	pink	early	fair-good	R:SP	S	SMS
PBA Twilight ^{db}	Me	SD-SL	high	early	pink	early	fair-good	R:SP	S	S
PBA Wharton ^{db}	Me	SD-SL	moderate	early-mid	pink	early	fair-good	R:SP	MT	MT
Australian dun grain type										
Morgan ^{db}	Sm	Tall-SL	high	late	purple	late	poor-fair	MR:NSP	S	S
Parafield	Me-Lg	C	high	mid	purple	mid	poor	MR:NSP	S	MS
PBA Coogee ^{db}	Lg	C	high	mid-late	purple	mid	poor	MR:NSP	T	MT
PBA Oura ^{db}	Me	SD-SL	moderate	early-mid	purple	early	fair-good	MR:NSP	MS	S
PBA Percy ^{db}	Me-Lg	C	high	early	purple	early	poor	MR:NSP	S	MT

Sm = small, Me = medium, Lg = large, SD = semi-dwarf, C = conventional, SL = semi-leafless, S = susceptible, MS = moderately susceptible, MR = moderately resistant, R = resistant, SP = sugar pod type pod, NSP = non sugar pod type, I = intolerant, MT = moderately intolerant

Source: J Couchman, K Hollaway (2016) NVT Victorian Winter Crop Summary 2017. Department of Economic Development, Jobs, Transport and Resources, www.grdc.com.au/NVT-Victorian-Winter-Crop-Summary

Disease resistance characteristics

When choosing varieties, it is essential to consider their disease susceptibility (Table 3), along with yield potential, price potential, marketing opportunities, maturity timing, lodging resistance and other agronomic features relevant to a growing region.

Varietal resistance to bacterial blight and black spot is extremely important. These diseases are potential problems for field pea in tight rotations, in higher-rainfall areas or wetter years.

(Note that fungicides are rarely economic and do not control bacterial blight.)

Improvements in varietal resistance offer the best long-term prospects for control of these diseases. For more information on disease management see [Section 9 Diseases](#) and [Section 10 Pre-harvest treatments](#).

⁸ J Couchman, K Hollaway (2016) NVT Victorian Winter Crop Summary 2017. Department of Economic Development, Jobs, Transport and Resources, www.grdc.com.au/NVT-Victorian-Winter-Crop-Summary

When comparing yields between varieties, it is important to note that under bacterial blight pressure or high moisture stress, varieties with greater susceptibility are more likely to suffer greater yield losses than less susceptible varieties.⁹

Table 3: Disease resistance characteristics of field pea varieties.¹⁰

Variety	Blackspot (Ascochyta)	Bacterial blight (field rating)	Downy mildew (Kaspa strain)	Downy mildew (Parafield strain)	Powdery mildew	PSbMV virus	BLRV virus (field rating)	Pratylenchus neglectus	Pratylenchus thornei
Yellow or blue pea grain type									
Excell	MS	S	S	MR	S	-	-	-	-
PBA Hayman [Ⓓ]	Sp	MRp	-	RMR	R	-	-	-	-
PBA Pearl [Ⓓ]	MS	MS	S	R	S	S	R	MR-MS	MR-MS
Sturt	MS	MS	S	MS	S	S	MS	MSp	MR
Kaspa grain type									
Kaspa [Ⓓ]	MS	S	S	MR	S	S	S	MR-MS	MR-MS
OZP1101	MS	MRMSp	MS	R	S	S	S	MR-MS	MR-MS
PBA Gonyah [Ⓓ]	MS	S	S	R	S	S	S	MR	MR-MS
PBA Twilight [Ⓓ]	MS	S	S	R	S	S	S	MRMSp	MR-MS
PBA Wharton [Ⓓ]	MS	S	S	MS	R	R	R	MRMSp	MRp
Australian dun grain type									
Morgan [Ⓓ]	MS	MS	S	MR	S	S	Sp	RMRp	MRp
Parafield	MS	MS	S	S	S	S	S	MR-MS	MRp
PBA Coogee [Ⓓ]	S	MRMSp		Sp	R	-	Sp	MRMSp	MRMSp
PBA Oura [Ⓓ]	MRMSp	MRMS	MR-MS	MR	S	S	MR	MRMSp	MRMSp
PBA Percy [Ⓓ]	MS	MR	S	S	S	S	S	MR-MS	RMRp

PBSV = Pea seed-borne mosaic virus, BLRV = Bean leaf roll virus
Resistance order from best to worst: R > RMR > MR > MR-MS > MS > MSS > S > SVS > VS
p = provisional ratings – treat with caution R = resistant, M = moderately, S = susceptible, V = very

Source: J Couchman, K Hollaway (2016) NVT Victorian Winter Crop Summary 2016. Department of Economic Development, Jobs, Transport and Resources, <http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-cropeed-sixoop-summary>

Field pea variety response to herbicides

For information on field pea variety responses to herbicides see *Pulse variety response in South Australia* (<http://www.nvtonline.com.au/wp-content/uploads/2016/04/SA-Pulses-2015.pdf>) (Table 4) and *Pulse variety response to herbicides in Victoria* (<http://www.nvtonline.com.au/wp-content/uploads/2013/03/Herbicide-Tolerance-VIC-Pulses-2003-2005.pdf>) (Table 5).

⁹ W Hawthorne and W Bedgood (2007). Field peas in South Australia and Victoria. Pulse Australia Fact sheet

¹⁰ J Couchman, K Hollaway (2016) NVT Victorian Winter Crop Summary 2016. Department of Economic Development, Jobs, Transport and Resources, www.grdc.com.au/NVT-Victorian-Winter-Crop-Summary

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Table 4: Field pea variety responses to herbicide, South Australia.

Herbicide	Years tested	Broadstrike®	Brodal Options® + MCPA Amine	Boxer Gold®	Diuron	Lexone®	Lexone®	Lexone®*	MCPA Sodium
		Flumetsulam	Diflufenican + MCPA Amine	Prosulfocarb + S-metolochlor	Diuron	Metribuzin	Metribuzin	Metribuzin	MCPA Sodium
Variety	Years tested	1994–2015	1994–2015	2015	2011–2014	1994–2010	1994–2015	2005–2008	1994–2008
Bundi	2006–2007	√(2)	√(2)	-	-	√(2)	√(2)	√(2)	√(2)
Kaspa ^{db}	2002–2012	N(1/11)	11(1/11)	-	N(1/2)	N(2/9)	N(4/11)	9(1/4)	10(1/7)
PBA Gonyah ^{db}	20008–2015	N(1/8)	√(8)	√(1)	√(4)	9(1/3)	N(3/8)	√(1)	√(1)
PBA Oura ^{db}	2011–2013	√(3)	√(3)	-	√(3)	-	√(3)	-	-
PBA Twilight ^{db}	2008–2011	N(1/4)	N(1/4)	-	√(1)	N(1/3)	13(1/4)	16(1/1)	√(1)
OZP1101	2012–2015	N(1/4)	14(1/4)	√(1)	√(3)	-	√(4)	-	-
Parafield	1996–2005	11–13(2/10)	√(10)	-	-	N(3/10)	N(5/10)	√(1)	5–20 (2/10)
PBA Percy ^{db}	2014–2015	13(1/2)	√(2)	√(1)	√(1)	-	√(2)	-	-
PBA Pearl ^{db}	2012–2013	√(2)	√(2)	-	√(2)	-	√(2)	-	-
Sturt	2002–2005	10–13(2/4)	√(4)	-	-	8(1/4)	12–17(2/4)	10(1/1)	√(4)
SW Celine	2006–2007	√(2)	√(2)	-	-	√(2)	√(2)	N(1/2)	√(2)
PBA Wharton ^{db}	2012–2015	√(3)	√(3)	√(1)	√(2)	-	√(3)	-	-
Rates (product/ha)		25 g	125 mL + 80 mL	2.5 L	1 k	280 g	280 g	280 g	900 mL
Crop stage at spraying		5 node	5 node	IBS	PSPE	PSPE	3 node	6 node	5 node

^dDenotes off-label use. This use is not endorsed by this data and no responsibility taken for its interpretation. IBS (incorporation by sowing); PSPE (post-sowing pre-emergent).

Source: Pulse variety response in South Australia, <http://www.nvtonline.com.au/wp-content/uploads/2016/04/SA-Pulses-2015.pdf>

The sensitivity of the variety is summarised, using the following symbols based on the yield responses across all trials.

- Not tested or insufficient data.

√ (z) no significant yield reductions at recommended rates or higher than recommended rates in (z) trials.

N (w/z) narrow margin, significant yield reductions at higher than recommended rate, but not at recommended rate, significant event occurring w years out of z years tested. Eg (2/5) = tested for 5 years, 2 returning significant yield loss.

x% (w/z) yield reduction (warning) significant yield reduction at recommended rate in 1 trial only in z years of testing.

x-y% (w/z) yield reductions (warning) significant yield reductions at recommended rate in w years out of z years tested.

Always follow label recommendations. All pesticide applications must accord with the currently registered label for that particular pesticide, crop, pest and region. Any research regarding pesticides of their use reported in this publication does not constitute a recommendation for that particular use by the authors, the author's organisations or GRDC. It must be emphasized that crop tolerance and yield responses to herbicides are strongly influenced by seasonal conditions.

Table continued on next page.

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Herbicide	Variety	Years tested	Outlook*	Simazine	Simazine + Diuron	Spinnaker®	Sakura®	Status®*	Raptor®	Terbyne®
			Di-Methenamid-P	Simazine	Simazine + Diuron	Imathapyr	Pyroxsulfone	Clethodim	Imazamox	Teruthylazine
			2011–2013	2011–2015	1994–2010	1994–2010	2015	2014	1994–2015	2009–2015
	Bundi	2006–2007	-	-	√(2)	15(1/2)	-	-	N(2/2)	-
	Kaspa [Ⓛ]	2002–2012	√(2)	N(1/2)	N(1/8)	√(9)	-	-	√(10)	N(1/4)
	PBA Gonyah [Ⓛ]	20008–2015	√(3)	14(1/5)	9–11(2/3)	N(1/3)	√(1)	√(1)	11(1/8)	9(1/7)
	PBA Oura [Ⓛ]	2011–2013	N(1/3)	√(3)	-	-	-	-	√(3)	√(3)
	PBA Twilight [Ⓛ]	2008–2011	√(1)	√(1)	9(1/3)	11(1/3)	-	-	√(4)	N(2/3)
	OZP1101	2012–2015	√(2)	16(1/4)	-	-	√(1)	√(1)	N(1/4)	N(1/4)
	Parafield	1996–2005	-	-	29(1/10)	11–15(2/10)	-	√(1)	7(1/10)	-
	PBA Percy [Ⓛ]	2014–2015	-	√(2)	-	-	√(1)	√(1)	√(2)	N(1/2)
	PBA Pearl [Ⓛ]	2012–2013	√(2)	15(1/2)	-	-	-	-	N(1/2)	N(1/2)
	Sturt	2002–2005	-	-	√(4)	7(1/4)	-	-	N(1/4)	-
	SW Celine	2006–2007	-	-	√(2)	√(2)	-	-	N(1/2)	-
	PBA Wharton [Ⓛ]	2012–2015	√(1)	√(3)	-	-	√(1)	√(1)	√(3)	√(3)
	Rates (product/ha)		1 L	1 kg	350 mL + 650 mL	70 g	118 g	1 L	45 g	1 kg
	Crop stage at spraying		IBS	PSPE	PSPE	3 node	IBS	3 node	3 node	PSPE

*Denotes off-label use. This use is not endorsed by this data and no responsibility taken for its interpretation. IBS (incorporation by sowing); PSPE (post-sowing pre-emergent).

Source: Pulse variety response in South Australia, <http://www.nvtonline.com.au/wp-content/uploads/2016/04/SA-Pulses-2015.pdf>

The sensitivity of the variety is summarised, using the following symbols based on the yield responses across all trials.

- Not tested or insufficient data.

√ (z) no significant yield reductions at recommended rates or higher than recommended rates in (z) trials.

N (w/z) narrow margin, significant yield reductions at higher than recommended rate, but not at recommended rate, significant event occurring w years out of z years tested. Eg (2/5) = tested for 5 years, 2 returning significant yield loss.

x% (w/z) yield reduction (warning) significant yield reduction at recommended rate in 1 trial only in z years of testing.

x-y% (w/z) yield reductions (warning) significant yield reductions at recommended rate in w years out of z years tested.

Always follow label recommendations. All pesticide applications must accord with the currently registered label for that particular pesticide, crop, pest and region. Any research regarding pesticides of their use reported in this publication does not constitute a recommendation for that particular use by the authors, the author's organisations or GRDC. It must be emphasized that crop tolerance and yield responses to herbicides are strongly influenced by seasonal conditions.

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Table 5: Field pea variety responses to herbicide, Victoria.

Herbicide		Trifluralin	Spinnaker® 240/700	Lexone®	Diuron 500/900	Raptor®	Brodel®	Brodel® + MCPA	
		trifluralin	imazethapyr	metri- buzin	diuron	imamox	difufen- ican	difufen- ican + MCPA	
Variety	Years tested	2003–04	2003–04	2003–04	2003–04	2003– 04	2003	2004	
		Site	AB	AB	AB	AB	A	B	
Dundale	2004	A	-	-	-	-	-	-	
Kaspa ^{db}	2003–04	AB	✓	✓	✓	✓	✓	✓	
Parafield	2004	A	-	-	-	-	-	-	
Snowpeak	2004	A	-	-	-	-	-	-	
Moonlight	2004	B	-	N	-	-	-	-	
Sturt	2003–04	AB	✓	N	✓	✓	✓	✓	
Rates (ai/ha)			576-720 g	48-70 5	210 g	600-756 g	31.5	75 g	75 g + 75 g
Rates (product/ha)			1200–1500 mL	200(240)- 100(700)	280 (Lex) 435 (Sen)	1200 (500) - 850 (900)	45g	150ml	150ml + 150ml
Crop stage at spraying			IBS	PSPE	PSPE	PSPE	3-4 node	3-4 node	3-4 node

Herbicide		Broadstrike®	Verdict®	Select®	
		Flumet- salum	Haloxypop	Clethodim	
Variety	Years tested	2003–04	2003–04	2004	
		Site	AB	AB	AB
Dundale	2004	A	-	-	-
Kaspa ^{db}	2003–04	AB	✓	✓	✓
Parafield	2004	A	-	-	-
Snowpeak	2004	A	-	-	-
Moonlight	2004	B	-	-	-
Sturt	2003–04	AB	✓	✓	✓
Rates (ai/ha)			20 g	52 g	96 g
Rates (product/ha)			25 g	75 ml	400 ml
Crop stage at spraying			3–4 node	z14 grass weeds	z14 grass weeds

The sensitivity of the variety is summarised, using the following symbols based on the yield responses across all trials.

- Not tested or insufficient data.

✓ no significant yield reductions at recommended rates or higher than recommended rates in 2 trials.

N (narrow margin) significant yield reductions at higher rate than recommended in 1+ trial but not at recommended rate.

x% yield reduction (warning) significant yield reduction at recommended rate in 1 trial only.

x-y% yield reductions (warning) significant yield reductions at recommended rate in 2+ trials.

Always follow label recommendations. All pesticide applications must accord with the currently registered label for that particular pesticide, crop, pest and region. Any research regarding pesticides of their use reported in this publication does not constitute a recommendation for that particular use by the authors, the author's organisations or GRDC. It must be emphasized that crop tolerance and yield responses to herbicides are strongly influenced by seasonal conditions.

IBS (incorporation by sowing); PSPE (post-sowing pre-emergent).
Source: <http://www.nvtonline.com.au/wp-content/uploads/2013/03/Herbicide-Tolerance-VIC-Pulses-2003-2005.pdf>

i MORE INFORMATION

Please see http://www.pulseaus.com.au/storage/app/media/crops/pulses/2016_Pulse-Variety-Charts-web.pdf for more details and images of pulse varieties

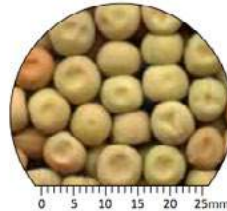
3.3 Field pea varieties

[Ⓛ] denotes Plant Breeders Rights apply

3.3.1 Dun types (dimpled)

PBA Coogee[Ⓛ]

<http://www.seednet.com.au/documents/PBA%20Coogee%202016.pdf>



PBA Coogee[Ⓛ]

Released: 2013
Seed weight: 22–27 g/100
Coat colour: brown-green
Production region: North

PBA Coogee[Ⓛ] is a mid-flowering and mid-maturing conventional dun pea suitable for either grain or forage production. It has higher grain yield and similar biomass production to Morgan[Ⓛ], and grain yield between Parafield and Kaspas[Ⓛ]. Flowering and podset are generally slightly later than both Parafield and Kaspas[Ⓛ]. PBA Coogee[Ⓛ] is resistant to powdery mildew and has improved tolerance to soil boron and salinity compared to other varieties. Seed is licensed to Seednet.

PBA Oura[Ⓛ]

<http://www.seednet.com.au/documents/PBAOura2012.pdf>



PBA Oura[Ⓛ]

Released: 2011
Seed weight: 18–25 g/100
Coat colour: brown-green
Production region: South and North

PBA Oura[Ⓛ] is a high-yielding, early to mid flowering, semi-dwarf dun variety with high yields and improved resistance (moderately resistant/moderately susceptible (MR-MS)) to bacterial blight (*pv. syringae*) over Kaspas[Ⓛ], PBA Gunyah[Ⓛ], PBA Twilight[Ⓛ] and PBA Wharton[Ⓛ]. This line has broad adaptation and high yield potential in short growing seasons. It produces non-sugar-type pods, but is not prone to shattering and has fair to good lodging resistance. PBA Oura[Ⓛ] has improved resistance (MR-MS) to the Kaspas[Ⓛ] strain of downy mildew and improved tolerance to metribuzin herbicide over Kaspas[Ⓛ]. Seed is licensed to Seednet.

PBA Percy[®]

<http://www.seednet.com.au/documents/PBAPercyWeb.pdf>



PBA Percy[®]

Released: 2011
 Seed weight: 20–26 g/100
 Coat colour: brown-green
 Production region: South and North

PBA Percy[®] is an early-flowering conventional dun variety with improved resistance (MR) to bacterial blight (*pv. syringae*) over all other varieties, making it a good option in areas prone to this disease. Its early flowering and early maturity make it well suited to delayed sowing for disease management and crop-topping. It produces non-sugar-type pods, but is not prone to shattering (similar to PBA Oura[®]). PBA Percy[®] generally produces yields similar to PBA Oura[®] but in low-rainfall environments can be the highest yielding dun variety in trials. Seed is licensed to Seednet.

Parafield

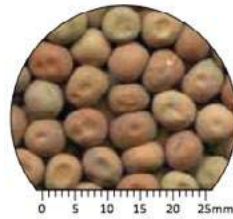


Parafield

Released: 1999
 Seed weight: 21–27 g/100
 Coat colour: brown-green
 Production region: South

Parafield is a traditional Australian dun field pea that is tall, mid to late-season flowering, and produces large, Australian dun-type grain. Parafield has a lower yield potential compared to recent variety releases. PBA Percy[®] is now a superior option for growers wanting to grow a conventional dun field pea. Parafield will need to be managed for all diseases in disease-prone areas. Parafield has poor lodging resistance and will require specialised pea pick-up fronts for harvesting. It has moderate non-sugar-pod resistance to shattering. Released in 1998, it can be freely marketed because it is no longer protected by PBR. Parafield has no commercialised partners.

Morgan[®]



Morgan[®]

Released: 1998
 Seed weight: 16–22 g/100
 Coat colour: brown-green
 Production region: South

A tall, late-flowering, semi-leafless pea, Morgan[®] produces small, Australian dun-type grain. Morgan[®] has lower grain yield potential than other varieties, but was released for the lower-rainfall regions of central and western NSW as a dual-purpose pea that could be used for forage in drought years. Morgan[®] is MR to downy mildew (Parafield strain). Morgan[®] will need to be managed for blackspot, bacterial blight, PSbMV, powdery mildew, downy mildew (Kaspa[®] strain) and BLRV in disease-prone areas. Pods are susceptible to pod shattering. Its grain size is small and less suitable for human consumption markets. It was commercialised by Hart Bros Seeds.

Yarrum

http://www.pulseaus.com.au/storage/app/media/crops/2011_VMP-Dunfieldpea-Yarrum.pdf



Yarrum

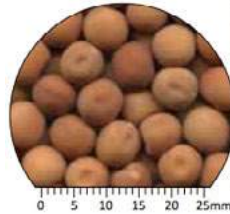
Released: 2004
 Seed weight: 20–26 g/100
 Coat colour: brown-green
 Production region: North

Yarrum is a semi-dwarf, semi-leafless dun type that has an erect habit during early growth, but can lodge at maturity when high yielding or weather conditions are unfavourable. It has mid maturity and will often commence flowering slightly earlier than Parafield, but maturation date is similar. Yarrum has shown widespread adaption and high yield potential across a range of environments, but its best relative long-term advantage is in the medium to higher-rainfall southern regions, where its powdery mildew and PSbMV resistance may be beneficial. Seed is licensed to Australian Grain Technologies.

3.3.2 Kaspas-type grain (rounded dun)

Kaspas[®]

http://www.pulseaus.com.au/storage/app/media/crops/2011_VMP-dunfieldpea-Kaspas.pdf



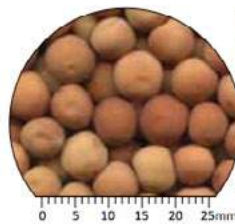
Kaspas[®]

Released: 2002
 Seed weight: 20–26 g/100
 Coat colour: pale brown
 Production region: South and West

Kaspas[®] is semi-leafless, late-flowering field pea that is resistant to shattering and has good early season vigour and moderate resistance to lodging. Kaspas[®] is susceptible to powdery mildew and blackspot and the Kaspas strain of downy mildew. The seed of Kaspas[®] is distinct from traditional dun types (e.g. Parafield) in that it is red-brown in colour and almost spherical in shape. Kaspas[®] is high yielding in many areas of southern Australia. However, it needs to be considered carefully before use as an option in low-rainfall areas or areas prone to early periods of high temperature and drought stress due to its late and condensed flowering period. Kaspas[®] should also be considered carefully in areas prone to frequent severe vegetative frosts due to potential for yield loss to bacterial blight. Kaspas[®] is under contract to Seednet.

PBA Gunyah[®]

http://www.seednet.com.au/documents/PBA_Gunyah_field_pea.pdf



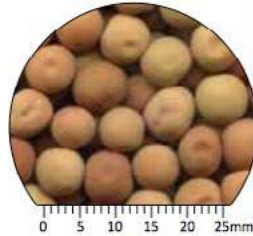
PBA Gunyah[®]

Released: 2010
 Seed weight: 20–26 g/100
 Coat colour: pale brown
 Production region: South and West

PBA Gunyah[®] is a Kaspas-type field pea with earlier and longer flowering than Kaspas[®] and higher yield in shorter-season environments and drier seasons (yield potential <2.25 t/ha) than this variety. It is early to mid-flowering and early maturing, making it more suitable to the practice of crop-topping than Kaspas[®]. It is well suited to delayed sowing for disease management. Its disease resistance profile is similar to Kaspas[®] and therefore not well suited to bacterial-blight-prone environments. Despite being susceptible to powdery mildew it is likely that PBA Gunyah[®] will incur less yield loss from this disease than Kaspas[®] due to its earlier maturity. PBA Gunyah[®] is licensed to Seednet.

PBA Twilight[®]

http://www.seednet.com.au/documents/PBA_Twilight_field_pea.pdf



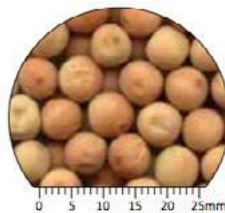
PBA Twilight[®]

Released: 2010
 Seed weight: 20–26 g/100
 Coat colour: pale brown
 Production region: South and West

PBA Twilight[®] is a Kaspas-type with similar attributes to PBA Gunyah[®]. It has a shorter flowering period and is earlier in maturity than PBA Gunyah[®] making it well suited to the low-rainfall and very short season field-pea growing environments. Widespread evaluation over a number of years shows that it is higher yielding than Kaspas[®] when yield potential is below 1.75 t/ha, and higher than PBA Gunyah[®] when yield potential is below 1.25 t/ha. Its disease resistance profile is similar to Kaspas[®] and therefore not well suited to bacterial-blight-prone environments. Despite being susceptible to powdery mildew it is likely that PBA Twilight[®] will incur less yield loss from this disease than Kaspas[®] due to its earlier maturity. PBA Twilight[®] is licensed to Seednet.

PBA Wharton[®]

<http://www.seednet.com.au/documents/PBAWhartonFactsheet.pdf>



PBA Wharton[®]

Released: 2013
 Seed weight: 20–26 g/100
 Coat colour: pale brown
 Production region: South, West and North

PBA Wharton[®] is a Kaspas-type dun pea offering improved powdery mildew and virus resistances (Bean leaf roll virus and Pea seed-borne mosaic virus). It provides the same agronomic benefits as Kaspas[®] (e.g. lodging and shattering resistance), and will provide a reliable alternative in those areas where powdery mildew and viruses are regular problems. PBA Wharton[®] is early to mid-flowering and early maturing, making it well suited to the practices of crop-topping and delayed sowing for blackspot management. It is particularly well suited to the Victorian Mallee where it is high-yielding long term. Seed is licensed to Seednet.

3.3.3 White types

White peas cannot be delivered to bulk export markets with dun peas. Some high-quality specialised white peas may fit into specific premium value markets for split peas. Higher prices may be achieved if supplying specific niche markets, but these markets may be small. Small-seeded white peas are likely to only suit domestic stockfeed markets. Growers are advised to secure markets before deciding to grow these pea types.

PBA Pearl[®]

<http://www.seednet.com.au/documents/PBAPearlFinal.pdf>



PBA Pearl[®]

Released: 2012
 Seed weight: 20–26 g/100
 Coat colour: white
 Production region: South, West and North

PBA Pearl[®] is a semi-leafless white pea variety, which is broadly adapted and has had high yields in evaluation trials in all districts. It has an erect growth habit, with excellent lodging resistance at maturity. It is early to mid-flowering and produces non-sugar-type pods but is not prone to shattering (similar to PBA Aura[®]). It has a favourable disease-resistance profile, with good resistance to Bean leaf roll virus and moderate susceptibility to bacterial blight. Seed is available through Seednet and growers are advised to secure markets before deciding to grow white peas as they cannot be delivered to bulk dun- or Kaspas-type export markets.

Sturt

http://www.pulseaus.com.au/storage/app/media/crops/2008_VMP-Wfieldpea-Sturt.pdf



Sturt

Released: 2006
 Seed weight: 17–24 g/100
 Coat colour: white
 Production region: South and North

Sturt is a conventional-leaf-type, small-seeded white pea similar to Parafield in height, lodging resistance and disease susceptibility. Flowering and maturity time of Sturt are similar but generally slightly earlier than Parafield. It consistently yields higher than all other varieties in trials affected by reproductive frosts, indicating some level of tolerance to this stress. Sturt is more sensitive than Kaspas[®] and Parafield to label rates of both post-sowing pre-emergent and post-emergent applications of metribuzin on alkaline soils in SA. Sturt is licensed to Premier Seeds.

PBA Hayman[®]

http://www.seednet.com.au/documents/PBA_Hayman_Factsheet.pdf



PBA Hayman[®]
 Released: 2013
 Seed weight: 12–18 g/100
 Coat colour: white
 Production region: South, West and North

PBA Hayman[®] is a late-flowering and late-maturing conventional pea suitable for forage production as a potential alternative to vetch. It has lower grain yield than Morgan[®] (which has been considered a dual-purpose variety) but has higher biomass production. Due to its low yields (20–80% of Kaska[®]) grain harvesting in dry seasons or low-rainfall districts can be difficult. Flowering and maturity of PBA Hayman[®] is much later than other field pea varieties and peak growth rates and biomass accumulation also occurs much later than other varieties. PBA Hayman[®] is rated R for powdery mildew, MR for bacterial blight (similar to PBA Percy[®]), and MR-R for the Parafield downy mildew strain (although its response against the Kaska downy mildew strain is unknown). It is more susceptible to blackspot than all varieties and this must be considered carefully before growing this variety. Seed is licensed to Seednet.

SW Celine

<http://www.nvtonline.com.au/wp-content/uploads/2013/03/Fact-Sheet-Field-Pea-SW-Celine-VMP.pdf>



SW Celine[®]
 Released: 2008
 Seed weight: 20–27 g/100
 Coat colour: white
 Production region: South and North

Bred in Sweden, SW Celine is a semi-leafless white pea of medium height with erect growth habit and white flowers. It has good early vigour and is early to commence flowering with a short to medium flowering duration with very early maturity making it suitable for crop-topping in most regions. SW Celine has good lodging resistance at harvest but does not have pod shatter resistance. It produces medium to large size creamy white grain that will be suitable to both human consumption and stockfeed markets. It has shown yield potential across a range of cropping zones in recent trials, but long-term comparisons are limited. SW Celine seed is commercially available from NuSeed.

3.3.4 Blue types (green cotyledons)

Some blue pea varieties are for specific premium value markets, which are usually only small. Quality is paramount in these markets used predominantly for canning and snack food. Important parameters include damage by insects, bleaching of seed coat and consistency of seed colour.

Two blue field pea varieties, Excell and Maki, are available to growers. Maki is best suited to the north-eastern field-pea growing areas of northern Australia, and limited testing has been done in southern Australia. Both varieties are outclassed by the newer dun and white pea releases in the southern region of Australia and they have a relatively poor disease resistance.

Excell

Excell is an early to mid-season flowering, semi-dwarf pea that produces medium-sized, spherical, smooth, blue seed suitable for premium human consumption markets. Excell has lower grain yield potential compared to new variety releases and is best suited to medium-rainfall environments of Victoria and southern NSW. Excell is moderately resistant to downy mildew (Parafield strain). Excell will need to be managed for blackspot, bacterial blight, PSbMV and powdery mildew in disease prone areas. Excell has good lodging resistance, although its pods are susceptible to shattering. Released in 1998, it can be freely marketed.^{11 12}

3.3.5 Forage peas

Two varieties (PBA HaymanA[®] and PBA CoogeeA[®]) have been released with suitability for foraging (hay/silage) or green/brown manuring. PBA Coogee[®] is considered a dual-purpose variety being suitable for grain (traditional dun type) and/or forage.

The southern pulse agronomy program has been assessing the biomass accumulation and grain yields in comparison with current standards, KaspA[®] (the predominant grain yield variety in south-eastern Australia) and Morgan[®] (a dual-purpose field pea variety). Results to date show:

- The ideal timing of hay cutting for both maximum biomass production and ease of drying (i.e. before podset) is likely to be approximately 4–7 days after commencement of flowering (i.e. early pod development).
- Varieties with later flowering and podset (e.g. PBA Hayman[®]) are likely to be better suited to hay production as this allows maximum vegetative growth prior to cutting, and extends hay cut timing into better (warmer and quicker) drying conditions.
- PBA Coogee[®] may not produce more biomass than KaspA[®] or Morgan[®] at the early pod stage.
- PBA Hayman[®] will generally produce more biomass at flowering than grain or dual-purpose varieties (due to its later flowering). This variety shows more rapid growth in early spring than other varieties.
- KaspA[®] and PBA Coogee[®] produce significantly higher grain yield than Morgan[®] or PBA Hayman[®].
- PBA Hayman[®] has shown the lowest yield and lowest harvest index, indicating that grain retrieval may be difficult in low-rainfall areas. However, due to its lower seed weight (averaging 14 grams/100 seeds compared with 20–25 g/100 seeds in other varieties); seed requirements for sowing will be significantly lower than for other varieties.¹³

¹¹ M Lines, L McMurray, P Kennedy (2015) Pea variety sowing guide 2015, South Australian Research Development Institute, http://www.pir.sa.gov.au/_data/assets/pdf_file/0010/237907/peas.pdf

¹² J Couchman, K Hollaway (2016) NVT Victorian Winter Crop Summary 2016. Department of Economic Development, Jobs, Transport and Resources, www.grdc.com.au/NVT-Victorian-Winter-Crop-Summary

¹³ J Brand, M Rodda, P Kennedy, M Lines, L McMurray, J Paull, K Hobson (2014). Pulse varieties and agronomy update (Ballarat). GRDC Update papers, 5 Feb 2014, <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2014/02/pulse-varieties-and-agronomy-update-ballarat>



Photo 1: Field pea cut for hay.

Photo: W Hawthorne, formerly Pulse Australia

3.3.6 Varieties subject to End Point Royalties (EPR) and seed distribution

Table 6: Field pea varieties subject to End Point Royalties (EPR) and seed distribution arrangements.

Registered name	Variety owner	Royalty manager charged with EPR collection	EPR rate \$/tonne (GST exclusive)	Seed distribution arrangements 2016	Grower sales permitted
Bundi	DPI (Vic)	Premier Seeds	\$5.00	Premier Seeds	No
PBA Coogee [Ⓛ]	DPI (Vic)	SeedNet	\$2.60	SeedNet	No
PBA Gunyah [Ⓛ]	DPI (Vic)	SeedNet	\$2.50	SeedNet	No
Helena	DPIRD	DPIRD	\$1.20	-	Yes
Kaspa [Ⓛ]	DPI (Vic)	SeedNet	\$2.00	SeedNet	No
Maki (AP18)	Plant Research NZ	Waratah Seeds	\$4.00	Waratah Seeds	No
PBA Oura [Ⓛ]	DPI (Vic)	SeedNet	\$2.60	SeedNet	No
PBA Pearl [Ⓛ]	DPI (Vic)	SeedNet	\$2.70	SeedNet	No
PBA Percy [Ⓛ]	DPI (Vic)	SeedNet	\$2.60	SeedNet	No
SW Celine	SW Seeds	NuSeed	\$3.00	NuSeed	No
PBA Twilight [Ⓛ]	DPI (Vic)	SeedNet	\$2.50	SeedNet	No
PBA Wharton [Ⓛ]	DPI (Vic)	SeedNet	\$2.60	SeedNet	No

Source: <http://varietycentral.com.au/varieties-and-rates/201617-harvest/pulse/>

3.4 Planting seed quality

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

If grower-retained seed is of low quality, then consider purchasing registered or certified seed from a commercial supplier. Always ask for a copy of the germination report, regardless of the source, and treat seed with a thiram-based fungicide.

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 through correct plant density and good seedling vigour is important to maximise yields of pulse crops. A targeted density can only be achieved by having quality seed with good vigour and a known germination percentage to accurately calculate seeding rates. A slight variation in seed size due to seasonal conditions or an incorrect germination percentage can make a significant difference in the final plant density.

Many seed buyers are unaware that the minimum germination requirement for certified pulse seed is 70%, compared to 80% in cereal grains and far less than 90% or greater which is often obtained in pulse seed. Test results must be made available under the Seeds Act, and Australian Seeds Federation guidelines, so ensure you receive a copy.

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

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

The fragile nature of pulse seed, particularly field pea, lentil, 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 header drum speed and opening the concave, or by reducing auger speed and lowering the flight angle and fall of grain. Rotary harvesters and belt conveyers are ideally suited to pulse grain and 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. Those that do emerge are unlikely to survive for long or produce less biomass and make little or no contribution to final yield.¹⁴

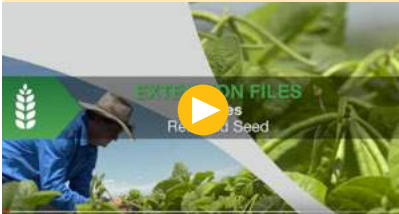
14 W Hawthorne, W Bedgood (2007) Field peas in South Australia and Victoria. Pulse Australia Fact sheet

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Watch GCTV16: Extension Files – Retained Pulse Seed
https://youtu.be/5lq9T6_f6Tg



MORE INFORMATION

Retaining Seed Fact Sheet: Saving weather damaged grain for seed (northern/southern regions)
http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC_FS_RetainingSeed2.pdf

3.4.1 Grower-retained planting seed

Grower-retained sowing seed should be harvested from the best part of the crop where weeds and diseases are negligible, the crop has been vigorous and healthy, matured evenly and has good grain size. Seed from this area should be harvested first, ideally at between 11% and 12% moisture to avoid low-moisture grain that is susceptible to cracking.

Seed should be professionally graded to remove unviable seeds and weed seeds.

Seed-borne diseases have the potential to lower germination levels. Specialist laboratories can test for seed-borne diseases, such as bacterial blight in field pea.

Seed with a poor germination potential or high levels of seed-borne disease should not be sown. Cheaper costs of this seed will be offset by higher sowing rates needed to make up for the lower germination and there is potential to introduce further disease on to the property.

Do not use grain for seed of pulse crops harvested from a paddock that was desiccated with glyphosate. Glyphosate will reduce the germination, normal seedling count and vigour of the seed.

The only way to accurately know the seed's germination rate, vigour and disease level is to have it tested.¹⁵

3.4.2 Seed size

As for most pulses, seed size varies between varieties and for different batches of a variety. To obtain the targeted plant density it is necessary to have high-quality seed and to know the seed weight and germination percentage. Do a seed count on each batch of seed for sowing to determine the weight in grams of 100 seeds.

The large size of pulse seeds makes them vulnerable to mechanical damage by the header at harvest and during subsequent handling.

A seed that has been damaged will produce an abnormal seedling: the shoot, the root, or both may be damaged.

The best time to sample is at or just after seed cleaning. This minimises the number of times the seed is likely to be augered or handled after the test is done. It also provides an ideal way to get a good representative sample. However, if you think a seed lot is likely to have reduced germination, testing should be done before seed cleaning. This minimises expenses and provides time to obtain replacement seed.¹⁶

¹⁵ W Hawthorne, W Bedgood (2007) Field peas in South Australia and Victoria. Pulse Australia Fact sheet

¹⁶ P Matthews, D Holding (2005) Pulse Point 20: Germination testing and seed rate calculation. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/157442/pulse-point-20.pdf

3.5 Seed testing

3.5.1 Germination

Ideally, only pulse seeds with more than 80% germination should be used and testing for germination and vigour should be done by an accredited laboratory.

A laboratory seed test for germination should be done before seeding to calculate seeding rates. However, a simple preliminary on-farm test can be done in soil after harvest or during storage. Results from a laboratory germination and vigour test should be used in seeding rate calculations (Figure 2).

$$\begin{array}{c}
 \text{Seed rate} \\
 \text{(kg/ha)}
 \end{array}
 = \frac{
 \begin{array}{c}
 \text{Target plant} \\
 \text{density} \\
 \text{(pl/m}^2\text{)}
 \end{array}
 \times
 \begin{array}{c}
 \text{100 seed} \\
 \text{weight} \\
 \text{(grams)}
 \end{array}
 \times 1000
 }{
 \begin{array}{c}
 \text{Germination} \\
 \text{percentage}
 \end{array}
 \times
 \begin{array}{c}
 \text{Establishment} \\
 \text{percentage}
 \end{array}
 }$$

Figure 2: Seeding rate calculation.¹⁷

Source: GRDC (2011) Retaining seed: saving weather-damaged grain for seed, GRDC Fact Sheet January 2011, www.grdc.com.au/GRDC-FS-RetainingSeed

Example seeding rate

$$\frac{45 \text{ plants/m}^2 \times 23\text{g} \times 1000}{90\% \times 90\%} = 128 \text{ kg/ha}$$

Field pea differs from other pulse crops when carrying out a home seed-germination test. When attempting to do your own field pea seed germination test it is recommended to soak the peas overnight. Use a shallow seeding tray about 5 cm deep. Place three to four pieces of paper towelling or newspaper in the base to cover drainage holes. Use clean sand, potting mix or a freely draining soil. Testing must be at a temperature of <20°C, so testing indoors may be required. Randomly count out 100 seeds per test, but do not discard any damaged seeds.

If the tray has been filled with soil, sow 10 rows of 10 seeds in a grid at the correct seeding depth. Do this by placing the seed on the levelled soil surface and gently pushing each in with a pencil marked to the required depth. Cover seed holes with a little more soil and water gently ([Photo 2](#)).

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

During the test, keep the soil moist, but not wet. Overwatering will result in fungal growth and possible rotting. After 7–14 days, the majority of viable seeds will have emerged. Count only normal, healthy seedlings. The number of normal and vigorous seedlings you count will be the germination percentage.

This germination test is also a vigour testing because it is done in soil. To further establish vigour under more adverse conditions, a second germination test can be done under colder or wetter conditions and used as a comparison with the normal germination test, done at the same time.¹⁸

¹⁷ GRDC (2011) Retaining seed: saving weather-damaged grain for seed, GRDC Retaining Seed Fact Sheet January 2011, www.grdc.com.au/GRDC-FS-RetainingSeed

¹⁸ GRDC (2011) Retaining seed: saving weather-damaged grain for seed, GRDC Retaining Seed Fact Sheet January 2011, www.grdc.com.au/GRDC-FS-RetainingSeed



Photo 2: Conducting a germination test at home.

Photo: Emma Leonard

3.5.2 Seed testing for disease

Many important diseases of pulses can be seed-borne. Pulse growers can minimise losses from these diseases by using high-quality seed. Seed testing is required to establish whether seed is infected. Seed health tests are currently available to detect the most important seed-borne pathogens of pulses. Only seed that is pathogen-free should be used for sowing. Testing seed before sowing will identify potential disease problems and allow steps to be taken to reduce the disease risk. Laboratory testing is usually required, as infected seed may have no visible disease symptoms.¹⁹



Photo 3: Field pea seed infected with Pea seed-borne mosaic virus.

Photo: J Davidson, SARDI

Seed-borne diseases such as Cucumber mosaic virus in field pea, lupin and lentil, along with black spot in field pea, pose a serious threat to yields. Seed-borne diseases can strike early in the growth of the crop when seedlings are most vulnerable and result in severe plant losses and hence lower yields.

When infected seed is sown, it gives rise to infected seedlings that act as a source of infection, often developing into hot spots of disease. Plants infected early often die or produce no seed. However, when late infection occurs, the seed becomes infected.

Growers who have retained seed on-farm for a number of years should test their seed for disease pathogens.

¹⁹ Agriculture Victoria (2013) Seed health testing in pulse crops. Agriculture Victoria, AG1250, June 2013, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops>

Testing seed before sowing will identify the presence of disease and allow steps to be taken to reduce the disease risk. If disease is detected, the seed may be treated with a fungicide before sowing or a clean seed source may be used.²⁰

For more information and a list of testing services see Seed Health Testing in Pulse Crops. (<http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops>)

3.5.3 Seed grading

While excessive handling of pulse seed is not recommended, grading of seed should be considered. Grading removes small, damaged seeds from the seed lot. These seeds often produce poor seedlings, which die from pathogen attack first. The largest seed is selected, producing healthy vigorous seedlings and ensuring optimum establishment. Grading also removes scleroties (fruiting bodies of the fungus which causes Sclerotinia), which would otherwise be sown with the seed.²¹

3.5.4 Safe storage of seed

Storing pulses successfully requires a balance between ideal harvest and storage conditions. Harvesting at 14% moisture content is ideal for grain quality and reduces mechanical damage to the seed but needs to be lower (12.5%) to avoid deterioration during storage.

Tips for storing pulses:

- Pulses stored at >12% moisture content require aeration cooling to maintain quality.
- Meticulous hygiene and aeration cooling are the first lines of defence against pest incursion.
- Fumigation is the only option available to control pests in stored pulses, and requires a gas-tight, sealable storage.
- Avoiding mechanical damage to pulse seeds will maintain market quality and seed viability, and be less attractive to insect pests.²²

Retained seed needs to be stored correctly to ensure its quality is maintained. Ideal storage conditions for pulses are at around 20°C and at a maximum of 12.5% moisture content.

Like other grain, field pea 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.

Reducing moisture and temperature increases longevity of the seed, although storage at very low moisture contents (<10%) may render field pea more vulnerable to mechanical damage during subsequent handling.

Reducing temperature in storage facilities is the easiest method of increasing seed longevity. Not only will it increase the viable lifespan of the seed, but it will slow down the rate that insect pests multiply in the grain.

VIDEO

Watch: Over the Fence: Insure seed viability with aerated storage
<https://youtu.be/8HFilsCnka0>



20 K Lindbeck (1999) Pulse Point 7: Reducing disease risk. NSW Agriculture, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/157144/pulse-point-07.pdf

21 K Lindbeck (1999) Pulse Point 7: Reducing disease risk. NSW Agriculture, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/157144/pulse-point-07.pdf

22 P Burrill, P Botta, C Newman, C Warrick (2014) Storing Pulses. GRDC Fact Sheet, July 2014, www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

To reduce the temperature in grain silos:

- Paint the outside of the silo with white paint. This reduces storage temperature by as much as 5°C and can double safe storage life of grains.
- Aerate silos with dry, ambient air. This option is more expensive, but in addition to reducing storage temperatures, is also effective in reducing moisture of seed harvested at high moisture content.
- Heat drying of field pea seed for sowing should be limited to temperatures $\leq 40^{\circ}\text{C}$.²³

3.6 Safe rates of fertiliser sown with the seed

All pulses can be affected by fertiliser toxicity. Higher rates of phosphorus (P) fertiliser can be toxic to pulse establishment and nodulation if drilled in direct contact with the seed at sowing.

Practices involving drilling 10 kg/ha of P with the seed at 18-cm row spacing through 10-cm points have rarely caused any problems. However, with the changes in sowing techniques to narrow sowing points, minimal soil disturbance, wider row spacing, and increased rates of fertiliser (all of which concentrate the fertiliser near the seed in the seeding furrow), the risk of toxicity is higher. Agronomists, however, can present anecdotal reports where toxicity has not been a problem.

Toxicity 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 nitrogen (N), e.g. DAP, banded with the seed when sowing pulse crops has the potential to reduce establishment and nodulation if higher rates are used. On sands, 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.

Deep banding of fertiliser is often preferred for lupin and other pulses, or else broadcasting and incorporating, drilling pre-seeding or splitting fertiliser applications so that lower rates of P or no P is in contact with the seed.

MORE INFORMATION

For more information, see [Section 12 Storage](#).

23 W Hawthorne, W Bedgood (2007) Field peas in South Australia and Victoria. Pulse Australia Fact sheet

Planting

Key points

- Ensure field pea is grown within the recommended window for your district. Time of sowing is a compromise between avoiding increased disease and frost risk from early sowing, and yield loss from late sowing due to high temperatures and/or dry conditions at flowering and pod-fill.
- Field pea is well suited to no-till, stubble-retention systems. Sow at the correct depth (3–5 cm) and avoid stubble clumping.
- Sowing can be dry; if weeds such as medics are not an issue and nodulation is assured. Be aware of blackspot risk with early sowing before seasonal opening rainfall.
- Sowing rate should be based on target plant density and will vary with seed size.
- Level paddocks are preferable, to make harvest manageable.
- Use Group E inoculant if there is likely to be a response to inoculation, such as in soils with pH (CaCl₂) less than 6, or if field pea hasn't been grown previously.

MORE INFORMATION

For more information: Field pea:
Western NSW Planting Guide,
<https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/field-peas/field-peaf>

MORE INFORMATION

For more information: Brown manure legumes lower total crop risk,
<https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-116-May-June-2015/Brown-manure-legumes-lower-total-crop-risk>

Field pea is a hardy winter pulse that can provide economic gross margins for grain growers and flow-on benefits to the following cereal crop. Most field pea is grown for grain; however, some varieties are also increasingly being used for green/brown manure, forage or hay.

Hay, silage, forage, green and brown manure

Field pea can be made into good quality hay, which provides another market and weed control option. The crop can also be made into silage or ploughed in as green manure. Green manuring is the least profitable option and provides no significant yield benefit over hay or silage making to a following cereal crop. Profitability of hay or silage making will depend on accessing a secure market for the product.

Hay making is a valuable tool to prevent weed seedset in problem weeds, it can also be used to salvage a financial return from diseased, frosted or drought-affected crops. Cutting for hay effectively extends the fallow period and therefore can increase fallow moisture for subsequent cereal crops.

All pea varieties will make good quality hay, but varieties with rapid early growth and high dry matter production are best. To maximise dry matter, field pea should be sown in the early part of the sowing window.¹ However, sowing too early can result in blackspot becoming a major limitation to forage yield and quality.

A crop production system involving a brown manure legume such as field pea can be as profitable as continuous cropping or slightly less profitable, with lower production and financial risk due to lower operating costs.

Brown manure cropping involves growing a grain legume crop with minimal fertiliser and herbicide inputs to achieve maximum dry-matter production before the major weed species have set viable seed.

The grain legume crop is sprayed with a knockdown herbicide before seedset to kill the crop and weeds, ideally no later than the start of the crop's pod development to also conserve soil moisture.

A second knockdown herbicide is generally applied to achieve a 'double knock'. This is different to green manure where the crop and weeds are cultivated.

While vetch is a common brown-manure crop, early-sown field pea may be more competitive against weeds and potentially produce more dry matter. Higher dry-matter production should lead to higher nitrogen accumulation, and more stubble cover provides shading to reduce evaporation and reduce sunlight available to germinate weeds.

Brown manure legume crops provide three major benefits over long fallows:

- competition for weeds (reducing knockdown herbicide use during the growing season);
- accumulation of soil nitrogen; and
- the maintenance of groundcover during the growing season and over the summer preceding the next crop.

The major disadvantage of brown manure pulse crops compared with long fallowing is the cost of the grain legume seed (\$30 to \$35 per hectare).²

¹ L Jenkins, P Matthew, B Haskins, K Hertel, G Brooke, E Armstrong, D McCaffery, G Lane (2005) Field pea: Western NSW Planting Guide, NSW Department of Primary Industries, <https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/field-peas/field-pea>

² R Patterson (2015) Brown manure legumes lower total crop risk, Ground Cover™, May-June 2015, GRDC, <https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-116-May-June-2015/Brown-manure-legumes-lower-total-crop-risk>

4.1 Planting overview

Field pea can be sown with machinery used for cereals. It is well suited to no-till, reduced-tillage and stubble-retention systems. Sow at the correct depth (3–5 cm) to ensure seed-to-soil contact for good emergence and improved safety to post-sow pre-emergent herbicides. Field peas sown between rows of standing cereal stubble are protected from wind erosion.

Field peas can be successfully dry sown if;

- problem weeds such as medic are not an issue;
- a level seed surface can be achieved before herbicide application; and
- nodulation is assured.

Sow into a friable soil ensuring good seed-to-soil contact. Retain adequate plant residue on the surface to protect the soil from erosion during growth and after harvest, and to reduce soil water evaporation in early growth stages. Retained cereal stubble does not affect field pea germination or growth, and can improve establishment on hard-setting, surface-crusting soils. The previous year's stubble can also offer an anchor for pea tendrils to grip, resulting in better standability at harvest. Stubble clumps however, can cause seed placement and harvesting difficulties. A flat surface assists harvest by ensuring clods or stones do not enter the harvester.

Sufficient moisture and a level soil surface must be present at application of some soil-active broadleaf herbicides for them to be fully effective and to avoid crop damage.³ A ridged soil surface can cause problems if heavy rain falls between sowing and germination or after post-sowing herbicide application. The rain can wash the herbicide into the furrow and leave a concentrated band of chemical on top of the germinating seed, which can result in crop damage.

4.2 Time of sowing

Time of sowing is a compromise between:

- avoiding increased disease and frost risk from early sowing; and
- yield loss from late sowing due to high temperatures and/or dry conditions at flowering and pod-fill.

Sow at the later end of the recommended optimum for districts where disease and frost risks are high. Field pea can be sown dry, however consider:

- Blackspot risks
 - » Early sowing increases exposure to blackspot spores over a longer period. Delay sowing 4 weeks later than the first rain. Early sowing may be possible if significant summer–autumn rains have fallen to release black spores from stubble. See [Section 9 Diseases](#), [Section 9.13 Ascochyta blight \(AB\)](#) and [Section 9.13.4 Management options](#).
 - » Early sowing results in more vegetative growth and in longer-growing-season areas increased lodging can lead to increased risk of leaf disease.⁴
- Frost risks – choose later-flowering pea varieties (mid-spring) to avoid frost risk (e.g. Kasper[®]). Semi-leafless varieties PBA Twilight[®] and PBA Gunyah[®] have been bred for shorter season climates or later sowings. They are more prone to frost if sown early. Semi-leafless types like Kasper[®] and PBA Gunyah[®] have lodging resistance and reduced pod shattering.⁵

3 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

4 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

5 A Leonforte (2013) A study of salinity tolerance in field pea. University of Melbourne Australia, https://minerva-access.unimelb.edu.au/bitstream/handle/11343/38605/307726_PHD%20Thesis%20Antonio%20Leonforte.pdf?sequence=1

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Table 1: Optimum sowing times for southern Australia.⁶

Region (annual rainfall)	Month	May				June				July				
		Week	1	2	3	4	1	2	3	4	1	2	3	4
Less than 350 mm – northern agricultural region – WA														
Less than 350 mm – central and southern agricultural areas – WA														
Greater than 350 mm – WA														
Less than 400 mm – SA/Vic														
400 – 450 mm – SA/Vic														
450 – 500 mm – SA/Vic														
500 – 600 mm* – SA/Vic														
Less than 450 mm – southern NSW														
450 – 550 mm – southern NSW														
500 – 650 mm* – southern NSW														

■ Marginal area or low disease risk areas
 ■ Preferred planting time
 ■ For high disease risk areas

NOTE: Use Blackspot Manager to determine Blackspot risk with particular sowing dates each year. Sow later if Blackspot is a threat following a late break, or if frost is a risk.
 * Preferred sowing time for spring-sown lentils is August-September

Source: GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

There are now a wider range of field pea varieties available, with differing maturities and some with better disease resistance and shatter-resistant pods. Growers should consider their preferred sowing window to minimise the risk of disease and frost, and select a variety that has a maturity to match. Any variety intended as a brown or green manure crop, or for hay, should be sown as early as possible within the recommended sowing window, to maximise dry matter production.⁷ (See [Table 2](#))

Trials conducted at Westmere in 2011 and 2012 investigated the adaptability of a range of field pea varieties to varying sowing dates, crop-topping and disease control. (See [Section 10.2.1 Field trial](#).)

4.3 Sowing rate and plant density

Sowing rate depends on seed size, likely emergence and plant density required. Target densities tend to be lower with early sowing and higher if later sowing or on hard-setting soils when germination can be less due to emergence problems.

In most rainfall areas, varieties that are short to medium in height with lower vigour are very responsive to higher seeding rates, due to their lower biomass and the need for tendrils to intertwine to keep the crop upright in semi-leafless varieties.

The vigorous tall and medium types respond well to lower seeding rates and plant densities

4.3.1 Calculating seed rates

Field pea establishment targets can only be achieved by accounting for seed size, germination and sowing conditions when calculating sowing rates. Also, consider the seedbed condition and adjust accordingly. Use [Table 3](#) to calculate the desired sowing rate based on target density, seed size, germination and potential establishment percentage of your seed.

⁶ GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

⁷ P Matthew, D McCaffery, L Jenkins (2017) Winter crop variety sowing guide 2017, NSW DPI Management Guide. NSW Government Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide>

SECTION 4 FIELD PEA

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Table 2: Field pea variety time of sowing guide.

	April	May	June	July
Mallee				
PBA Coogee ^o , PBA Hayman ^o	>	>	X	<
Kaspa ^o , Parafield, PBA Gunyah ^o , PBA Oura ^o , PBA Percy ^o , PBA Twilight ^o , PBA Wharton ^o , Sturt	>	>	X	<
Wimmera				
PBA Hayman ^o		>	X	<
Kaspa ^o , Parafield, PBA Coogee ^o , PBA Gunyah ^o , PBA Oura ^o , PBA Percy ^o , PBA Twilight ^o , PBA Wharton ^o , Sturt		>	X	<
North Central				
PBA Coogee ^o , PBA Hayman ^o	>	X	X	<
Kaspa ^o , Parafield, PBA Gunyah ^o , PBA Oura ^o , PBA Percy ^o , PBA Twilight ^o , Sturt	>	X	X	<
North east				
PBA Hayman ^o	>	X	X	<
Kaspa ^o , Parafield, PBA Coogee ^o , PBA Gunyah ^o , PBA Oura ^o , PBA Percy ^o , PBA Twilight ^o , PBA Wharton ^o , Sturt	>	X	X	<
South west				
Kaspa ^o , PBA Coogee ^o , PBA Gunyah ^o , PBA Hayman ^o , PBA Oura ^o , PBA Percy ^o , PBA Twilight ^o , PBA Wharton ^o	*	X	X	*
South west (spring sowing)				
Above varieties for spring sowing	*	*	X	<

> = earlier than ideal, X = optimum sowing time, < = later than ideal but acceptable * If conditions allow (e.g. raised beds, dry season, non-waterlogging paddocks).

Source: Victoria winter crop summary 2017, <https://grdc.com.au/resources-and-publications/all-publications/publications/2017/03/mvt-victoria-winter-crop-summary>

Table 3: Suggested plant density and seeding rate for field pea varieties.⁸

Field pea type	Variety	Average 100 seed weight (g)	Target plant density/m ²			
			30	40	50	60
Tall scrambling	PBA Hayman [Ⓛ]	13	–	65	81	–
	Morgan	18	68	90	–	–
	Sturt	19	71	95	–	–
	PBA Coogee [Ⓛ]	20	–	100	125	–
	Parafield, PBA Percy [Ⓛ]	23	86	115	–	–
Medium–tall semi leafless	Excell, Maki, PBA Pearl [Ⓛ] , PBA Oura [Ⓛ] , SW Celine [Ⓛ] , Yarrum	22	–	110	138	165
Kaspa types	Kaspa [Ⓛ] , PBA Gunyah [Ⓛ] , PBA Twilight [Ⓛ] , PBA Wharton [Ⓛ]	22	–	110	138	–

Source: P Matthew, D McCaffery, L Jenkins (2017) Winter crop variety sowing guide 2017, NSW DPI Management Guide. NSW Government Department of Primary Industries, <https://www.dpi.nsw.gov.au/about-us/media-centre/releases/2017/2017-winter-crop-variety-sowing-guide-now-available>

Seedling rate for the target plant density can be calculated using germination percentage, 100 seed weight and establishment percentage.

Seedling rate (kg/ha) =

$$\frac{100 \text{ seed weight (grams)} \# \times \text{target plant population (per m}^2\text{)} \times 1000}{\text{Germination \%} \times \text{Estimated Establishment \%}}$$

*Establishment percentage: 90–95% is a reasonable estimate, unless sowing into adverse conditions.

To determine your seed weight, weigh 100 seeds in grams.

Example

100-seed weight = 23 grams

Target plant density = 40 plants/m² (i.e. 400,000 plants/ha)

Germination % = 90%

Estimated establishment % = 95%

Seeding rate (kg/ha) = $\frac{23 \times 40 \times 1000}{90 \times 95}$

90 x 95

= 108 kg/ha

If you have seeds per kilogram from a laboratory test, this can be easily converted to 100 seed weight as follows:

100 seed weight = $\frac{1000 \times 100}{\text{seeds per kg}}$

seeds per kg

Note: Optimum plant populations vary with the location grown, the variety sown and the pulse crop being sown.

⁸ P Matthew, D McCaffery, L Jenkins (2017) Winter crop variety sowing guide 2017, NSW DPI Management Guide. NSW Government Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide>

4.4 Sowing depth

Sow at a depth of between 3 and 5 cm. Adjust sowing depth based on the soil type and texture, and take into account depth of soil covering seed.

On friable clays, loams and lighter soils, sow deeper (>5 cm), but on hard-setting soils sow shallower (near 3 cm) to ensure establishment. On some well-structured, lighter soils it may be possible to sow deeper than normal if seeking subsoil moisture to maximise germination.⁹ Do not sow dry or moisture-seek field pea at depth if uneven moisture is present, as crops will germinate unevenly, causing management difficulties such as herbicide timing. Crops sown later in the sowing window (e.g. due to a delay in sowing rainfall) should be sown shallower to improve germination under cold conditions.¹⁰

Rolling or harrowing after sowing or wind erosion can lead to an increased depth for seedlings to emerge.

Post-sowing herbicides can wash into seed rows from ridges if left unflattened after seeding.

4.4.1 Stubble retention

Field pea fit well into stubble-retention systems with no tillage, using the stubble as a supportive trellis (Photos 1 and 2).



Photo 1: Trial demonstrating different heights of retained stubble to aid field pea growth and standability.

Photo: Felicity Pritchard

⁹ GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

¹⁰ P Matthew, D McCaffery, L Jenkins (2017) Winter crop variety sowing guide 2017, NSW DPI Management Guide. NSW Government Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide>

VIDEO

Watch: Stubble Management
<https://youtu.be/hjJ5HtyLluU>

Watch GCTV15: Stubble height Pt. 1
<https://youtu.be/XDTSbGcZxpM>

and Stubble height Pt. 2
<https://youtu.be/SqJCa7vm1CO>

Watch GCTV4: Burning for stubble retention.
<https://youtu.be/BJJvMhYDv5c>

Watch: Southern farm groups cutting through stubble issues.
<https://youtu.be/pyC91wE-DBI>

MORE INFORMATION

For more information, see: Profitable stubble retention systems for the high-rainfall zone,
<https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/profitable-stubble-retention-systems-for-the-high-rainfall-zone>

MORE INFORMATION

For more information, see Wide row pulses and stubble retention, Pulse Australia,
<http://www.pulseaus.com.au/growing-pulses/publications/wide-rows-and-stubble-retention>



Photo 2: Trial demonstrating the difference between high (40 cm) stubble and low stubble (0 cm) on field pea height and standability.

Photo: Felicity Pritchard

Retention of adequate plant residues on the surface is important to protect the soil from erosion both during growth and after harvest. This will not affect pulse germination and growth, and can improve establishment on hard-setting, surface-crusting soils. Sowing into cereal stubble reduces soil moisture losses from evaporation.¹¹

4.5 Row spacing

Row spacing can be varied (15–45 cm), but the wider rows are only used if sowing into standing cereal stubble to minimise lodging at harvest and for intra-row herbicide application with shielded sprayers. Medium to wide row spacing (25–36cm) suits trash clearance and intra-row weed control, and allows more air movement between rows to reduce blackspot disease risk. Row spacing greater than 45 cm is not a practical option for field pea in the southern region.

The height to bottom pods is often increased with increased row spacing or with higher seeding rates. Weed control can be more difficult with wider row spacing unless shielded sprayers are used.¹²

4.5.1 Wide row and stubble retention

Growers use wider seeding rows in pulses (and oilseeds) for a range of different reasons, largely driven by combinations of seeking consistency or stability of yield, disease control, fit in their system and general practicalities. However, row spacing should never be looked at in isolation, as it is only part of an overall system. Having stubble cover, preferably standing stubble, is an important component of a wider row system. For some growers the motivation to sow pulses in wider rows is to achieve better drought tolerance. Others are using it as a means to sow early, minimise foliar disease risk and achieve better early podset. Achieving better stubble flow during seeding, or better weed control through less soil disturbance, are also key drivers for many.

Wider rows are untested commercially for field pea.¹³

¹¹ Pulse Australia, Chickpea Production: Southern and Western region, <http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide>

¹² GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

¹³ Pulse Australia (2016) Wide row pulses and stubble retention. Pulse Australia website, <http://www.pulseaus.com.au/growing-pulses/publications/wide-rows-and-stubble-retention>

i MORE INFORMATION

For more information see Row placement strategies in break crop wheat sequence, GRDC Grains Research Updates, <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2013/02/row-placement-strategies-in-a-break-crop-wheat-sequence>

4.5.2 Row placement for field pea as a break crop

Following a cereal crop, the break crop (pulse or oilseed) should be sown between the standing stubble rows. In the following year, the cereal crop should be sown directly over the previous season’s break-crop row. Then in the next year of the rotation the break crop should shift back and be sown between the standing wheat rows. Finally, in the fifth year, the wheat crop again should be sown directly over the previous year’s break-crop row.

There are two simple rules that need to be followed:

1. Sow break crops between standing wheat rows, which need to be kept intact.
2. Sow the following wheat crop directly over the row of the previous year’s break crop.

By following these two rules it ensures the following:

- 4 years occur between wheat crops being sown in the same row space;
- a substantial reduction in the incidence of crown rot in wheat crops;
- improved germination of break crops, especially canola, not hindered by stubble;
- reduction in impact of viral infections in chickpeas from standing stubble; and
- improved protection for break-crop seedlings from standing wheat stubble.¹⁴

4.6 Sowing equipment

To be successful with pulses, seeders need to be equipped to cope with the larger-sized seed. If your seeder is not suitable, there are several options available.

The machine may be adapted by minor modifications such as:

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

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 required.¹⁵

4.6.1 Rolling

Leaving a flat, firm soil surface free of sticks, stones and clumps is essential when growing most pulse crops. With field pea, rolling is helpful for herbicide application and to enable a flat soil surface at harvest. Rolling field pea is beneficial after sowing to aid harvestability where height to bottom pods is often low, particularly in lower-rainfall areas or late-sown crops. Rolling leaving a flat surface prevents post-sowing herbicide wash accumulating in furrows. Rolling also improves seed-soil contact in sandy non-wetting soils, although press-wheels normally achieve this.¹⁶

Rolling is often post-sowing pre-emergence. A rubber-tyre roller is best used when the soil is moist but not too wet or dry. Rolling post-emergence is not recommended in areas where bacterial blight disease is a risk. (See [Section 9.14 Bacterial blight of field pea](#)) If rolling is post-emergence, it is best done at the 3–5 node stage under warm conditions when plants are limp and well established. Avoid rolling when plants are just emerging as the young shoots can be damaged. Choose an afternoon on a warmer day to minimise crop damage.

¹⁴ A Verrell (2013) Row placement strategies in a break crop wheat sequence. GRDC Update Papers, 26 Feb 2013, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Row-placement-strategies-in-a-break-crop-wheat-sequence>

¹⁵ J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

¹⁶ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training

Avoid rolling 2 weeks before or after applying a post-emergent herbicide. Delay rolling until the crop has emerged if the soil is prone to hard-setting or crusting, or sandy or sloping ground prone to erosion.¹⁷



Photo 3: Field pea need to be rolled to minimise dirt and stones entering the harvest sample.

Photo: W. Hawthorne, formerly Pulse Australia

4.7 Dry sowing

Dry sowing is a means of getting crops sown on time in seasons with a delayed break. It allows:

- optimisation of all crop yields by sowing each one on time;
- sowing of more crop on time without the cost of increasing machinery size;
- the spread of labour requirements and operations;
- better handling of more trash while stubble is dry; and
- improved crop establishment under warm soil conditions.

A big risk of failure when dry sowing pulse crops is the survival of rhizobia and subsequent reduced nodulation. With field pea, a big risk with dry sowing is increased blackspot incidence if there have been no preceding rains to allow spore release (See [Section 9.13.4 Management options](#)).

The ability to control broadleaf weeds is another key factor to consider when dry sowing, as weeds may germinate with the pulse seed.

Paddock selection criteria apply for each pulse species. Consider soil pH, soil drainage and weed burden. The best results from dry sowing occur on freely draining, well-structured soils, but dry sowing has also been successful on other soil types. Avoid hard-setting or crusting soils and avoid sowing in front of a large rainfall event that may result in waterlogging of the crop and affect subsequent germination.

Major changes to seeding machinery for dry sowing are not required. You will need enough tyne break out pressure to penetrate the soil and maintain even seeding depth. Narrow seeding points with tungsten tips give better results and trash flow is often better when stubble is dry.

¹⁷ GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

Ensure that the sowing boot is set up so the seed is dropped at the desired depth, but with some loose soil beneath it. Press-wheels or culti-packers are the better covering devices. They pack soil over the seed providing good seed–soil contact and do not create dust problems like covering harrows.

Start dry sowing at the beginning of the normal sowing window for that species and variety.

Row spacing, seeding rate and seed depth should all be maintained as for normal sowing. Place seed at the deeper end of the recommended range to reduce the risk of partial germination on light rain, and to maximise rhizobia survival. Row spacing can be increased to handle heavy stubbles with minimal reduction in yield.¹⁸

4.8 Inoculation

4.8.1 Rhizobia and nitrogen fixation

Symbiotic nitrogen fixation is the result of the mutually beneficial relationship between the pulse host and Rhizobium bacteria. These bacteria colonise legume roots soon after seed germination then form root nodules. Rhizobia live in the soil, on plant roots and in legume nodules, but only fix nitrogen when inside a legume nodule. Rhizobia in the nodules are dependent on the host plant for water, nutrients and energy, but in return supply the plant with available nitrogen for growth. This ‘fixed’ nitrogen is derived from the gaseous nitrogen in the air.¹⁹

Nitrogen fixation by legumes does not happen as a matter of course. Compatible, effective rhizobia must be present in the soil in which the legume is growing before nodulation and nitrogen fixation can occur. When a legume is grown for the first time in a paddock, it is highly likely that compatible, effective rhizobia will not be present. In such circumstances, the rhizobia must be supplied in highly concentrated form as inoculants.

A well-nodulated and productive crop of field pea will fix up to 150 kg of nitrogen/ha. Some differences have been measured among cultivars (Table 4). In general, tall-form, conventional leaf varieties (e.g. PBA Percy[®] and PBA Coogee[®]) that produce more biomass will fix more N and leave more fixed N behind in the stubble because of their lower harvest index¹, compared with shorter-form, semi-leafless varieties such as PBA Oura[®] and PBA Twilight[®]. After grain harvest, more than 100 kg fixed N can remain in the stubble and roots of some varieties, which, when mineralised, becomes available to the following crop.



Photo 4: Different forms of rhizobia: (from left) EasyRhiz[®] freeze-dried, Nodulator[®] granules, Alosca[®] granules, N-Prove[®] granules and Nodulaid[®] peat inoculant.

Photo: M Denton, formerly Victorian DPI

¹⁸ D Carpenter (1999) Pulse Point 6: Dry sowing. NSW Agriculture and Grains Research & Development Corporation. http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/157117/pulse-point-06.pdf

¹⁹ E Armstrong, D Holding (2015) Pulses: putting life into the farming system. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/558958/Pulses-putting-life-into-the-farming-system.pdf

Table 4: Estimates of fixed nitrogen(N) provided by different pea cultivars.

Cultivar	* Growth form	Fixed N (kg/t shoot DM)	Fixed N Grain, stubble and roots (kg/ha)	Fixed N Stubble and roots (lg/ha)
PBA Percy [Ⓛ]	C-T	19	150	110
Parafield	C-T	18	154	107
PBA Coogee [Ⓛ]	C-T	18	146	109
Kaspa [Ⓛ]	SL-MT	17	145	91
Morgan	SL-T	17	143	99
PBA Pearl [Ⓛ]	SL-MT	16	144	86
PBA Hayman [Ⓛ]	C-T	16	150	127
PBA Gunyah [Ⓛ]	SL-MT	16	139	79
PBA Oura [Ⓛ]	SL-MT	16	130	78
PBA Twilight [Ⓛ]	SL-MT	15	129	76
Wharton	SL-MT	15	124	84

Source: Unkovic *et al.* (2010)

4.8.2 Inoculant for field pea

Like bean, lentil and vetch, field pea is nodulated by *Rhizobium leguminosarum* bv. *viciae*. This species of rhizobia is produced and sold commercially as inoculant Groups E and F (Table 5).²⁰

Table 5: Inoculation Group E and Group F.

Field pea and vetch	Strain: SUS303 (Group E)
<i>Pisum sativum</i> <i>Vicia species</i>	<i>Rhizobium leguminosarum</i> bv. <i>Viciae</i>
Faba bean, broadbean and lentil	Strain: WSM1455 (Group F)
<i>Vicia faba</i> <i>Lens culinaris</i>	<i>Rhizobium leguminosarum</i> bv. <i>Viciae</i>

Source: E Drew, D Herridge, R Ballard, G O'Hara, R Deaker, M Denton, R Yates, G Gemell, E Hartley, L Phillips, N Seymour, J Howieson, N Ballard (2014) Inoculating legumes: A practical guide. Grains Research & Development Corporation, <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>

Two inoculant strains are provided for pea, bean, lentil and vetch to optimise nitrogen fixation potential of the different legume hosts. Group E (strain SU303) inoculant is preferred for field pea, but Group F (strain WSM1455) can be used in its place because it is only marginally less effective.

Field pea is not nodulated by the rhizobia that nodulate chickpea (Group N), lupin (Group G) or pasture legumes.

²⁰ E Drew, D Herridge, R Ballard, G O'Hara, R Deaker, M Denton, R Yates, G Gemell, E Hartley, L Phillips, N Seymour, J Howieson, N Ballard (2014) Inoculating legumes: A practical guide. Grains Research & Development Corporation, <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>



Photo 5: Well-nodulated roots of field pea.

Photo: Drew et al. (2014) <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>

4.8.3 Inoculation in practice

Field pea will be responsive to inoculation if it (or bean, lentil or vetch) has not previously been grown in the paddock. Field pea is also likely to be responsive to inoculation on acidic soils because the rhizobia of these legumes are moderately sensitive to soil acidity. Pea rhizobia may be absent or their number may be suboptimal where soil pH (CaCl₂) is less than 6.0, even where there has been recent history of legumes that support pea rhizobia. See Table 6 for likelihood of response to inoculation.

Table 6: Likelihood of response to inoculation for sown pea, faba bean, lentil and vetch.

High	<ul style="list-style-type: none"> • Soils with pH(CaCl₂) below 6.0 and high summer soil temperatures (>35°C for 40 days); OR • legume host (pea, faba bean, lentil, vetch) not previously grown
Moderate	<ul style="list-style-type: none"> • No legume host (pea, faba bean, lentil, vetch) in previous four years (recommended pulse rotation); OR • prior host crop not inoculated or lacked good nodulation.
Low	<ul style="list-style-type: none"> • Loam or clay soils with neutral or alkaline pH and a recent history of host crop with good nodulation

Source: Drew et al, (2014)

Inoculation of field pea is generally not necessary where well-nodulated pea (or bean, lentil or vetch) has been grown in the preceding 5 years and soil conditions are favourable to the survival of the rhizobia. Loam or clay soils with neutral or alkaline pH are favourable to the survival of pea rhizobia.

If paddock conditions and legume history indicate a likelihood of a response to inoculation (Table 6) then the following guidelines should be followed:

- Inoculate with AIRG-approved* inoculants ('Green Tick' logo).
- Use Group E inoculant for pea; Group F may be used in place of E.
- Do not expose inoculants to direct sunlight, high temperatures (>30°C), chemicals or freezing temperatures as they contain live bacteria.
- Always use inoculants before their expiry date has passed.
- Keep inoculants dry and cool. Reseal opened bags of inoculant and refrigerate; use resealed bags within a short time (days).
- Follow instructions on recommended rates of inoculation.
- Consider doubling the inoculation rate in very acidic soils or where pea, vetch, bean or lentil have not been grown previously. Start with a small batch of

VIDEO

Watch GCTV13: Legumes – Sowing Preparation

<https://youtu.be/kcGu2CKwMS8>



seed to establish that it can be satisfactorily dried in order to avoid auger and seeder blockages.

- Always sow freshly inoculated seed as soon as possible, within 24 hours.
- When applying liquid or slurry inoculants, use clean, potable, non-chlorinated water and ensure the mixing tanks are free of toxic chemical residues.
- Do not mix zinc or sodium molybdate with liquid or slurry inoculants.
- Check the product label or contact the manufacturer for compatibility of inoculants with fertilisers and seed dressings.
- Ensure inoculants remain cool in transport and do not leave inoculants or inoculated seed in the sun.

*AIRG is the Australian Inoculants Research Group, part of the NSW Department of Primary Industries.

SARDI Hart trial data 2014 – Effect of rhizobia and other microbial inoculation treatments on field pea

Key findings:

The Hart Field Site in South Australia has a background of pea rhizobia that are numerous, but only moderately effective.

Inoculation treatment did not affect measured root parameters.

Some inoculation treatments increased shoot biomass and pod number, but not grain yield or grain N content.

The N benefit from the extra biomass residues was estimated to be 51 kg N/ha.

For details on the trial visit: <http://www.farmtrials.com.au/trial/16967>

4.8.4 Types of inoculant

A range of different inoculant formulations are available to Australian legume growers (Table 7). Inoculant for pea can be obtained as peat, freeze-dried or granular formulations.

Table 7: Inoculant formulations available to Australian growers.

Inoculant formulation	Composition
Peat	High organic matter soil, milled and irradiated, with rhizobia added in a nutrient suspension
Freeze dried	Concentrated pure cells of rhizobia following extraction of water under vacuum
Granular	Clay or peat granules impregnated with rhizobia
Liquid	Suspension of rhizobia in a protective nutrient solution
Preinoculated seed	Seed coated with polymers and peat inoculant

Source: G O'Hara, J Howieson, E Drew, R Ballard, D Herridge, G Gemmill, E Hartley, L Phillips, R Decker, M Denton, R Yates, N Seymour, N Ballard (2014) Inoculating legumes: A practical guide. Grains Research & Development Corporation, <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>

The different formulations vary in the number of rhizobia they contain and so it is important that recommended application rates are followed.

Peat is the most commonly used formulation and provides reliable nodulation across a range of sowing conditions. Peat inoculants also provide some protection to the rhizobia where they are applied to seed treated with pesticides.

Freeze-dried inoculants should only be used where legumes are sown into moist soils. They provide a good option where liquid injection systems are used to deliver inoculant in-furrow.

MORE INFORMATION

For more information, see:

GRDC Inoculating legumes:

A practical guide.

<https://grdc.com.au/resources-and-publications/all-publications/bookshop/2015/07/inoculating-legumes>

The back pocket guide: inoculating legumes.

<https://grdc.com.au/resources-and-publications/all-publications/publications/2013/09/grdc-bpg-inoculatinglegumes>

GRDC Fact Sheet Rhizobial inoculants.

<https://grdc.com.au/resources-and-publications/all-publications/factsheets/2013/01/grdc-fs-rhizobialinoculants>

Granular inoculants can be used where separation between the rhizobia and pesticides or fertilisers is needed.²¹

4.8.5 Storing inoculants

For maximum survival, peat and freeze-dried inoculants should be stored in a refrigerator until used. Both types of inoculant can be kept for many months if stored correctly (4–10°C), but pay attention to the date of expiry and do not freeze inoculant. If refrigeration is not possible, store in a cool, dry place away from direct sunlight. Granules also need to be stored in a cool place out of direct sunlight. Opened peat inoculum packets are best discarded, but if resealed and kept cool can be used within a few days.

Discard the inoculant after the expiry date shown because the rhizobia population may have dropped to an unacceptable level.^{22 23}

4.8.6 Inoculum survival

Moist peat provides protection and energy while the unopened pack is being stored. Rhizobia can dry out and lose viability once applied to seed and not in moist soil. Granular inoculant forms may not dry out as quickly, and most peat inoculants now contain an adhesive which delays drying and increases survival of the rhizobia. Use a peat slurry mix within 24 hours and sow seed inoculated with peat slurry as soon as possible, or store for up to 3 days in a cool place, away from sunlight.

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

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.

Dry-dusting the peat inoculant into the seed box is not an effective means of either getting or keeping rhizobia 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.²⁴

4.8.7 Inoculation methods

Inoculation with rhizobia is a numbers game: we aim is to get as many rhizobia as possible onto the seed or near the seed, to maximise the potential for nodulation. There will always be a loss of rhizobia, but by using appropriate methods these losses can be minimised to obtain effective nodulation. It is advisable to use high-quality inoculants, such as AIRG-approved ('Green Tick') products.

Peas have historically been inoculated with a slurry of peat inoculant onto the seed. But now rhizobia can also be purchased in a freeze-dried form suitable for application to seed or water injection into the soil, or granules that are sown at same time as the seed from a separate box.

Peat inoculants

Most peat inoculants for pea now contain a pre-mixed sticker, and only require the addition of water to make the slurry. When preparing the slurry do not use hot or chlorinated or saline water.

²¹ E Drew, D Herridge, R Ballard, G O'Hara, R Deaker, M Denton, R Yates, G Gemell, E Hartley, L Phillips, N Seymour, J Howieson, N Ballard (2014) Inoculating legumes: A practical guide. Grains Research & Development Corporation, <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>

²² E Drew, D Herridge, R Ballard, G O'Hara, R Deaker, M Denton, R Yates, G Gemell, E Hartley, L Phillips, N Seymour, J Howieson, N Ballard (2014) Inoculating legumes: A practical guide. Grains Research & Development Corporation, <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>

²³ GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>

²⁴ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 2-2016

How to apply slurry to the seed:

- Through an auger – make sure the auger is turning as slowly as possible, to achieve effective mixing. Reduce the height of the auger to minimise the height of seed fall.
- Meter the peat slurry in, according to the flow rate of the auger (remember: 250 g packet per 100 kg of seed).
- Through a tubulator – similar to applying through an auger, except that the tubulator reduces the risk of damaging the seed. Its mixing ability is not as effective as an auger.
- In a cement mixer – only practical for small lots unless a cement truck is used.

Peat inoculant can also be injected as dilute, filtered slurry directly into the sowing furrow, with or below the seed.²⁵ Agitators and in-line filters may be necessary to avoid blockages to nozzles and capillary tubes. Typically, the peat inoculant is filtered and applied at low pressure in a water volume of 50–100 L/ha.

Dry-dusting the peat inoculant into the seed box is not recommended. This is not an effective means of getting good contact between rhizobia and seed. Attachment of the rhizobia to the seed can be very poor, and under some conditions rhizobial death is so rapid that no inoculant is alive by the time the seed reaches the soil.²⁶

Freeze-dried inoculants

Freeze-dried inoculants can be applied to seed or delivered as a liquid into the furrow. Freeze-dried inoculants are not suitable for application to dry soils.

The rhizobia become active when the inoculant is reconstituted with liquid. The product comes with a protective polymer in a separate packet, which assists survival of the rhizobia. A 30 millilitre vial of inoculant will treat up to 500 kg of pea seed.

Treated seeds need to be sown into moist soil within 5 hours of application. Contact with seed-applied pesticides and fungicides must be avoided.

For liquid injection into the seeding furrow, add the inoculant suspension to 2 L of cool water containing the protective polymer. Add this solution to the clean spray tank and deliver at 50–100 L per hectare into the furrow.

Granular inoculants

Granular inoculants are applied as a solid product directly into the seed furrow, near the seed or below the seed. They avoid many of the compatibility problems that rhizobia have with fertilisers and fungicides. They also eliminate the need to inoculate seed before sowing. Granular inoculants are reported to be effective where dry sowing is practiced.

If granules are mixed with the seed, rather than applied separately, then distribution of both seed and inoculum may be uneven, causing either poor and uneven establishment and/or patchy nodulation. Granules should not be stored in seeding boxes overnight because they can settle or solidify and cause blockages.

²⁵ J Brockwell, RR Gault and RJ Roughley (1982) Fact Sheet: Spray inoculating grain legumes. Available at www.ua.edu.au/legume-inoculation

²⁶ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 2-2016



Photo 6: An ‘after-market’ third box fitted to a Flexicoil box to enable application of granular inoculums. Note that granular inoculums cannot be applied mixed with the seed (uneven distribution of seed and/or inoculums occurs). *Rhizobia* survival is severely jeopardised if granular inoculums are applied mixed with fertiliser.

Photo: W. Hawthorne, formerly Pulse Australia

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

Water injection

Water-injection methods can use peat, freeze-dried or liquid forms of inoculum. The inoculants are diluted with water in tanks mounted on tractors and applied through spray lines attached behind each planting tyne/boot (Photo 7). Agitators and in-line filters may be necessary, particularly for peat-based inoculum. Rates of inoculum need to be calculated for planting rates (kilograms of seed per hectare) and water volumes able to be carried. Typically, application rates are 50–100 L/ha.



Photo 7: Spray line attached behind each planting tyne/boot dispense inoculants by water injection.

Photo: Drew *et al.* (2014) Inoculating legumes: A practical guide. Grains Research & Development Corporation, <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>

i MORE INFORMATION

For more information, see

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

Inoculating legumes: the back pocket guide <https://grdc.com.au/resources-and-publications/all-publications/publications/2013/09/grdc-bpg-inoculatinglegumes>

GRDC Rhizobial inoculants Fact Sheet
www.grdc.com.au/GRDC-FS-RhizobialInoculants

▶ VIDEO

Watch GCTV17: Legume Nodulation – field sampling
<https://youtu.be/bfnBsEM64tO>

Watch GCTV17: Legume Nodulation – sample preparation
<https://youtu.be/OVL7CIY-K9w>

Watch GCTV17: Legume Nodulation – sample scoring
<https://youtu.be/Nd303SFITDk>

Dry inoculation – a warning

This involves mixing packets of peat inoculum with the seed, or dusting it in the seed box. This method is not recommended because survival of the inoculum is low, and most of the inoculum is lost from the seed before and during planting. Increasing the rate of inoculant applied can partially help improve efficiency.²⁷

4.9 Check for nodulation

It is important to determine how effective inoculant application has been and if the nodules are actively fixing nitrogen. By checking the number of nodules and their distribution on the roots, you can assess the effectiveness of the inoculum product used and the application method.

If you have not inoculated, it can still be helpful to assess nodulation of your pea crop, to assess whether inoculation may be needed in the future.

For pea, 50–100 pink nodules per plant after approximately 10 weeks’ plant growth is an adequate level of nodulation (Photo 10). A strong pink colour inside the nodule indicates the rhizobia are actively fixing nitrogen for use by the plant (Photo 8).



Photo 8: A healthy, nitrogen-fixing nodule has a rusty red or pink centre.

Photo: G Cumming, formerly Pulse Australia

4.9.1 Sampling and processing

At least 30 plants should be sampled, 10 at each of 3 locations, spaced 40 metres apart in the crop. Plants should be gently dug from the soil and the root system carefully rinsed in several changes of water before estimating nodule number. It is helpful to float the root systems in water on a white background (a cut down, clean chemical drum is easy to use).

4.9.2 Nodule number and distribution

Score each plant for nodulation. At least 50 pink nodules per plant is considered adequate (Photo 10). Separate plants into adequate and inadequate groups. If the adequate group contains more than 70% of the plants then inoculation has been successful.

27 GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>



Photo 9: (Left) a well-nodulated field pea plant and (right) a poorly nodulated plant. Note the difference in green colour of the foliage.

Photo: DPIRD

i MORE INFORMATION

For more information on nitrogen fixation go to the GRDC Factsheet:

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

Observe the pattern of nodules on the root system. Following inoculation, nodules on the main taproot clustered near the seed are a clear indication that nodulation occurred early. These are referred to as 'crown nodules'. If there are no crown nodules, but nodules on the lateral roots, then it is more likely nodulation has been delayed, indicating that there may have been issues with the inoculation process.

Nodules on both the crown and lateral roots indicate that inoculation was successful, and that bacteria have spread in the soil. This is the ideal situation, with the crown nodules providing good levels of N fixation early in the plant's growth, supported by the lateral root nodules, which may extend N fixation activity later into the season because they are less affected by drying of the surface soil.



Photo 10: Well-nodulated roots of field pea showing active pink nodules.

Photo: Liz Farquharson, SARDI

4.9.3 Nodule appearance

If necessary, cut or break open a few root nodules to check the colour. Very young nodules (after a couple of weeks' plant growth) are usually white because they still need to develop. However, in older plants (at 10–12 weeks growth when assessment is recommended) an abundance of white nodules may indicate the rhizobia in the soil that formed the nodules were poorly effective and they will not fix nitrogen (Photo 11). This is rare for field pea, but indicates that the crop should be inoculated next time it is grown. White nodules can also result from trace element deficiencies such as molybdenum.



Photo 11: Field pea roots with active large pink nodules (pink arrows) and small white inactive nodules (white arrows). The white nodules indicate some of the rhizobia forming nodules were ineffective at nitrogen fixation.

Photo: Drew *et al.* (2014) Inoculating legumes: A practical guide. Grains Research & Development Corporation, <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>

Some nodules may appear green or grey inside. At the 10-week growth stage, this would likely indicate herbicide damage or that the plant has suffered water stress. These nodules are unlikely to recover N-fixation activity. However, later in the season, as plants approach flowering, the development of green pigmentation in the nodules occurs as a normal part of nodule maturation. Field pea nodules are indeterminate. This means they continue to grow and form lobed structures with distinctly different zones visible inside the nodule. With maturity, the section of nodule closest the plant root loses its pink coloration, turning grey or green. As long as the section of the nodule furthest from the root retains some pink tissue, the nodule remains actively fixing nitrogen.

If you have spent time and resources on inoculation, it is worthwhile to carry out this nodulation check, to determine whether your inoculation has been successful and is likely to provide N benefits. It may also indicate whether troubleshooting is required, or whether inoculation is needed in future.

4.9.4 Rating nodulation and nitrogen fixation

The amount of nitrogen fixed is strongly correlated with nodule rating (0 to 5) as detailed in the following photo standards (Figure 1).

When using this rating system, 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).

- **Rate the level of nodulation using the photo standards provided** (Figure 1). This is based on nodule number and their position on the root system.
- **Observe the pattern of nodules on the root system.** Nodules on the main taproot clustered near the seed are a clear indication that nodulation occurred as a result of the inoculation process. These are referred to as 'crown nodules'.

If there are no crown nodules, but nodules on the lateral roots, then it is more likely that they have formed from native soil bacteria that are usually less effective in fixing nitrogen, even in field pea.

Nodules on both the crown and lateral branches indicate that inoculation was successful, and that bacteria have spread in the soil.

- **Inspect nodules for nitrogen-fixation activity.** The best method is to slice a few nodules open with a razor blade or sharp knife and look at their internal colour (see Figure 1).

Young nodules are usually white and still need to develop. White nodules can also indicate the wrong bacteria in the nodule and these will not fix nitrogen. Effective nodules are a rusty red or pink colour inside and these are usually actively fixing nitrogen. Effective red nodules can sometimes turn green when a plant comes under water, disease or other stress, or is suffering from nutrient deficiencies. These do not fix nitrogen, but they can change back to red and start fixing again if the stress is relieved without too much damage being done. Finally, black nodules are usually dead or dying. These are often seen as the crop matures, or after a crop has suffered severe waterlogging.²⁸

4.9.5 Key for assessing nodulation in winter pulse crops

Figure 1 shows nodulation scores (0–5), based on nodulation number and distribution, where 0–1 is inadequate nodulation, 2–3 is adequate nodulation and 4–5 is good nodulation.



Score 0: taproot – absent, lateral – absent/few

Score 1: taproot – few/medium, lateral – absent

Score 2: taproot – medium, lateral – absent/low



Score 3: taproot – medium/high, lateral – low

Score 4: taproot – high, lateral – medium

Score 5: taproot – high, lateral – high

Figure 1: Nodulation scores based on number and distribution of nodules.

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

28 TopCrop, Growers guide to assessing nodulation in pulse crops

VIDEO

Watch GCTV13: Legumes – Inoculant Compatibility

<https://youtu.be/gHBDSYeq0Ss>



Interpreting the impacts of the nodulation score:

- Where plant-available soil N is low, the crop relies heavily on good nodulation for its nitrogen 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 to supply nitrogen.
- A high score indicates that the crop will yield well and conserve N for use by a following crop.

A low score suggests that the crop will yield poorly and deplete soil N.²⁹

4.10 Seed treatments

An insecticide seed dressing is a simple and cost-effective way to protect emerging crops from insect attack in the early growth stages. Gaucho® 600 Red Flowable Seed Treatment Insecticide (imidacloprid) is registered as a seed treatment for early aphid protection to help control persistently transmitted viruses at the seedling stages. According to the label, Gaucho® seed treatment does not affect the viability of rhizobia when mixed with inoculant.

Seed treatments are also a cheap and effective method of suppressing some diseases, although growers need to be aware that the P-Pickle-T® seed treatment has caused phytotoxic responses in treated field pea, particularly in white and blue types.

Fungicidal seed dressing is part of an overall disease-management strategy protecting against certain root and leaf diseases. It can improve seed emergence, especially in wet winters. Downy mildew is best controlled by metalaxyl seed treatment, which will also provide protection from some other root rots such as Pythium. Thiram and thiabendazole fungicidal seed treatment can control seed-borne spores of blackspot and some root rots for up to 8–10 weeks after sowing and may improve yield. This is more likely to be economic in higher-risk situations such as early sowing.

If using both inoculum and seed dressing, apply the seed dressing first and then inoculate seed immediately before seeding. Do not mix inoculants and seed dressings together unless the inoculant’s label specifies compatibility.

Table 8: Compatibility of different rhizobia groups with seed-applied fungicides and insecticides.

Inoculant group / crop	Fungicide type	Planting window of inoculated seed
E – pea, vetch	P-Pickel T	6 hours
	Gaucho® 600 FL	4 hours
F – faba bean, lentil	Gaucho® 600 FL	24 hours
	P-Pickel T	24 hours
	Thiram	Compatibility not known
G – lupin	Rovral	6 hours
	Thiram	24 hours
H – soybean	not compatible with seed dressings	
N – chickpea	P-Pickel T	6 hours
	Thiram	6 hours
	Apron® XL 350	6 hours
	Gaucho® 600 FL	6 hours
P – peanut	not compatible with seed dressings	

Information sourced from commercial product information guides (BASF and Novozymes)

Source: G O’Hara, J Howieson, E Drew, R Ballard, D Herridge, G Gemmell, E Hartley, L Phillips, R Decker, M Denton, R Yates, N Seymour, N Ballard (2014) Inoculating legumes: A practical guide. Grains Research & Development Corporation, <https://grdc.com.au/GRDC-Booklet-InoculatingLegumes>

²⁹ TopCrop, Growers guide to assessing nodulation in pulse crops

4.11 Further research projects

DAS00128 – Optimising nitrogen fixation of grain legumes - southern region

DAS00128 – Effect of rhizobia and other microbial inoculation treatments on field pea (<https://www.farmtrials.com.au/trial/16967>)

Plant growth and physiology

- Field pea varieties range in growth habit from trailing, leafy types to being semi-leafless and so erect at maturity. Trailing types can be difficult to harvest.
- More recent Australian-bred cultivars are predominantly semi-leafless and have been bred with traits such as: late flowering, early maturing, resistance to pod shattering, reduced disease risk, frost tolerance and ease of management at harvest.
- Field pea growth stages are divided into vegetative (V) and reproductive (R) stages.
- Field pea has hypogeal emergence (seed germination remains below the ground), which can be an advantage.
- Factors affecting emergence include: seed quality, sowing depth, plant density, seed treatments, diseases, nodulation, insects, waterlogging and herbicide wash.
- Field pea respond well to minimum temperatures of not less than 7°C during establishment and canopy expansion, and 25°C and less during critical reproductive phases.

5.1 Field pea type and physiology

Field pea varieties range in growth habit from trailing to erect at maturity. The trailing growth type can be difficult to harvest and were commonly grown until the early 2000s (e.g. early dun, Alma, Parafield). More recently there has been a shift across southern Australia towards uniquely Australian-bred field pea cultivars (e.g. Kaska[®], PBA Twilight[®]) that are semi-leafless/semi-dwarf, range from late flowering to early maturing, semi-erect at maturity and highly resistant to seed shattering. The development of semi-leafless/semi-dwarf types have given growers options with better standing ability which makes harvesting easier. In these semi-leafless pea cultivars the leaves have been modified into tendrils, which tend to wrap themselves together and hold the plant upright (Figures 1 and 2).

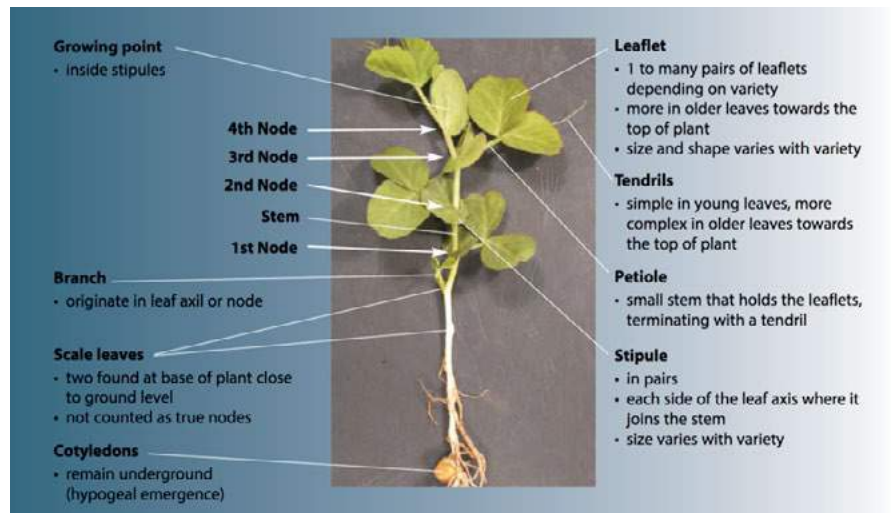


Figure 1: Field pea (*Pisum sativum*) conventional leaf type e.g. Dundale, Parafield, Alma.

Source: G Brooke, C McMaster (2017) Weed control in winter crops 2017: NSW DPI Management Guide. NSW Government Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops>

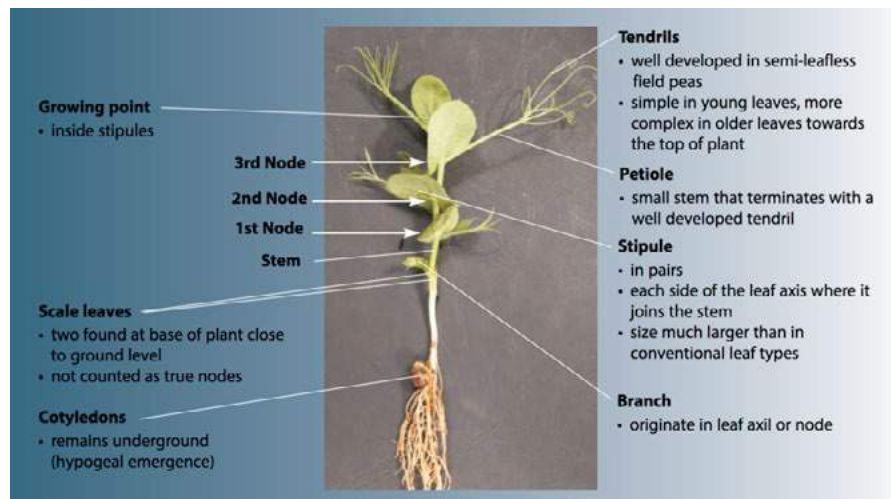


Figure 2: Field pea (*Pisum sativum*) semi-leafless type e.g. Kaska[®], Excell, Snowpeak, Mukta, Morgan[®].

Source: G Brooke, C McMaster (2017) Weed control in winter crops 2017: NSW DPI Management Guide. NSW Government Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops>

5.2 Field pea growth stages

Field pea growth stages are based on counting the number of nodes on the main stem. This identifies various vegetative (V) and reproductive events (R).

When field pea emerges, two small scale or scar leaves appear. The scar leaves do not form stipules and are therefore not counted. This is best seen in Figure 3, which shows a field pea at the 3-node stage. When counting nodes, only count those where the stipule leaves are fully unfolded.¹

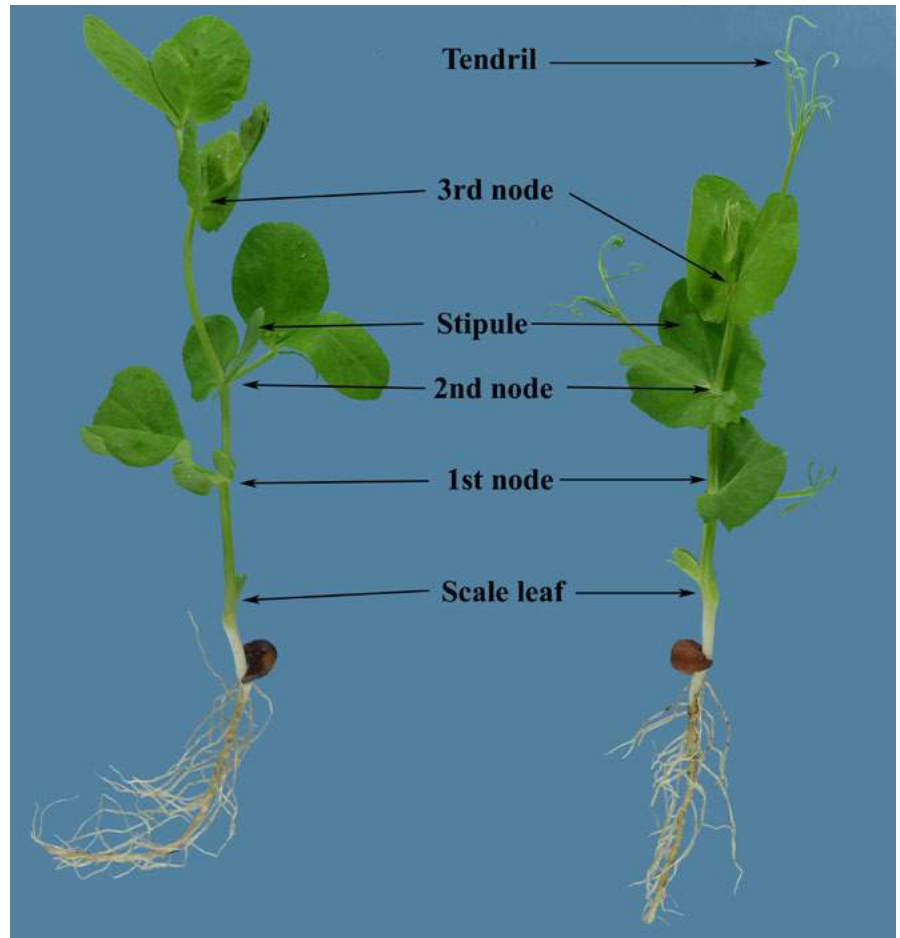


Figure 3: Trailing field pea (left) and semi-leafless field pea (right) at 3-node stage.

Source: I Pritchard (2015) A visual guide to key stages in the growth and maturity of field pea. Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/field-peas/visual-guide-key-stages-growth-and-maturity-field-pea>

Field pea varieties exhibit either indeterminate or semi-determinate growth habits depending on the variety. The terminal bud of an indeterminate plant is always vegetative and keeps growing while conditions allow it. 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.

There is a uniform system for the description of the developmental stages of field pea (*Pisum sativum*) that is universally applicable to all growing environments and divergent cultivars (Table 1).

¹ I Pritchard (2015) A visual guide to key stages in the growth and maturity of field pea. Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/field-peas/visual-guide-key-stages-growth-and-maturity-field-pea>

Vegetative (V) growth stages: these are described by counting nodes on the main stem and continuing the count up the basal primary branch to include the highest fully developed leaf. Count the number of visible nodes on the main stem up to the node subtending the basal primary branch, and then continuing the node count up the basal primary branch to include the highest fully developed leaf. The basal primary branch usually develops between nodes 1 to 5.

Reproductive (R) growth stages: flowering of field pea is indeterminate, occurring from axillary buds on the main stem and branches. It proceeds from lower to higher nodes. Reproductive stages R1 and R2 are based on flowering, R3 to R5 on pod and seed development, and R6 and R7 on maturation.

Physiological maturity: this is when the seed can develop no further dry matter.

Table 1: Growth stages of a field pea plant.

Development phase	Growth stage (GS)	Description
Germination and emergence	VE	Seedling emerges from the soil.
	VS	Two small scale leaves appear on the stem, do not count this node.
Vegetative growth stages Count the number of visible nodes above the ground (VS) on the main stem, continuing the node count up the basal primary branch to include the highest fully developed pinnately compound leaf.	V1	The true leaf (pair of leaflets) has unfolded at the first node above VS, no tendrils
	V2	second true (one or more pairs of leaflets) has unfolded at the second node
	V3	third true leaf (one or more pairs of leaflets) has unfolded at the third node
	Vn	the nth true leaf (one or more pairs of leaflets) has unfolded at the nth node
Reproductive growth stages Field pea is indeterminate, and flower buds are initiated in leaf axils at the apical meristem approximately 20 days after they become visible.	R1	Flower bud present at one or more node
	R2	First open flower at one or more node
	R3	First flat pod present at one or more nodes
	R4	Green seeds fill the pod cavity at one or more nodes
	R5	The leaves start yellowing and low pods have turned yellow to golden brown
	R6	Yellow or dry seeds fill the pod cavity at one or more nodes
	R7	Most pods on the plant are yellow to golden-brown
Physiological maturity	R7	leaves start yellowing and 50% of the pods have turned yellow
	R8	90% of pods on the plant are golden-brown.

For populations of plants; vegetative stages can be averaged. Reproductive stages should not be averaged.
 For populations of plants; a reproductive stage is classified unchanged until 50% of the plants in the sample demonstrate the trait of the next reproductive (R) stage.
 For a single plant the reproductive stage is set by the first occurrence of the specific trait on the plant.
 Source: Erskine *et al.* (1990)

Field pea is classified as a hermaphroditic plant because its flowers have both male and female parts. All the flowering components that peas need to reproduce are contained in a single blossom, which is the site where the transfer of pollen is carried out in a process known as self-pollination.

Flower terminals develop from the auxiliary bud at the base of each node, with flowering commencing at approximately the 6th to 10th node, depending on the variety, time of sowing and temperature. Field pea flowers vary in colour from shades of purple, pink to white. Flowers are borne on a peduncle that arises from nodes.²

About half of the flowers are fertilised and capable of forming pods. The pods formed early are usually larger than those formed later in the season. Each pod usually develops 3–7 seeds. The seeds take 30–40 days after flowering to reach

² Pulse Australia (2016). Southern/western field pea best management practices training course, module 2-2016. Draft. Pulse Australia Limited

physiological maturity. The crop is normally ready for harvest about 6 weeks after flowering.

Eighty per cent of field pea yield is off the main stem.

The first flower will form the bottom pods and, because they are the first and most advanced, are the fullest at any stage of plant growth. Development of pods at the flowering nodes becomes sequentially later as they go up the stem. The top 2–3 nodes are the latest to flower and rarely form pods in Australia due to hot weather or lack of moisture. An isolated frost event can have a great impact on the node flowering at that time. Therefore, sequential podding along a stem provides a good timeline and map of the plant’s environmental history. All the above descriptions refer to the main stem, which is the continuation of the germinating shoot.

Basal branches often develop from the bottom three nodes, and these form a secondary flowering branch. This is like tillering in cereals and is variety, season and density dependent. A strongly branching type can make up for a lower seedling density. These basal branches also develop the typical node structure identical to the main stem, and start flowering at about node 5–8 and can develop 6–15 flowering nodes. In some varieties and in very good seasons, aerial branches can also develop from the three nodes immediately below the first flowering node. These can produce some yield but are rarely significant.³

5.3 Germination and emergence

Pulses are classed as ‘epigeal’ if the cotyledons appear above the ground (e.g. lupin) or ‘hypogeal’ (e.g. field pea) if they remain below the ground (Figure 4).

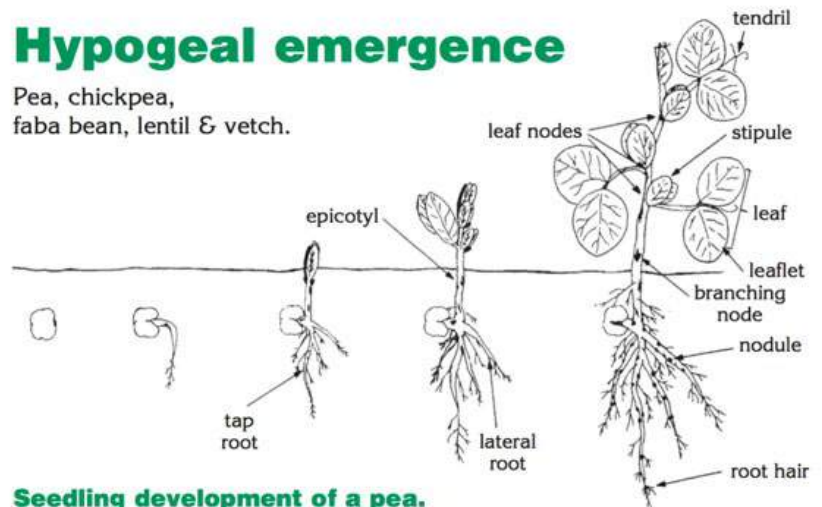
Field pea plants are hypogeal, which means the cotyledons of the germinating seed remain below the ground and inside the seed coat. Seedlings with hypogeal emergence are less likely to be killed at emergence by frost, wind erosion or insect attack as new stems can develop from buds at nodes at or below ground level. Their growth may however be slowed considerably relative to unaffected shoots. In contrast, if an epigeal pulse is broken or damaged below the cotyledons, the plant will die as there are no buds from which to shoot.⁴

³ GRDC (2015) Field pea Northern Region GrowNotes™, <https://www.grdc.com.au/grownotes>

⁴ J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry, Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

Hypogeal emergence

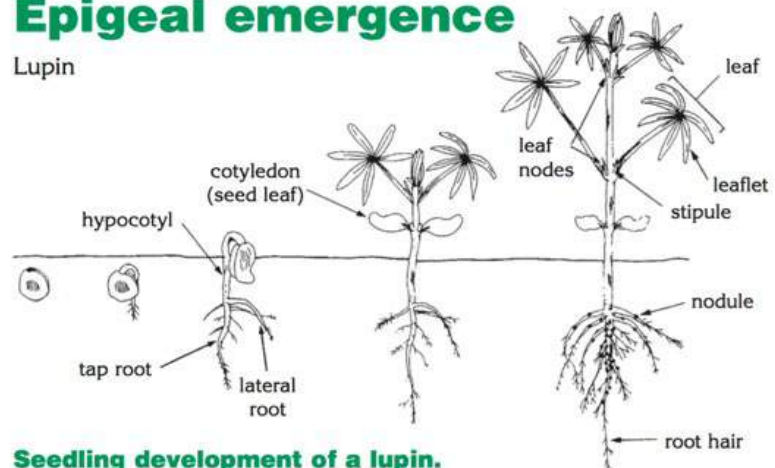
Pea, chickpea, faba bean, lentil & vetch.



Seedling development of a pea.

Epigeal emergence

Lupin



Seedling development of a lupin.

Figure 4: Hypogeal and epigeal emergence patterns in pulses.

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

5.3.1 Emergence issues

Field pea seed is larger than the seed of many crops at around 13–24 grams per 100 seeds depending on variety. The seed size doubles in volume in the first 2 days of germination and requires three times the moisture for germination than smaller seeds.

Field pea germination requires a minimum of 5°C. The warmer the soil temperature the quicker emergence occurs:

- 5–7.2°C: 17–21 days to emerge
- 7.2–10°C: 14–17 days to emerge
- 10–12.8°C+: 10–14 days to emerge.

Approximate time to reach growth stages:

- 1st node/leaf stage: depends on soil temperature, approximately 14 days
- 2nd node/leaf stage and after: every 4–5 days.⁵

⁵ K McKay, Growing Peas and Lentils, Key Growth Stages, NCREC, Minot, ND, https://www.ag.ndsu.edu/NorthCentralREC/crop-production-extension/Pea%20Growth_Stages_Considerations.pdf

Other factors that can affect the emergence of field pea include:

- poor seed quality, see [Section 3.4 Planting seed quality](#)
- plant density, see [Section 4.3 Sowing rate and plant density](#)
- seed treatments, see [Section 4.10 Seed treatments](#) and [Section 9.6.1 Seed dressings](#)
- diseases, see [Section 9 Diseases](#) and [Section 10 Pre-harvest treatments](#)
- nodulation, see [Section 4.8 Inoculation](#)
- waterlogging, see [Section 5.5 Abiotic stresses \(environmental effects\) on plant growth and physiology](#) and [Section 13.2 Waterlogging](#).
- insects both above and below ground level, see [Section 8.3 Key pests of field pea](#)
- herbicide wash and concentration, see [Section 2.3 Seedbed requirements](#)
- sowing depth, see [Section 2.3 Seedbed requirements](#) and [Section 4.4 Sowing depth](#).

5.4 Nodulation and nodulation failure

The taproot and lateral roots near the soil surface carry small round or oblong shaped nodules if the correct strain of Rhizobium is present. Group E (SU303) is preferred for field pea but group F (WSM1455) can be used in its place because it is only marginally less effective. For more information, see [Section 4.9 Check for nodulation](#).

Nodules might start appearing as early as 15 days after emergence. Peak nodule growth and development occurs at peak vegetative production and starts to decline at the commencement of flowering or later if adequate soil moisture is available. Healthy nodules have a pinkish-white appearance and when cut show a pink discolouration of leghaemoglobin (haem-containing protein binding and/or transporting oxygen or nitrogen).⁶

Nitrogen deficiency from nodule dysfunction can be caused by lack of rhizobia, soil acidity (pH ((CaCl₂) less than 6.0), herbicide toxicity, or molybdenum or sulfur deficiency.

Symptoms may appear within a month of seeding. The signs of nodulation failure are when the plants are smaller and paler with a pink shade, with restricted growth, especially during cold, wet periods through the seedling stages. Oldest growth is first and the worst affected. As deficiency worsens plants becomes stunted and pale; older leaves become progressively pinkish pale and die, leaving green new growth (Photo 1). Nodules are reduced or absent. If nodules are present they are small, and when split have a pale or white interior rather than the pink-red interior.⁷

6 Pulse Australia (2016) Southern/western field pea best management practices training course, module 2-2016. Pulse Australia Limited

7 I Pritchard (2015) Diagnosing dysfunction in field peas, Department of Agriculture, Western Australia <https://agric.wa.gov.au/n/4476>



Photo 1: Both plants show poor nodulation, but the plant on the left has had adequate soil nitrogen.

Photo: R Yates (2015) Diagnosing nodule dysfunction in field peas. DPIRD, <https://www.agric.wa.gov.au/mycrop/diagnosing-nodule-dysfunction-field-peas>

The easier and best way to identify nodulation failure is to dig up several plants, keeping intact as much root material as possible. Be careful as root nodules are very fragile and will break off easily. Wash off any residual soil and stones very carefully not to knock off nodules. Slice the nodules open with a pocket knife or thumbnail and look at the colour of the nodules. Red and pink coloured interior nodules depict healthy nodules fixing nitrogen. Yellow, green, black or brown nodules depict poor or low N fixation potential.

As a salvage operation, apply nitrogen to affected crops if economic. Ensure future crops are adequately covered with viable Group E inoculum.⁸

⁸ GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

5.5 Abiotic stresses (environmental effects) on plant growth and physiology

The major abiotic stresses of pulses such as field peas in Australia are those associated with cold, frost, waterlogging, drought, heat, soil pH, salinity, sodicity and boron toxicity.

The extent of the damage caused by abiotic stress depends on the pulse species (Table 2), the prevailing environmental conditions and stage of crop growth.

Table 2: Importance of major abiotic stresses affecting cool-season pulse crops in Australia.

Stress	Field pea	Chickpea	Faba bean	Lentil
Cold	X	XXX	X	X
Frost	XXX	XXX	XX	XX
Waterlogging	XX	XXX	X	XXX
Drought	XXX	XX	XXX	XX
Heat	XXXX	XX	XXX	XXX
Salinity	XX	XXX	XX	XX
Boron toxicity	XX	XXX	XX	XXX

XXX = very important, XX = important, X = not very important

Source: K Siddique (1999) Abiotic stresses of cool season pulses in Australia. University of Western Australia, <http://www.farmtrials.com.au/trial/13486>

For a particular stress, the time at which it occurs in the plant's life cycle will affect plant production through its yield components (total biomass, number of pods, number of seeds, seed weight and harvest index).

The optimal temperatures for cool-season pulses range between 10°C and 30°C. Temperatures that fall outside the optimum range cause stress. Daily maximum temperatures above 25°C are considered the threshold for heat stress in cool-season pulse crops.

Pulses are particularly sensitive to heat at the full bloom stage. A few days of exposure to high temperatures (30–35°C) causes heavy yield losses through flower drop and pod abortion.⁹

An Australia-wide research project 'Improving yield and reliability of field peas under water deficit' confirmed this and found a correlation between yield and temperature indicated by two distinct stages.

In the first stage, field pea yield was positively associated with minimum temperatures during crop establishment and canopy expansion, before flowering. Temperatures below 7°C had a negative effect on growth. In the second stage, grain yield was negatively associated with maximum temperature over 25°C during critical reproductive phases.¹⁰

⁹ K Siddique (1999) Abiotic stresses of cool season pulses in Australia. University of Western Australia, <http://www.farmtrials.com.au/trial/13486>

¹⁰ V Sadras (2013) Improving yield and reliability of field peas under water deficit. Grains Research & Development Corporation, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/01/Improving-yield-and-reliability-of-field-peas-under-water-deficit>

Drought and heat stress

Drought stress during vegetative stages of growth alone does not appear to cause a significant yield loss in chickpea or field pea. Flowering is the most sensitive stage to drought.

Cold

Reproductive organs, mainly flower buds and flowers, are most susceptible to cold or chilling injury.

Frost

The threshold level for frost injury in winter pulses occurs when the daily minimal temperature is below 0°C. Frost damage in spring (radiation frost) is a major cause of yield loss in crops including pulses in Australia. The most important stress in the freezing process is ice formation and the associated mechanical damage of the tissue. Flowering, early pod formation and seed filling are the most sensitive stages in winter pulses. Critical temperatures for frost injury appear to be higher for chickpea than field pea, lentil or faba bean. Among the pulses, field pea seems to be the most susceptible to frost injury during the reproductive stage.

Waterlogging

Transient waterlogging is common in winter on fine-textured (clay) soils in Australia. Seed germination is very susceptible to waterlogging. Poor crop establishment is a common problem when waterlogging occurs at seedling emergence. Among cool-season pulses faba bean is relatively tolerant to waterlogging at germination compared with lentil, field pea or chickpea. Waterlogging 6 days after germination of field pea can delay the emergence by up to 5 days and reduce the final plant density by 80%. Waterlogging depresses vegetative growth of plants but affects root growth more than shoot growth.¹¹

Field pea are most sensitive to waterlogging at flowering, with flower and pod abortion, and leaf senescence (ageing).¹²

Soil pH

Cool-season pulses are sensitive to acid soil conditions and require a neutral to alkaline soil pH for optimum growth and yield.

Nutrient availability can change with increments in soil pH, particularly in soils low in organic carbon. On such soils, toxicity of aluminum (Al), iron (Fe) and manganese (Mn) occur when the pH falls from 5.5 to 4.5. Root growth of pulses is severely restricted on acid soils. Symptoms of nutrient deficiency and water stress, therefore, commonly occur in pulse crops growing on unsuitably acid soils.

Salinity and sodicity

Cool-season pulses are relatively sensitive to salinity compared with cereals and canola. Yield reduction in field pea has been reported at about 20% at an electrical conductivity (EC) of 2 dS/m, and 90–100% reduction at an EC of 3 dS/m.¹³

Crop response to salinity changes with crop stage of growth. For example, lentil and faba bean are more sensitive at germination than at subsequent growth stages and the converse is true for chickpea.¹⁴

A study (Leonforte 2013) found that Chinese landrace lines of field pea were far more tolerant of salinity than Australian cultivars. Salinity-induced symptoms were closely

11 K Siddique (1999) Abiotic stresses of cool season pulses in Australia. University of Western Australia <http://www.farmtrials.com.au/trial/13486>

12 Pulse Australia (2016). Southern/western field pea best management practices training course, module 2-2016, Draft. Pulse Australia Limited

13 Pulse Australia (2016) Southern/western field pea best management practices training course, module 2-2016, Draft. Pulse Australia Limited

14 A Leonforte (2013) A study of salinity tolerance in field pea. University of Melbourne Australia, <https://minerva-access.unimelb.edu.au/handle/11343/38605>

related to reductions in growth rate, height, root and shoot dry matter, and with increased concentration of sodium ions (Na⁺) at the plant growing tip. The variety Kaspas[®] was quicker to suffer from salinity than Parafield and Yarrum. Helena showed slightly slower susceptibility. It was the line ACT01836 that was least sensitive of several introduced landrace lines.

Salinity tolerance score (1–10):

1. Plant healthy green, no obvious salinity symptoms.
2. Beginning to yellow, not very many symptoms.
3. Some chlorosis bottom half of plant, no necrosis, overall yellowing.
4. Necrosis beginning on bottom half of plant.
5. Chlorosis and necrosis bottom half of plant, yellowing overall (50% affected).
6. Chlorosis becoming more severe on upper part of plant, not necrotic on upper plant.
7. Chlorosis and necrosis more than half of plant.
8. More necrosis than 7, but still some green leaves.
9. Stem and very young leaves green, rest dead (all leaves may be dead).
- 9.5 Only top of stem (or small part stem) and very youngest leaves still green, rest dead (all leaves may be dead).
10. Plant dead.

Salinity tolerance score (1–10)

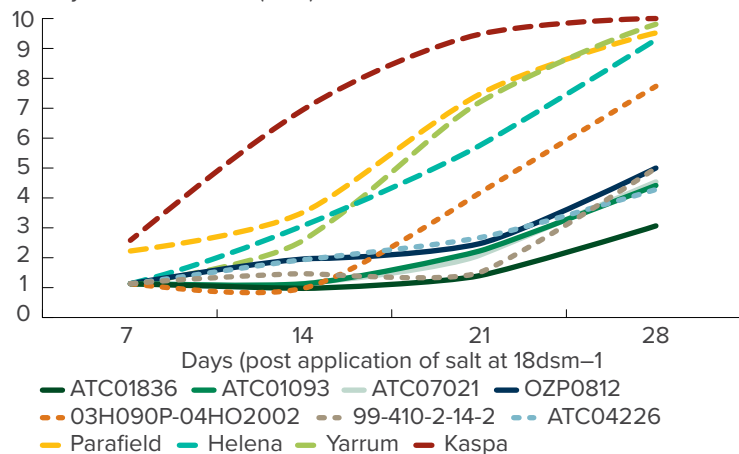


Figure 5: Salinity tolerance comparisons of three categories of field pea (unadapted accessions - solid lines, adapted breeding lines - dotted lines and Australian commercial varieties - dashed lines).

Source: A Leonforte (2013) A study of salinity tolerance in field pea. University of Melbourne Australia, <https://minerva-access.unimelb.edu.au/handle/11343/38605>

5.6 Crop lodging

Erectness

Field pea production across southern Australia was originally based on the 'dun types' that grow vigorously over winter: tall (long internodes), conventional-types that exhibit indeterminate flowering. The scrambling plant growth habit characteristics of these varieties can make management of weeds and diseases and harvest difficult, and result in poor and variable grain quality for export to human consumption markets.

The development of semi-leafless, semi-dwarf determinate types that grow more erect to seed maturity combines genes that control absence of leaflets and reduce plant internode length. Several dwarf, semi-leafless types were released but these were not commercially a success, largely because of low yields. Twenty years of breeding have led to the semi-leafless, semi-dwarf types for Australia (e.g. Kasp[®]). Traits include: reproductive commencement in mid spring to avoid frost risk, lodging resistance and reduced pod shattering. More recent varieties PBA Twilight[®] and PBA Gonyah[®] have been developed for shorter-season climates.¹⁵

Lodging leads to shading of other plants, loss of flowers and pods, and increased incidence and severity of leaf disease. It is more likely in higher-rainfall areas.

Tall trailing field pea types with poor resistance to lodging (e.g. PBA Hayman[®], PBA Percy[®]) are more likely to fall over in spring. Areas of ground exposed by lodging enable late spring weeds to grow and set seed, of particular concern for the management of annual ryegrass.

Difficulty in lifting the crop at harvest makes harvesting more difficult, slower and less efficient.

Grow varieties with greater resistance to lodging. These are likely to be the more erect types. Plant peas into standing cereal stubble, which will help anchor the plant and provide a natural trellis for the crop to grow up.¹⁶ Narrower row spacings and higher sowing rates can also aid in standability.

For more information on harvest see [Section 11 Harvest](#).

15 A Leonforte (2013) A study of salinity tolerance in field pea. University of Melbourne Australia, <https://minerva-access.unimelb.edu.au/handle/11343/38605>

16 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

5.7 Reduced shattering

The introduction of the sugar-pod trait into field pea varieties has meant shatter resistance is present now in the semi-leafless Kaspera-type field peas (e.g. PBA Wharton[®]). Other conventional, trailing-type field peas have also had some degree of shatter resistance incorporated by breeding, but not with the sugar-pod trait (e.g. PBA Oura[®]).



Photo 2: *Kaspera-type field pea with the sugar-pod trait to minimise shattering.*

Photo: W. Hawthorne, formerly Pulse Australia

5.8 National field pea breeding objectives

For a summary of field pea breeding objectives and techniques, see A Fresh Look at Field Pea Breeding by Dr Garry Rosewarne Agriculture Victoria, https://www.csu.edu.au/_data/assets/pdf_file/0003/2647650/CSU-symposiumRosewarne.pdf

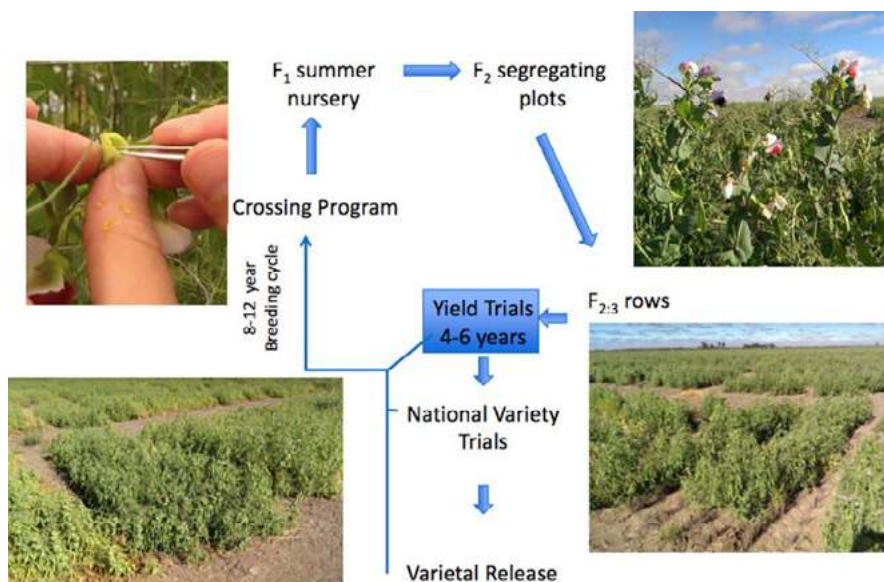


Figure 6: Field pea breeding stages.

Source: Rosewarne 2015, https://www.csu.edu.au/_data/assets/pdf_file/0003/2647650/CSU-symposiumRosewarne.pdf

The existing Pulse Breeding Australia (PBA) field pea breeding strategy has worked well in the past, but now breeding uses:

- statistical analysis to improve understanding of genotype and environmental interactions (GxE);
- alternative strategies to better combine multiple traits;
- advance generations to fixation to improve yield and incorporate molecular markers; and
- new technologies to dramatically shorten the breeding cycle.¹⁷

The PBA breeding programs, including for field pea, are delivering new pulse varieties with:

- improved regional adaptation;
- higher yield;
- superior resistance to diseases (such as Ascochyta and bacterial blight, Botrytis grey mould);
- outstanding quality parameters for mainstream and special purpose end users; and
- improved abiotic stress tolerance (such as salt, boron, heat, frost) compared to currently available varieties.

Together with its commercial partners, PBA has developed models of variety release that ensure varieties are available to Australian growers up to 3 years faster by providing commercial parties with access to a pipeline of varieties and by ensuring:

- seed production begins earlier in the development process; and
- crop-specific release advisory groups critically review data to identify varieties that can be fast-tracked to commercial release.

¹⁷ G Rosewarne (2015). A Fresh Look at Field Pea Breeding. Agriculture Victoria, https://www.csu.edu.au/_data/assets/pdf_file/0003/2647650/CSU-symposiumRosewarne.pdf

Nutrition and fertiliser

Key points

- Fertilisers are a major cost of growing a crop. Fertiliser decisions are complex and individual growers may have different objectives but, regardless of circumstances, growers need to know what nutrients are in short supply and which are adequate.¹
- Under-fertilisation and over-fertilisation can lead to economic losses due to unrealised crop potential or wasted inputs.
- Understanding the nutrient status of a paddock is essential for optimum plant growth.
- Nutrients are removed as grain and need to be replaced to ensure adequate soil fertility for following crop yields.
- Each tonne of field pea grain removes 40 kg/ha of nitrogen, 4 kg/ha phosphorus, 8 kg/ha potassium, 2 kg/ha sulfur and 1 kg/ha magnesium. Field pea should not normally require nitrogen fertiliser, except for 'starter' nitrogen in soils with extremely low levels.
- Fertilisers must supply a balance of required nutrients for a crop to achieve its potential yield. Nutrient budgeting and soil and plant tissue tests are tools to help determine fertiliser needs.
- Microbial activity in the soil is also affected by soil pH, with most activity occurring in soils of pH 5.0 to 7.0.
- Soil pH affects the availability of nutrients and affects how the nutrients react with each other. At a low pH, beneficial elements such as Mo, P, Mg and Ca become less available to plants. Other elements such as Al, Fe and Mn may become more available and Al and Mn may reach levels that are toxic to plants.
- Micronutrient deficiencies and toxicities show specific symptoms in field pea.
- Fertiliser applied too close to the seed can be toxic. Acid fertilisers can also inhibit rhizobia activity and nodulation.

¹ GRDC (2013) Better fertiliser decisions for crop nutrition. GRDC Crop Nutrition Fact Sheet November 2013, <http://www.grdc.com.au/GRDC-FS-BFDCN>

6.1 Nutrients

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

Macronutrients are those elements that are needed in relatively large amounts. They include nitrogen (N), phosphorus (P) and potassium (K), which are the primary macronutrients, with calcium (Ca), magnesium (Mg) and sulfur (S) considered as 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, with different requirements for nutrients and may display different symptoms of deficiency.

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

Macro- and micronutrients are taken up by the roots and certain soil conditions are required for that to occur. Soil must be sufficiently moist to allow roots to take up and transport the nutrients. Plants that are moisture-stressed from either too little or too much moisture (saturation) can often exhibit deficiencies even though a soil test may show these nutrients to be adequate.

The optimum range of temperature, pH and moisture can vary for different pulse species. Soil pH has an effect on the availability of most nutrients and must be within a particular range for nutrients to be released from soil particles.

Soil temperature must be within a certain range for nutrient uptake to occur.²

6.1.1 Understanding soil pH

A soil pH (CaCl₂) of 5.2 to 8.0 provides optimum conditions for most agricultural plants. All plants are affected by the extremes of pH but there is wide variation in their tolerance of acidity and alkalinity. Some plants grow well over a wide pH range, while others are very sensitive to small variations in acidity or alkalinity. Figure 1 provides a guide to the preferred pH (CaCl₂) for some common crops and pastures.

Microbial activity in the soil is also affected by soil pH with most activity occurring in soils of pH 5.0 to 7.0. Where the extremities of acidity or alkalinity occur, various species of earthworms and nitrifying bacteria are fewer. Legume root colonising bacteria (rhizobia) vary in their sensitivity to soil pH and have preferred ranges in which they are effective. In some crops and pastures (e.g. faba bean and lucerne) the rhizobia specific to these plants are more sensitive than the plant itself.

Soil pH affects the availability of nutrients and affects how the nutrients react with each other. At a low pH, beneficial elements such as Mo, P, Mg and Ca become less available to plants. Other elements such as Al, Fe and Mn may become more available and Al and Mn may reach levels that are toxic to plants (Figure 1).³

Lime can be applied to increase low pH levels. The pH-mapping process can deliver immediate lime savings of 20–60%, with an average saving of 30%. A 10% lime saving is generally required to cover the cost of the mapping process.⁴ See more in the GRDC Update paper pH-mapping and variable rate lime: 50,000 plus hectares of experience (<https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/08/ph-mapping-and-variable-rate-lime-50000-plus-hectares-of-experience>).

MORE INFORMATION

For more information on crop-specific reactions to soil pH, download the NSW Department of Primary Industries leaflet Understanding soil pH:
http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/167187/soil-ph.pdf

2 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>
 3 B Lake (2000) Understanding soil pH. Acid Soil Management Series. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/167187/soil-ph.pdf
 4 A Whitlock (2015) pH mapping and variable rate lime. GRDC Update Papers, 27 August 2015, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/ph-mapping-and-variable-rate-lime-50000-plus-hectares-of-experience>

Soil pH in calcium chloride

This is the standard method of measuring soil pH in all states other than Queensland. An air-dry soil sample is mixed with five times its weight of a dilute concentration (0.01 M) of calcium chloride (CaCl₂), shaken for 1 hour and the pH is measured using an electrode. The results are usually expressed as pH (CaCl₂).

Soil pH in water

Distilled water is used in place of 0.01 M calcium chloride and results are expressed as pH (w).

The pH (CaCl₂) test is the more accurate of the two pH tests, as it reflects what the plant experiences in the soil. The values of pH(CaCl₂) are normally lower than pH (w) by 0.5 to 0.9. A useful, but not consistently accurate, conversion is to subtract 0.8 from the pH (w) value to obtain a pH (CaCl₂) value. The difference between the methods can be significant when interpreting results and it is important to know which method has been used, especially if pH figures derived some years apart are being compared to assess any pH fluctuations.

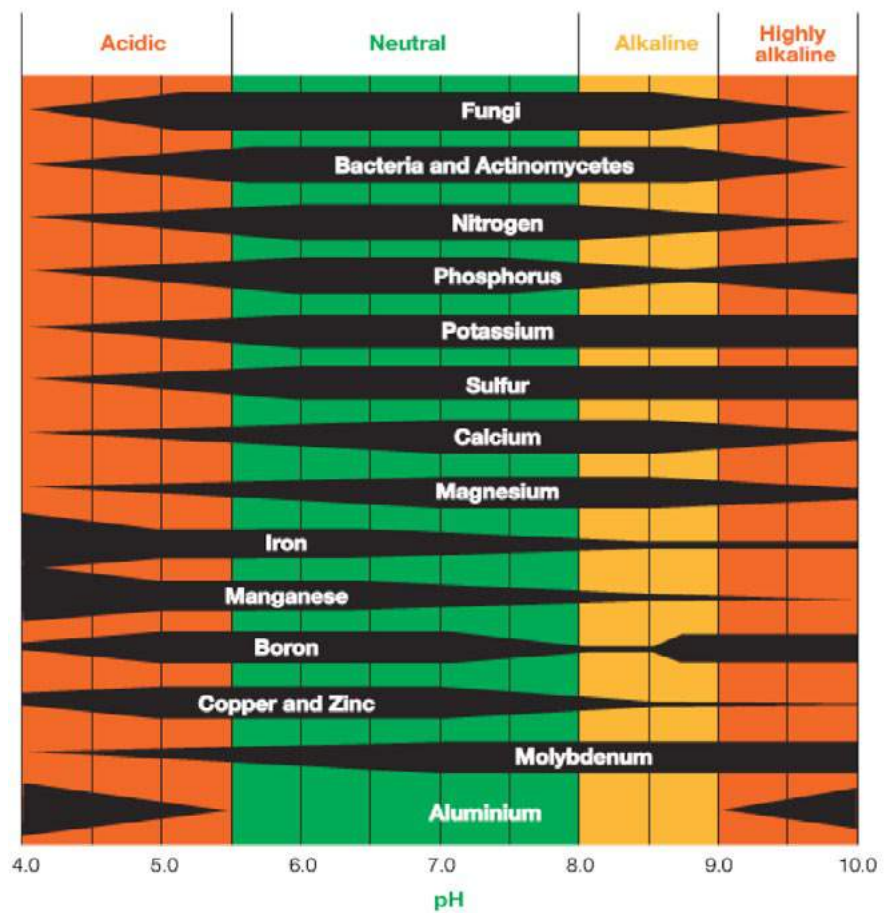


Figure 1: Availability of nutrients and other elements varies with soil pH.

Source: GRDC GrowNotes™ Barley (Southern)

6.2 Declining soil fertility

The natural fertility of cropped agricultural soils is declining over time. Grain growers must continually review their management programs to ensure the long-term sustainability of high-quality grain production. Pasture leys, legume rotations, fertilisers and the farming systems employed, all play an important role in maintaining the chemical, biological and physical fertility of soils.

Nutrition programs should be reviewed regularly due to more frequent opportunity cropping from improved farming techniques and new higher-yielding varieties. Paddock records, fertiliser test strips, crop monitoring, and soil and plant tissue tests all assist in the formulation of an efficient cropping program.

Although crop rotations with pulses and ley pastures play an important role in maintaining and improving soil fertility, fertilisers remain the major source of nutrients to replace those removed by grain production. Fertiliser programs must supply a balance of the required nutrients in amounts needed to achieve a crop's yield potential. High-yielding crops remove large amounts of nutrients in the grain.

The yield potential of a crop will be limited by any nutrient the soil cannot adequately supply. Poor crop response to one nutrient is often linked to a deficiency in another nutrient or management technique. Sometimes, poor crop response can also be linked to acidity, sodicity or salinity, pathogens or a problem with beneficial soil microorganisms.⁵

6.3 Crop removal rates and balancing inputs

Ultimately, nutrients removed from paddocks will need to be replaced to sustain production.

The nutrient removal per tonne (t) of field pea is shown in Table 1. Actual values may vary by 30%, or sometimes more, because of differences in soil fertility, varieties and seasons.

Table 1: Amounts of macro- and micro-nutrients removed per tonne of field pea.

Major nutrients (kg)	
Nitrogen (N)	40
Phosphorus (P)	3.9
Potassium (K)	8
Sulfur (S)	1.8
Calcium (Ca)	0.7
Magnesium (Mg)	0.9
Minor nutrients (g)	
Copper (Cu)	7
Zinc (Zn)	28
Manganese (Mn)	14

⁵Representative products of many for most chemicals

Source: GRDC (2009) Field Peas: The Ute Guide

From the table it can be seen that a 3 t/ha crop of field pea will remove, on average, 3 x 4 kg/ha = 12 kg/ha of phosphorus. To maintain long-term soil fertility this is the amount of phosphorus that needs to be replaced. Higher quantities may be needed to build up soil fertility or overcome soil fixation of phosphorus.

5 Queensland DAF (2010) Nutrition management: overview. Queensland Department of Agriculture and Fisheries, <https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview>

Soil types do vary in their nutrient reserves. For example, most black and red soils in the eastern states have sufficient reserves of potassium to grow many crops. However, grain crops grown on the light, white sandy soils which have less than 50 ppm (Bicarb test) of potassium will respond to applications of potassium fertiliser.

Other soils may have substantial nutrient reserves which vary in availability during the growing season or are unavailable due to the soil's pH. This can often be the case with micro-nutrients. Foliar sprays may correct micro-nutrient deficiencies if timing is appropriate.⁶

6.4 Testing for balanced nutrition

To obtain the maximum benefit from every dollar spent, fertiliser programs must provide a balance of required nutrients. There is little point in applying enough N if P or Zn deficiency is limiting yield. To make better crop nutrition decisions, growers need to consider the use of paddock records, soil tests, plant tissue tests and paddock test strips.

6.4.1 Paddock records

Paddock records help:

- establish realistic target grain yield/protein levels prior to planting;
- modify target yield/protein levels based on previous crop performance, planting soil moisture, planting time, fallow conditions, expected in-crop seasonal conditions and grain quality requirements;
- determine appropriate fertiliser type, rate and application method; and
- compare expected with actual performance per paddock and modify fertiliser strategies to optimise future yield/protein levels.

6.4.2 Soil testing

Soil test results are part of the information that support decisions about fertiliser type, rate, timing and placement. Principal reasons for soil testing for nutrition include:

- monitoring soil fertility levels;
- estimating which nutrients are likely to limit yield;
- measuring properties such as pH, sodium (sodicity) and salinity, which affect the crop water demand as well as the ability to access nutrients;
- zoning paddocks for variable fertiliser application rates; and
- as a diagnostic tool, to identify reasons for poor plant performance.

Types of test

The soil test for measuring N, P, K or S in the southern region are:

- bicarbonate extractable P (Colwell-P)
- diffusive gradients in thin-films (DGT) for P
- bicarbonate extractable K (Colwell-K)
- KCl-40 extractable S
- 2 M KCl extractable inorganic N, which provides measurement of nitrate-N and ammonium-N.⁷

DGT-P is the preferred test for calcareous soils in southern Australia and western Victoria.⁸

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

7 GRDC (2014) Soil testing for crop nutrition, southern region. GRDC Crop Nutrition Fact Sheet, January 2014 <http://www.grdc.com.au/GRDC-FS-SoilTestingS>

8 GRDC (2013) Better fertiliser decisions for crop nutrition. GRDC Crop Nutrition Fact Sheet, November 2013, www.grdc.com.au/GRDC-FS-BFDCN

The more consideration we give to all of the activities that contribute to the nutrient management process (Figure 2), the better the outcome we will get from the soil and plant testing. Testing may not provide a useful contribution if one or more of these activities is not done well.

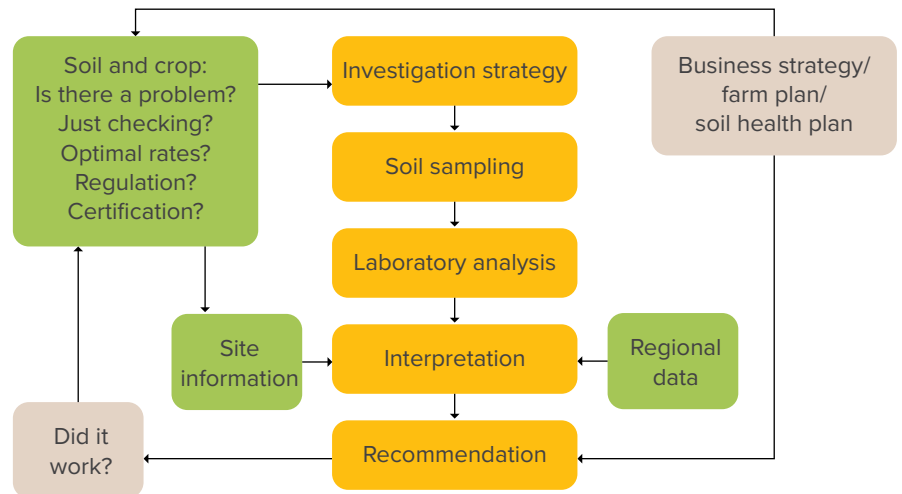


Figure 2: Nutrient management flow chart.

Source: GRDC (2013) Better fertiliser decisions for crop nutrition. GRDC Crop Nutrition Fact Sheet, November 2013, <http://www.grdc.com.au/GRDC-FS-BFDCN>

Sampling depth

Soil sampling depth for most nutrient analyses is 0–10 cm. For N and S, which are highly mobile in the soil, 0–60 cm is recommended. There is increasing evidence of the value of assessing soil-based physicochemical constraints to production, including sodicity, salinity and acidity/aluminium, from both the surface and subsoil layers.

In some regions, evidence suggests that deep soil samples should be analysed for nutrients other than N. This is still not fully supported for the soils in the Southern Region. Deep sampling especially for S, EC and B to the depth of any root barriers is now carried out regularly.

To ensure that a sample is representative:

- Check that the soil type and plant growth is typical of the whole zone or paddock.
- Avoid areas such as stock camps, old fence lines and headlands.
- Ensure that each subsample is taken to the full sampling depth.
- Do not sample in very wet conditions or within 2 weeks after significant summer rain.
- Do not take shortcuts in sampling, such as taking only one or two cores, a handful, or a spadeful of soil, as this will give misleading results.
- Avoid contaminating the sample, the sampling equipment and the sample storage bag with fertilisers or other sources of nutrients (e.g. sunscreen, which can contain Zn).

Soils must be sampled to the correct depth. Sampling depths of 0–10 and 10–60 cm are generally used. The 0–10 cm sample should be used for a comprehensive soil test (all nutrients, cations, pH, EC, sodium). The 10–60 cm sample (or known rooting depth) is more commonly used to determine levels of N, S, EC and boron (or other nutrient constraints) and moisture. Sulfur testing at 0–10 cm is not as indicative of crop needs as 0–60 cm, and this is more so on sandy soils where leaching of S from the topsoil readily occurs. If subsoil constraints are suspected, pH, EC, sodium and chloride are tested at intervals (e.g. 30 cm) to 120 cm where possible.

Critical values and ranges

A soil-test critical value is the soil test value required to achieve 90% of crop yield potential (Figure 3).

The critical range around the critical value indicates the reliability of that single value. The narrower the range the more reliable the data. See Table 2 for Colwell-P test for field pea.

The critical value indicates whether nutrient supply is likely to result in a crop yield response.

Table 2: Critical soil test values at 0–10cm sampling for 90% of relative yield.

Soil test	Crop	Soil type*	Critical values (mg/kg)	Critical range (mg/kg)
Colwell-P**	Wheat and barley	Vertosol	17	12–25
		Chromosol/sodosol	22	17–28
		Brown/red chromosol	25	18–35
		Calcarosol	34	26–44
	Barley	Ferrosols	76	46–130
	Canola	All soils	18	16–19
	Field pea	All soils	24	21–28
Colwell-K	Wheat	Chromosols	40	35–45
		Brown ferrosols	64	57–70
		Kandosols	49	45–52
		Tenosols	41	32–52
	Canola	All soils	45	43–47
	Lupin	Tenosols (WA data)	24	22–27
KCI-40 S+	Wheat	Chromosols/ kandosols/sodosols/ tenosols/vertosols	4.5	3.2–6.4
		Canola	NSW data (0 to 15cm)	8.6
		Canola	NSW data (0 to 60cm)	31

* Soil types are based on the Australian Soil Classification. ** Currently insufficient data to provide similar calibration criteria for DGT-P. Check BFDC Interrogator for DGT-P. + There was insufficient S data to measure 0 to 10cm

Source: GRDC (2014) Soil testing for crop nutrition, southern region. GRDC Crop Nutrition Fact Sheet, January 2014, <http://www.grdc.com.au/GRDC-FS-SoilTestingS>

The values used to determine the soil test and crop response relationship have been derived from fertiliser rate trials, where various fertiliser rates were applied and the crop yield response measured. With many of these experiments, soil test values and crop response graphed.

If a soil test value is less than the lower limit of the range (Figure 3), the site is highly likely to respond to an application of the nutrient. For values within the critical range, there is less certainty about whether a response will occur. If a response does occur, it will likely be small. Growers must exercise judgement about the costs and benefits of adding fertiliser in the forthcoming season versus those associated with not applying. If the soil test is outside the critical range, fertiliser must be considered to maintain soil levels or to lower the risk of encountering deficiency.⁹

To determine how much fertiliser to apply, soil test results need to be considered in combination with information about potential yield, soil type and nutrient removal in previous seasons.

⁹ GRDC (2014) Soil testing for crop nutrition, southern region. GRDC Crop Nutrition Fact Sheet, January 2014, <http://www.grdc.com.au/GRDC-FS-SoilTestingS>

i MORE INFORMATION

For more information GRDC Crop Nutrition Fact Sheet: Soil testing for crop nutrition, Southern Region <https://grdc.com.au/GRDC-FS-SoilTestingS>

i MORE INFORMATION

A number of local Grower Groups conduct nutrition trials.

For more information: Guidelines for Successful on Farm Trials http://www.spaa.com.au/files/conducting_on_farm_trials.pdf

For more information Agriculture Victoria: Using fertiliser test strips on pasture <http://agriculture.vic.gov.au/agriculture/farm-management/chemical-use/agricultural-chemical-use/fertilisers/using-fertiliser-test-strips-on-pasture>

Relative yield (%)

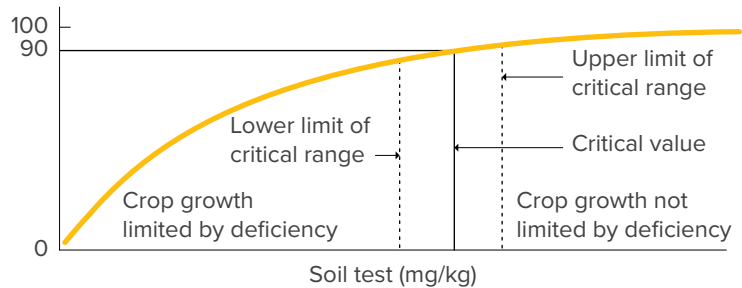


Figure 3: A generalised soil test/crop response relationship between soil test value and percent grain yield expected.

Source: GRDC (2014) Soil testing for crop nutrition, southern region, GRDC Crop Nutrition Fact Sheet January 2014 <http://www.grdc.com.au/GRDC-FS-SoilTestingS>

In Figure 3, a critical value and critical range are defined from this relationship. The relative yield is the unfertilised yield divided by maximum yield, expressed as a percentage. Normally 90% of maximum yield is used to define the critical value but critical values and ranges at 80% and 95% of maximum yield can also be produced.

6.4.3 Fertiliser test strips

Test strips allow you to fine tune your fertiliser program. To gain the maximum benefit:

- Run them over a number of years, as results from any single year can be misleading.
- Obtain accurate strip yield weights.
- Protein test a sample of grain from each strip.
- Harvest strips before your main harvest, as the difference between the strips is more important than the moisture content.

When setting up a test strip area:

- Ensure you can accurately locate the strips, a GPS reading would be valuable.
- Repeat each fertiliser treatment two or three times within the paddock to get a better average.
- Change only one product rate at a time.
- Separate each strip of fertiliser by a nil fertiliser strip.
- Ensure the tests are done over a part of the paddock with uniform soil types.
- Keep clear of shade lines, trees, fences, headlands and any known anomalies in the field.
- Ensure that the test strip area is around 100 m long, with each strip 1–2 header widths.¹⁰

¹⁰ Queensland DAF (2010) Nutrition management: Overview, Queensland Department of Agriculture and Fisheries, <https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview>

6.4.4 Rules of thumb for sampling procedures

Choose the same soil test package each year (including methods), otherwise comparisons between years will be useless. For example, do not use Colwell-P in one year, then DGT-P the next. The two tests measure different forms of available P in the soil.

If you do not use a standard approach to sampling, comparison of the data between different tests will not be reliable. Aim for data that have the best chance of representing the whole paddock, and mix the sample thoroughly.

For monitoring, sampling needs to cover roughly the same area each time to ensure comparisons between years are meaningful. Permanent markers on fence posts to mark a sampling transect or a handheld GPS or your smartphone, will serve this purpose.

Soil testing laboratories should be able to provide information on appropriate soil sampling and sample-handling protocols for specific industries and crop types. Refer to the Australian Soil Fertility Manual (<http://www.publish.csiro.au/book/5338>) from CSIRO Publishing or download the GRDC Fact sheet Better fertiliser decisions for crop nutrition (<https://grdc.com.au/GRDC-FS-BFDCN>).

Utilise the Australian Soil and Plant Analysis Council (ASPAC) or National Association of Testing Authorities (NATA) accredited testing services. The results are more likely to be statistically significant and have reduced variation between tests.¹¹

6.4.5 Plant tissue testing

Plant tissue testing is a helpful tool to diagnose nutrient deficiency and monitor general health of pulse crops. It is beneficial because the reliance on visible symptoms can take longer before problems are noticeable and crop yield can be markedly reduced.

As with soil tests, different plants have different critical concentrations (critical values and ranges) for a nutrient. In some cases, varieties can vary in their critical concentrations. [Table 3](#) lists the critical nutrient levels for field pea at flowering. These should be used as a guide only. Care should be taken to use the plant tissue tests for the intended purpose. They cannot reliably indicate the effect on a particular deficiency on grain yield.

Table 3: Critical nutrient levels for field pea at flowering.

Nutrient	Plant part	Critical range*
Nitrogen (%)	YML**	0.25–0.30
Phosphorus (%)	YML	1.5–2.0
Potassium (%)	YML	0.6
Calcium (%)	YML	0.2
Magnesium (%)	YML	0.2
Sulfur (%)	Whole shoot	20
Boron (mg/kg)	YML	3.0–5.0
Copper (mg/kg)	YML	30
Manganese (mg/kg)	YML	18
Zinc (mg/ha)	YML	18

*Any nutrient level below the critical range will be deficient, any level above will be adequate. **Youngest mature leaf
 Note: Application of remedial fertiliser is much too late at the flowering stage, but an indicator for the following year.
 Source: Grain Legume Handbook (update 2008), Grain legumeHandbookCommittee. GRDC <https://grdc.com.au/grainlegumehandbook>

¹¹ GRDC (2013) Better fertiliser decisions for crop nutrition. Crop Nutrition Fact Sheet, GRDC, 4 November 2013, <http://www.grdc.com.au/GRDC-FS-BFDCN>

The critical range can be difficult to use. Wide variations in tissue test results can be due to stress, such as frost or waterlogging, or even more subtle factors such as solar radiation or time of day sampling was carried out.¹²

Plant tissue testing is a more reliable method than soil testing for diagnosing and monitoring micronutrient status.

It is essential to collect a proper sample for tissue testing. The distribution of micronutrients can be different in leaves, stems or whole plants.

Plant nutrient status may also vary according to the age of the plant, the variety and the weather conditions.¹³

The successful use of plant tissue analysis depends on sampling the correct plant part at the appropriate growth stage. Use the guide provided from the lab to collect your sample as your samples results will be assessed against these interpretative guidelines.¹⁴ Cleanliness is paramount. Do not contaminate samples with dirt or extraneous material.

Although a valuable tool, tissue testing must be used as only one part of the integrated nutrition program.¹⁵

6.5 Nutrient imbalances

Grain cropping is about converting rainfall into a harvestable commodity as often and as efficiently as possible. Adequate nutrition is a constraint that can have a significant influence on the overall productivity of the system.¹⁶

Incorrect levels of nutrient (too little, too much or in the wrong proportion) can cause problems. If the condition is extreme, plants will show visible symptoms that can sometimes be identified, however visual symptoms do not develop until a major effect on growth, development or yield has occurred.

Plant tissue analysis can play an important role in detecting non-visible symptoms and in fine-tuning nutrient requirements.

Tissue tests also help to identify the cause of symptoms being expressed by plants but not fitting a visual diagnosis. Technology is enabling quicker analysis and reporting of results to enable foliar or soil-applied remedies to be applied in a timely manner for quick crop response.¹⁷

6.5.1 Considerations when diagnosing nutrient disorders

Visual symptoms of nutrient disorders can assist in diagnosis. However, considerable yield loss can occur without there necessarily being any visual symptoms present.

The following points should be considered when diagnosing nutrient disorders:

- Visual symptoms on field pea may be caused by damage from herbicides, insects and pathogens. Damage may also be from physiological disorders arising from adverse environmental effects such as salinity, drought, cold, heat or high temperature stresses. Such symptoms can be indistinguishable from nutrient deficiency, although it should be obvious if environmental conditions are limiting (moisture stress).
- Factors that influence both nodulation and nitrogen fixation can result in symptoms of nitrogen deficiency.

12 GRDC Chickpea Northern Region GrowNotes™, <https://www.grdc.com.au/grownotes>

13 GRDC (2013) Micronutrients. GRDC Crop Nutrition Fact Sheet, November 2013, <http://www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients>

14 GRDC (2010) Research & Development: Plant tissue testing an under-utilised tool for diagnosing hidden hunger in crops, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/PLANT-TISSUE-TESTING-AN-UNDER-UTILISED-TOOL-FOR-DIAGNOSING-HIDDEN-HUNGER-IN-CROPS>

15 Pulse Australia (2013) Northern chickpea best management practices training course manual-2013, Pulse Australia Limited

16 GRDC (2010) Research & Development: Plant tissue testing an under-utilised tool for diagnosing hidden hunger in crops, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/PLANT-TISSUE-TESTING-AN-UNDER-UTILISED-TOOL-FOR-DIAGNOSING-HIDDEN-HUNGER-IN-CROPS>

17 Pulse Australia (2013) Northern chickpea best management practices training course manual-2013, Pulse Australia Limited

- There can be differences between cultivars in the manifestation of symptoms.
- Visual symptoms in one pulse do not necessarily mean that it is the same in other pulses.

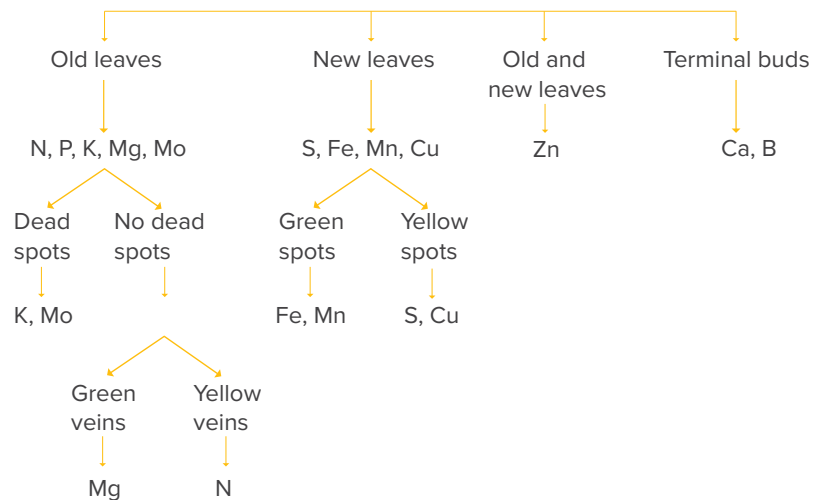


Figure 4: Flow chart for the identification of deficiency symptoms.

Source: T Reddy, G Reddi (1997) Mineral nutrition, manures and fertilizers. In Principles of Agronomy, Kalyani Publishers, Ludhiana, India; pp. 204–256

6.5.2 Identifying nutrient deficiencies

Many nutrient deficiencies may look similar. To identify deficiencies:

- Know what a healthy plant looks like in order to recognise symptoms of distress.
- Determine what the affected areas of the crop look like. For example, are they discoloured (yellow, red, brown), dead (necrotic), wilted or stunted?
- Identify the pattern of symptoms in the field (patches, scattered plants, crop perimeters).
- Assess affected areas in relation to soil type (pH, colour, texture) or elevation.
- Look at individual plants for more detailed symptoms such as stunting, wilting and where the symptoms are appearing (whole plant, new leaves, old leaves, edge of leaf, veins etc).

If more than one problem is present, typical visual symptoms may not occur. For example, water stress, disease or insect damage can mask or be confused with a nutrient deficiency.

If two nutrients are simultaneously deficient, symptoms may differ from the deficiency symptoms of the individual nutrients.

Micronutrients are often used by plants to process other nutrients or work together with other nutrients, so a deficiency of one may look like deficiency of another. For instance, molybdenum (Mo) is required by pulses to complete the process of nitrogen (N) fixation.

Soil pH has an effect on the availability of most nutrients and must be within a particular range for nutrients to be released from soil particles (see [Figure 1](#)). On acid soils, aluminium (Al) and Mn levels can increase and may restrict plant growth, usually by restricting the rhizobia and so the plant's ability to nodulate.

Soil temperature must lie within a certain range for nutrient uptake to occur. Cold and wet conditions can induce deficiencies of nutrients such as Fe, Zn or P. Iron deficiency is common in field pea mid-winter on calcareous soils (see [Section 6.6.8](#)).

SECTION 6 FIELD PEA

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The optimum range of temperature, pH and moisture can vary for different pulse species. 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 very useful for predicting which nutrients may become deficient. Tissue tests can help to confirm the plant nutrient status.¹⁸

Table 4: Key to nutrient deficiencies in field pea.

Symptom Deficiency	Old to middle leaves					Middle to new leaves					New leaves to terminal shoots						
	N	P	K	Mg	Zn	N	Zn	Ca	Mn	B	S	Mg	Mn	Fe	Cu	Ca	B
Chlorosis (yellowing)																	
Complete											x						x
Mottled	x	x		x			x	x	x								x
Interveinal											x						x
Crescent form								x									
Necrosis (tissue death)																	
Complete				x													x
Distinct areas (including spotting)	x			x	x				x			x	x	x			
Margins			x	x		x	x				x						x
Tips			x			x	x				x		x	x	x		x
Pigmentation within necrotic (yellow) or chlorotic (dead) areas																	
Opaque																	x
Light brown						x	x				x			x			
Brown			x														
Pink				x	x				x	x			x				x
Malformation of leaflets																	
Rolling in of margin				x	x									x			x
Wilting						x	x										x
Twisting			x								x						
Puckering														x			x
Malformation of leaves																	
Cupping										x							
Rosetting										x							x
Tendrils distortion						x							x	x			x
Internode shortening			x														x
Stem lesions										x							x
Petiole collapse																	x
Root distortion											x						x

Source: K Snowball and AD Robson (1991) Symptoms of nutrient disorders: Faba beans and Field peas. University of WA

i MORE INFORMATION

More information on diagnosing nutrient deficiencies and toxicities see:

Field peas: The Ute Guide by GRDC at the iTunes or App Store

Field pea diagnostic tool, DPIRD <https://agric.wa.gov.au/n/4505>

6.5.3 Field pea nutrient deficiencies

The main deficiencies encountered in field pea are:

- Nitrogen, when nodulation is poor or ineffective (e.g. in acid soils).
- Phosphorus, on high production or calcareous ground with inadequate history of phosphorus input.
- Zinc, on many alkaline cropping soils.
- Manganese, on soils with high lime content.¹⁹
- Iron, on soils of high pH, especially where soils are wet and cold conditions exist.

6.5.4 Nutrient toxicity

Soil pH affects the availability of most nutrients (Table 1). Occasionally some nutrients are so available that they inhibit plant growth. For example, on some acid soils, aluminium (Al) and manganese (Mn) levels may restrict plant growth, usually by restricting the rhizobia and so the plants' ability to nodulate (Table 5).

Table 5: Pulse reactions to nutrient toxicities.

	Boron	Aluminium	Manganese
Chickpea	sensitive	very sensitive	very sensitive
Faba bean	tolerant	sensitive	sensitive
Lentil	very sensitive	very sensitive	very sensitive
Lupin	*	tolerant	tolerant
Field pea	sensitive	sensitive	sensitive

*This crop not usually grown on alkaline - high boron soils.

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

Field peas are affected by high salinity and boron levels, often found in subsoils in many areas of the southern cropping zone. They are also sensitive to aluminium and manganese toxicity, which affect acidic soils generally, making them unsuitable for peas.²⁰

Boron (B) toxicity occurs on many of the alkaline soils of the southern cropping areas (Figure 5). The most characteristic symptom of B toxicity in pulses is chlorosis (yellowing) and, if severe, some necrosis (death) of leaf tips or margins. Older leaves are usually more affected.

¹⁹ GRDC (2009) Field peas: The Ute Guide, Southern region. GRDC Ground Cover Direct

²⁰ GRDC (2009) Field peas: The Ute Guide, Southern region. GRDC Ground Cover Direct

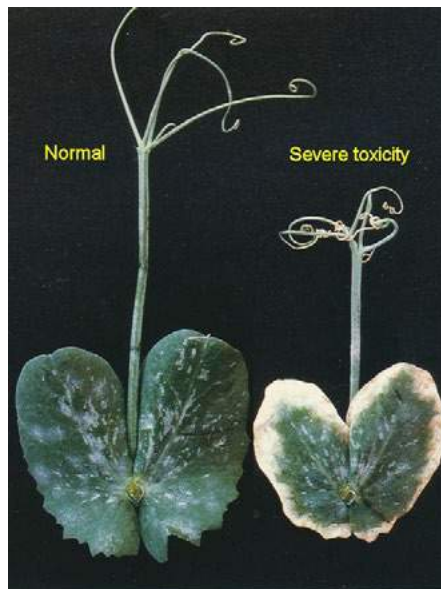


Figure 5: Symptoms of boron toxicity in field pea.

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

Manganese toxicity (Figure 6) is worse in acidic, heavy textured parts of paddocks. New leaves and tendrils are first and most severely affected.

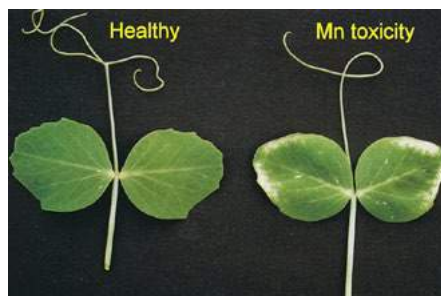


Figure 6: Symptoms of manganese (Mn) toxicity in field pea.

Photo: © A Robson, DPIRD (2015). <https://agric.wa.gov.au/n/4475>

Aluminium toxicity in field pea is often associated with acid soils. Old and middle leaves develop large, cream coloured necrotic patches (Figure 7).

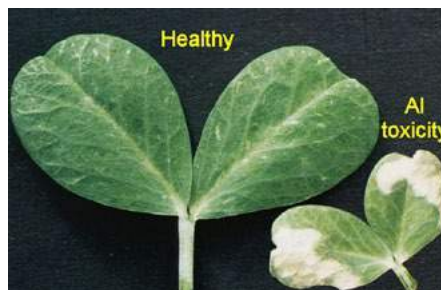


Figure 7: Symptoms of aluminium (Al) toxicity in field pea.

Photo: © A Robson, DPIRD 2015 <https://agric.wa.gov.au/n/44872014>

6.6 Fertiliser

Fertiliser recommendations for field pea, as with most pulses, tend to be generic, with an over-reliance on the recommendation of MAP-based starter fertilisers across nearly all situations. This is often driven by convenience and availability, rather than meeting the specific nutrient requirements of the crop.

Fertiliser recommendations need to be more prescriptive and should take into account:

- soil type;
- rotation (fallow length and impact arbuscular mycorrhizal fungi (AMF), <http://www.soilquality.org.au/factsheets/arbuscular-mycorrhizas-s-a-levels>);
- yield potential of the crop;
- plant configuration (row spacing, type of opener and risk of 'seed burn');
- soil analysis; and
- effectiveness of inoculation techniques.

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

Soil P levels influence the rate of nodule growth. Phosphorus-based fertilisers with nitrogen i.e. monoammonium phosphate (MAP) and diammonium phosphate (DAP) can be used in small amounts (5–15 kg N/ha). They are not harmful to nodulation and can be beneficial by enhancing early root growth to establish a stronger plant. MAP or DAP fertilisers can be used.

However, excessive amounts of N will restrict nodulation and thereby reduce N fixation.

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
- MAP, also known as 11:23:0 and Starter 12.

Neutral fertilisers include:

- 'Super lime'.

Alkaline fertilisers include:

- DAP, also known as 18:20:0
- starter NP
- lime.²¹

6.6.1 Pulses and fertiliser toxicity

All pulses can be affected by fertiliser toxicity. Lupins are especially susceptible. Higher rates of P fertiliser can be toxic to lupin establishment and nodulation if drilled in close contact with the seed at sowing.

Changes in sowing techniques to narrow sowing points or disc seeders with minimal soil disturbance, and wider row spacing has increased the concentration of fertiliser near the seed. In turn this increases the risk of toxicity.

The effects are also increased in highly acidic soils, and 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.

²¹ Pulse Australia (2016) Southern Field Pea – Best management practices training course manual-2014, Module 4, General Agronomy, Draft. Pulse Australia Limited (2016)

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 at 18 cm row spacing.

Deep banding of fertiliser is often preferred for lupin, otherwise broadcasting and incorporating, drilling pre-seeding or splitting fertiliser application so that a lower P rate or no P is in contact with the seed.²²

6.6.2 Nitrogen (N)

Field pea should not normally need nitrogen fertiliser provided plants have effectively nodulated. However, field pea crops may benefit from nitrogen fertiliser applied at seeding, particularly where crop fertility is low and where nodulation may be restricted through late sowing, acid soils or waterlogging. Nitrogen should be applied at rates of 5–10 kg/ha as at this rate, nodulation will not be affected.

Key points

- If field pea plants have effectively nodulated, they should not normally need N fertiliser.
- Nitrate (NO_3^-) is the highly mobile form of inorganic nitrogen in both the soil and the plant (Figure 8).
- Sandy soils and nitrogen models will help determine seasonal nitrogen requirements.²³

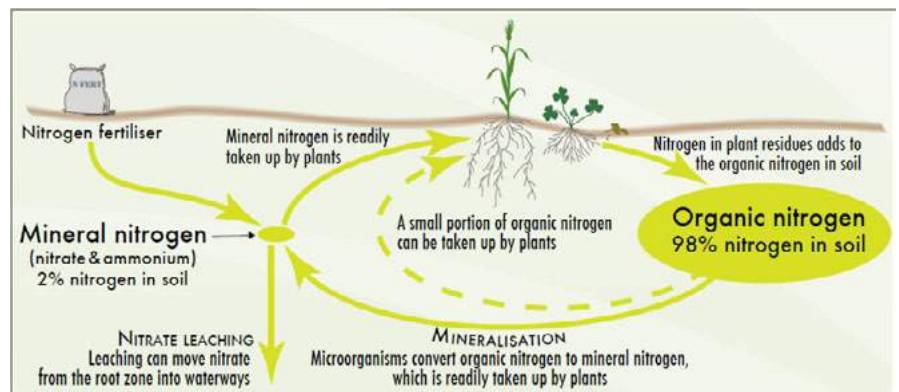


Figure 8: The soil nitrogen cycle showing the role of mineralisation in making organic nitrogen in soil available for plants to take up.

Source: Soil Quality Pty Ltd 2017 <http://www.soilquality.org.au/factsheets/soil-nitrogen-supply>

Factors influencing nitrogen supply from soils and stubbles

Nitrogen is the key major nutrient influencing crop production in Australian agricultural systems, and maintaining a close balance between inputs and outputs, as well as better synchronisation between N supply and plant demand, is the role of soil management, fertiliser, crop residues and crops.

Fertiliser N use in Australia has increased at an annual rate of approximately 14% compared to use in 1992, which is not only considered economically unsustainable but also environmentally undesirable. Most of the N-cycling processes such as N fixation, mineralisation and gaseous loss are biologically mediated. A diverse group of microbial communities are involved in the release of nitrate N from soil organic matter and they are present in all agricultural soils. There are direct links between processes involved in soil organic N cycling that also play a role in the transformation of fertiliser nitrogen (Figure 1). Therefore, management strategies that manipulate

²² Pulse Australia (2016) Southern Field Pea – Best management practices training course manual-2014, Module 4, General Agronomy, Draft. Pulse Australia Limited (2016)

²³ Soilquality.—Nitrogen – Western Australia, <http://www.soilquality.org.au/factsheets/mineral-nitrogen>

microbial communities controlling organic N cycling would help optimise both organic and fertiliser N use efficiency.

Soil type, crop rotation and management practices associated with tillage, stubble retention and fertiliser application can influence the diversity of microbial populations and, along with the environment, they affect biological processes involved in nitrogen fixation, mineralisation, and availability and losses. All of these processes and the associated microorganisms can be manipulated to optimise N use efficiency both by improving the supply of N from organic N and decreasing the losses via denitrification and leaching.

Nitrogen mineralised from soil organic matter and crop residues contributes to a large part of crop N requirements in the rainfed cropping regions across southern Australia. For example, in the year of application, fertiliser N contributes approximately 20–40% of the total N supply of wheat. Soil N supply comes from soil organic matter and recent crop residues and the rate of supply is influenced by the soil biological capacity and modulated by management and environmental factors.

The nitrogen mineralisation potential of the top 10 cm of soils generally ranges from 10–35 kg N/ha/season in sandy soils, 25–70 kg N/ha/year in clay and loam soils, and 30–100kg N/ha/year in red-brown earth soils.

The magnitude of soil biological processes and their impact on the farming system varies seasonally due to the variation in the time of their occurrence relative to the crop growth and demand. The effect of soil organisms involved in N mineralisation can be seen in both the off-season (fallow) and in-crop season (Figure 8). Nitrogen mineralised during the off-season may accumulate and/or be lost through leaching, denitrification or weed uptake, whereas the N mineralised during the growing season in the rhizosphere may be utilised immediately by the crop. In a farming system, factors influencing nutrient mineralisation/immobilisation processes need to be understood in order to synchronise nutrient availability to plant needs and also to reduce nutrient losses. Additionally, critical periods of biological activity must be taken into consideration to optimise management strategies that help synchronise N supply and availability to crops.

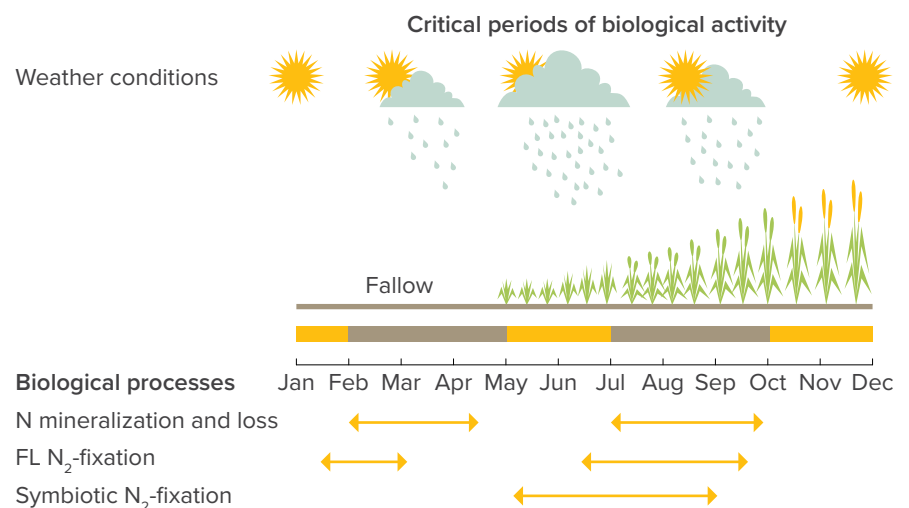


Figure 9: A conceptual diagram showing functionally important periods for different N-cycling biological processes and their impact within the farming systems in Australian winter-cropping growing regions.

Source: V Gupta (2016), <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/factors-influencing-nitrogen-supply-from-soils-and-stubbles>

Decomposition and N mineralisation

In low-fertility Australian agricultural soils, crop residues are one of the major sources of carbon (C) for soil biota and retention of stubble after harvest contributes to the conservation of nutrients taken up by the plant within the cropping system. A large portion of N used by crops is mineralised from previous crop and pasture residues through the activity of soil microorganisms (microbial biomass, MB).

Decomposition of crop residues is mainly a biological process involving diverse groups of microbial communities and facilitated by the activity of soil fauna. Land use changes from mixed farms where crop rotation with legume pastures was common to continuous cereal cropping generally resulted in a decline in crop-residue-based N mineralisation (Angus *et al.* 2006). The decline occurred mainly through altered crop residue quality, e.g. wider C:N ratio (100:1) cereal residues replacing N-rich legume residues (15:1 to 25:1). It is considered that crop residues with a C:N ratio >22:1 generally result in immobilisation (tie-up) of mineral N in microbial biomass.

The rate and timing of availability of nutrients from stubble to the following crops is determined by the rate of decomposition and immobilisation (tie-up) by soil microorganisms (N in microbial biomass, MB-N). The amount of N in microbial biomass varies with soil type, crop rotation, tillage and other management practices that can influence microbial populations (Table 6). In southern Australian cropping regions, the effect of loss of nutrients from stubble removal may be greater than the temporary tie-up of the nutrients during decomposition when retained. However, the scale of these effects varies depending upon stubble load, time and type of burning and tillage.

Table 6: Amount of nitrogen in microbial biomass and the soil N supply potential as influenced by soil type.

Location	Soil type	Microbial biomass (MB) (kg N/ha)	N supply potential (kg N/ha)
Waikerie/Karoonda, SA	Sand and sandy loam	25–45	10–35
Streaky Bay, SA	Calcarosol	30–60	15–50
Kerrabee, NSW	Loam	60–75	35–50
Temora, NSW	Red earth	75–105	50–100
Rutherglen, Victoria	Red-brown earth	50–100	30–100
Leeton/Warialda, NSW	Clay	50–110	25–75

N supply potential is calculated from N in MB plus N mineralisation measured in a lab incubation assay.

Source: V Gupta (2016) <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/factors-influencing-nitrogen-supply-from-soils-and-stubbles>

Stubble retention can provide benefits through changes in soils' physical, chemical and biological properties. However, the selection of stubble-management strategy has a substantial impact on the potential benefits to be gained from the activity of soil biota in their role in carbon turnover, nutrient mineralisation and subsequent availability of nutrients to crops. For example, tillage practices accelerate the decomposition and microbial turnover resulting in quick accumulation of mineral N, especially in soils with lower microbial biomass levels.

In addition, research from Victoria and South Australia has shown that tillage can disrupt the linkages between the activity of microbes processing organic N and those related to fertiliser and mineral N transformations influencing the rate of release and accumulation of mineral N in soil (Phillips *et al.* 2015; Gupta *et al.* 2011). This means strategic tillage practices could be developed to manipulate N release and losses (especially from legume residues), for example to synchronise the release of N to plant demand and avoid losses through leaching and denitrification.

Nitrogen released during decomposition and soil organic matter turnover is rapidly assimilated by MB, which is subsequently released through microbial turnover and microbe/fauna interactions. Results from field experiments in SA indicated that in the

sandy soils in the Mallee with lower levels of MB, there can be substantial movement (leaching) of mineral N (25–50 kg N/ha; $P < 0.05$) down the soil profile following summer rainfall (Figure 8). Retention of stubble, which generally increases the amount of MB, can therefore arrest the leaching of mineral N to lower depths.

Research at Karoonda in SA, on a dune–swale landscape, has shown that plant type (e.g. wheat, cereal rye, canola or pasture) can cause large changes in the functional diversity of microorganisms, i.e. microbial communities involved in various biological functions including N-cycling processes. Thus, in a crop rotation such changes, coupled with differences in the quantity and quality of organic residues (tops and roots), can significantly modify the N mineralisation/immobilisation processes and availability of N (McBeath *et al.* 2014). The magnitudes of these effects varies with soil type and region, which needs to be considered when designing fertiliser N management strategy in a cropping sequence.

Nitrogen fixation – free-living N fixation

Biological nitrogen fixation by symbiotic and free-living (FL) bacteria can provide economic and environmental sustainability to N management in Australian agriculture. Free-living N fixation refers to N fixation by bacteria growing independently in soil or in close association with plant roots where symbiotic N fixation occurs through legume–rhizobia interaction in nodules. Research has shown that communities of free-living and endophytic N-fixing bacteria have been found in association with cereal crops, grasses (including summer-active perennial pastures) and non-leguminous plants. With the increased adoption of intensive cropping and area under consecutive cereal crops (>50%), FL-N fixation has the potential to make a major contribution to N requirements in cereal crops.

Additionally, current day conservation farming systems support a habitat that promotes activity of FL-N fixing (*nifH* gene harbouring) bacterial communities both during off-season and in-crop, i.e. increased microsites with C availability, wide C/N ratio etc. Improvements in FL-N fixing capacity in soils can provide multiple benefits through reduced requirement for N inputs, disease suppression, C sequestration, etc.

Estimates of FL-N fixation, measured using a laboratory based incubation (^{15}N isotope) assay, ranged from less than 0.15 to 2.3 kg N fixed/ha/day under optimal soil moisture and temperature conditions. FL-N fixation ranged from 0.2 to 1.5kg N/ha/day in sand and sandy loam soils in low to medium-rainfall regions of southern Australia and Western Australia compared to 0.5 to 2 kg/ha/day in the clay and loam soils in high-rainfall regions. The number of optimal days per season does vary in different agricultural regions. The amount of N fixed varied with soil type and influenced by the time of sampling (in-crop versus non-crop/fallow period), crop type and mineral nitrogen levels. The amount of FL-N fixed during summer significantly increases (>50%, $P < 0.05$) in the presence of summer-active grasses such as Rhodes grass and Panicum species, compared to winter-cereal crop only systems (Figure 10).

The abundance of FL-N fixing bacteria, percentage clay content (soil type), soil moisture content and carbon availability are some of the major factors influencing FL-N fixation in cropping soils. Therefore, removal of stubble (one of the major sources of available C) either by burning or grazing would have negative impact on the amount of N fixed by FL- N_2 fixing bacteria. Research in the southern Australian agricultural region has shown that FL- N_2 fixation was higher immediately after harvest and decreased as summer progresses (Figure 9). Thus, careful consideration should be given to how stubble is managed in order to maximise FL-N fixation in cropping soils. Free-living N fixation is generally higher soon after rainfall when the water content is adequate to provide the required low-oxygen conditions (to protect O_2 -sensitive N fixing enzymes) and carry the carbon to where these bacteria are located. Higher levels of mineral N in the surface soil (0–10cm) could have a negative effect on the amount of fixation by free-living bacteria, but this varies with soil type so needs region-specific solutions.

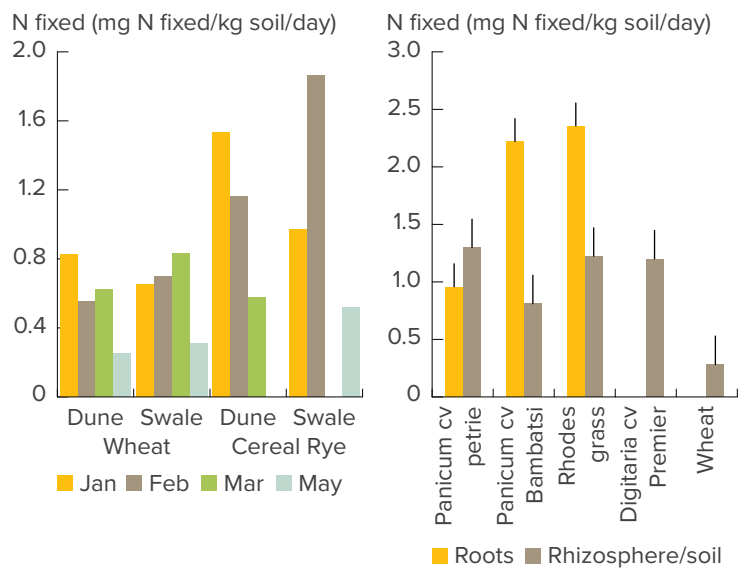


Figure 10: Amount of FL-N fixation in soils collected from field experiment at Karoonda, SA, during summer 2011–12 (left) and with summer-active perennial grasses (right).

Source: V Gupta (2016) <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/factors-influencing-nitrogen-supply-from-soils-and-stubbles>

Soil type and stubble retention have a large influence on the abundance of nifH-gene harbouring bacteria, for example abundance increased with clay content ($P < 0.01$) and stubble retention ($P < 0.05$). Populations of FL-N fixing bacteria are generally higher in the rhizosphere soil (soil closely surrounding roots) than those found in the bulk soil.

Genetic profiling of N_2 -fixing bacteria (nifH gene sequencing analysis) in cereal crop field soils (from Queensland, NSW, SA and WA) indicated the presence of a diverse group of free-living community (112 genera) in different agricultural regions indicating differences based on soil type and environment. Crop and variety types can influence the abundances of various groups thereby affecting the amount of FL-N fixation. Further research could suggest specific management strategies and identify crop varieties that help promote FL-N fixation by specific communities of N_2 -fixing bacteria in different soils and regions.

Denitrification and gaseous N losses

The composition and abundance of soil bacteria involved in gaseous N losses (e.g. denitrification and nitrification) varies with soil type, and the denitrification losses are highest where soil nitrate N levels are high and when sufficient biologically available C is present along with low oxygen (O_2) concentrations e.g. waterlogging. In the southern Australian cropping regions, N losses are sporadic in time and space and vary widely in different agricultural systems (Grace *et al.* 2015). In cropping soils, the primary consideration for reducing gaseous N losses is by matching the supply of mineral N to crop demand and management practices that promote tie-up of N in microbial biomass (immobilisation) generally reduce N losses both through denitrification and leaching.

Nitrification of N fertilisers

The conversion of ammonia and urea N found in commonly used N fertilisers into nitrate N is a biological process mediated by specific group of microorganisms, i.e. nitrifiers, which are mostly abundant in surface soils. The abundance and type of nitrifiers present varies with soil type and depth and their activity can be influenced by management practices. Research has shown that banding fertilisers can influence the activity of these microbes and the accumulation of nitrate N (Angus *et al.* 2014). Thus, fertiliser N use efficiency could be manipulated by targeting fertiliser placement or the

VIDEO

Watch Nitrogen Deficiency
<https://youtu.be/EWeZGHYpJcs>



VIDEO

Watch GCTV13: Phosphorus Uptake
<https://youtu.be/qSiQIKRb9bA>



MORE INFORMATION

For more information GRDC Fact Sheets: Crop nutrition–phosphorus management
<https://grdc.com.au/GRDC-FS-PhosphorusManagement>

VIDEO

Watch Improving phosphate use efficiency
<https://youtu.be/IHo9FDGTqAY>



use of nitrification inhibitors. Immobilisation of fertiliser N in MB, becoming unavailable to plants, is generally short term and has been found to be available to crops later in the crop season or to the following crop, provided it is not leached or lost through gaseous losses.

Conclusions

- Nitrogen mineralised from soil organic material (SOM) and crop residues makes a large contribution to crop N uptake (>50%)
- A diverse group of microbial communities are involved in the release of nitrate N from SOM and they are present in all agricultural soils
- Management strategies (such as stubble retention, tillage, fertiliser application and green manuring) and crop and variety selection can help manipulate microbial communities involved in N mineralisation from organic matter and crop residues and also influence fertiliser N use efficiency
- Free-living N fixation can make an agronomically important contribution to the available N pool in stubble-retained, cereal-based systems and perennial grass systems.²⁴

Deficiency symptoms

The first sign of nitrogen deficiency in field pea is a general paleness of the whole plant, even before a general reduction in plant growth. There may be a cupping of the middle to new leaves. With time, a mottled chlorosis of old leaves slowly develops with little sign of necrosis.

Check for nodulation and if nodules are fixing nitrogen to confirm suspected nitrogen deficiency from visual plant symptoms.²⁵

See [Section 4.9 Check for nodulation](#).

6.6.3 Phosphorus (P)

Ancient and highly weathered soils with very low levels of natural phosphorus (P) dominate much of Australia. Many of our agricultural soils are among the most acutely phosphorus deficient in the world, and profitable crop production has only been possible through significant applications of P fertilisers.

Phosphorus is an essential element for plant and animal growth and important during cell division and growth.

Complex soil processes influence the availability of phosphorus applied to the soil, with many soils able to ‘tie up’ phosphorus, making it unavailable to plants. Each soil’s ability to do this must be measured when determining requirements for crops and pastures.²⁶

Like other pulses, field pea requires high levels of phosphorus for growth and also removes large amounts of phosphorus in the grain. Adequate phosphorus is essential for seed germination, root development and in the ripening process of fruits and seeds.

Phosphorus is best applied at planting in a band to the side of or 2–3 cm below the seed. Placing fertiliser away from the seed prevents acid scorching. Nutrient release from deeper placement coincides well with root development.²⁷

24 V Gupta (2016) Factors influencing nitrogen supply from soils and stubbles. GRDC Update papers, <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/factors-influencing-nitrogen-supply-from-soils-and-stubbles>

25 Pulse Australia (2016) Southern Field Pea – Best management practices training course manual-2014, Module 4, General Agronomy, Draft. Pulse Australia Limited (2016)

26 Soilquality.org.Phosphorus – Western Australia <http://www.soilquality.org.au/factsheets/phosphorus>

27 C Scanlon (2015) Diagnosing phosphorus deficiency in field peas. Department of Agriculture and Food, Western Australia <https://agric.wa.gov.au/n/4478>

Deficiency symptoms

Symptoms of phosphorus deficiency may take time to develop because of initial seed reserves of P. When symptoms start to appear, there are growth differences apparent and smaller leaves compared with P adequate plants. Visual symptoms appear first on the oldest leaves as a mildly mottled chlorosis (yellowing of leaf tissue due to lack of chlorophyll) over much of the leaf. These symptoms could be confused for either nitrogen or sulfur deficiency, but middle and new leaves remain a healthy green such that the whole plant does not appear pale.

As symptoms on old leaves develop, round purple spots may appear within areas of dark green in an otherwise mildly chlorotic leaf.²⁸



Figure 11: Phosphorus deficiency in field pea.

Photo: © A Robson 2014, DPIRD <https://agric.wa.gov.au/n/4478>

6.6.4 Sulfur (S)

Sulfur is important to legumes for the nodulation and nitrogen-fixation process. Sulfur is required at higher rates for field pea than for cereals. If soil sulfur levels are low, then an appropriate legume mix could be applied. Consider the application of a sulfur-based fertiliser where the soil S level is <10 mg/kg KCL40.²⁹

Deficiency symptoms

Sulfur deficiency symptoms on younger leaves include the veins turning yellow. In severe deficiency situations the older leaves also turn yellow, and the plants tend to be small and slender.³⁰



Figure 12: Sulfur deficiency in field pea. Growth and colour are both affected and new leaves and tendrils become evenly chlorotic.

Photo: 2014 © A. Robson, DPIRD 2015 <https://agric.wa.gov.au/n/4488>

28 Pulse Australia (2016) Southern Field Pea – Best management practices training course manual-2014, Module 4, Draft, Pulse Australia Limited (2016).

29 AWB Seeds. KaspA: Field Pea Factsheet. AWB Seeds, <http://modraseeds.com.au/pdf/KaspAFactsheet.pdf>

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

6.6.5 Potassium (K)

Field pea have a high potassium (K) requirement, but deficiency has been rare because they are mainly grown on heavy-textured soils.

Deficiency symptoms

The earliest symptom is pale grey necrosis of leaf veins (particularly the midrib) of the second oldest leaf. This is followed by pale to pink necrotic spots on older leaves, which spread until the leaf shrivels and dies. New growth is darker than normal.³¹



Figure 13: *Potassium deficiency in field pea.*

Photo: © A. Robson 2014, DPIRD <https://agric.wa.gov.au/n/4480>

6.6.6 Zinc (Zn)

Most pulse crops have comparable requirements for zinc and the requirements of field pea are thought to be similar to chickpea.

Zinc should be applied to soil every 2–7 years, depending on soil type, as it lasts longer on loamy soils than on heavy, calcareous clays.³²

Pre-plant treatments

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

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 Zn may not be fully effective and a foliar Zn spray may be required.

Seed treatments

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

- Broadacre Zinc (Agrichem): contains 650 g/L of Zn and is applied as 4 L product/t seed. Pre-mix with 1 L water prior to application. To minimise damage to the rhizobia, the Broadacre Zinc treatment needs to be applied first and then allowed to dry before applying the inoculum.
- Teprosyn Zn (Phosyn): contains 600 g/L of Zn and is applied as 4 L product/t seed. Pre-mix with 2–3 L water to assist coverage. Apply inoculum first and allow to dry before applying the Teprosyn.

Fertilisers applied at sowing

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

³¹ C Scanlon (2015) Diagnosing potassium deficiency in field peas. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/4480>

³² AWB Seeds. KaspA: Field Pea Factsheet. AWB Seeds, <http://modraseeds.com.au/pdf/KaspAFactsheet.pdf>

Foliar zinc sprays

A foliar spray of 1 kg zinc sulfate heptahydrate + 1 kg urea + 1200ml of non-ionic wetter (1000 g/L) in at least 100 L of water per hectare will correct a mild deficiency. One or two sprays will need to be applied within 6–8 weeks of emergence.

Hard water (high in carbonate) will produce an insoluble sediment (zinc carbonate) when the zinc sulfate is dissolved, with the spray mix turning cloudy. Buffer back with L1-700 of Agri Buffa® if only hard water is available; zinc oxide products are highly alkaline, with a pH of 9.5–10.5.³³

Zinc deficiency

Zinc deficiency will vary with soil type, being worst on highly alkaline soils and worse in cold, wet weather.

Symptoms include older leaves of young plants initially wilting. Cream coloured necrosis on older leaf margins moves to the midrib, leaving a small green residual at the leaf base. The whole leaf turns white and dies. Tendrils go limp, curl and finally die. Later, new leaves are small, pale and cupped. Red-brown lesions develop on new leaf and upper main stems.³⁴

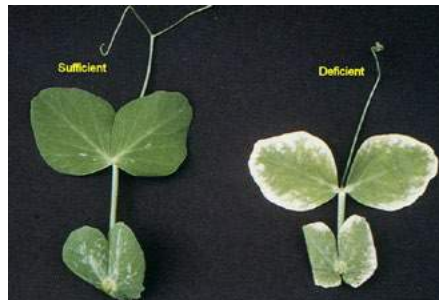


Figure 14: Zinc deficiency in field pea.

Photo © A Robson 2014, DPIRD <https://agric.wa.gov.au/n/4490>

6.6.7 Manganese (Mn) deficiency

Manganese (Mn) deficiency is common on highly alkaline calcareous soils. Younger leaves show yellowing between the veins, often specks.³⁵ Figures 15 and 16 show manganese deficiency in dun and white seed field pea varieties.



Figure 15: Manganese deficiency in dun-type field pea.

Source: DPIRD (2015) <https://agric.wa.gov.au/n/4473>

33 Pulse Australia (2016) Southern Field Pea – Best management practices training course manual-2014, Module 4, Draft. Pulse Australia Limited (2016)

34 R Brennan (2015) Diagnosing zinc deficiency in field peas. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/4490>

35 GRDC (2009) Field peas: The Ute Guide, Southern region. GRDC Ground Cover Direct

New leaves become puckered and narrowly cupped with necrotic tipping on leaves and tendrils.³⁶



Figure 16: Manganese deficiency in white-seed-type field pea.

Photo: DPIRD 2015, <https://agric.wa.gov.au/n/4472>

In white-seed varieties, affected leaves curl downwards along the length of the leaf. Yellowing between the veins turns to light brown spotting. Tendrils on new leaves have pale and excessively curled ends.³⁷

6.6.8 Iron (Fe) deficiency

Iron deficiency often appears in young plants and is related to soil type where there is a high lime content under cold, wet conditions. Plants often recover as conditions warm.

Deficiency shows as yellowing leaves and poor growth. New leaves and growth become yellow, causing smaller unfolded leaves (Figure 17). The deficiency then spreads to older leaves and young growth stops. Stems become slender and shortened.³⁸



Figure 17: Iron deficiency in field pea.

Photo: DPIRD 2015, <https://agric.wa.gov.au/n/4472>

³⁶ R Brennan (2015) Diagnosing manganese deficiency in field peas. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/4473>

³⁷ R Brennan (2015) Diagnosing manganese deficiency in field peas. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/4473g>

³⁸ GRDC (2009) Field peas: The Ute Guide, Southern region. GRDC Ground Cover Direct

6.6.9 Copper (Cu) deficiency

Copper deficiency is worse on alkaline soils, very infertile siliceous sands and soils with a low zinc fertiliser history.

Symptoms include old to middle leaves becoming mottled yellow and brownish pink, with dead tissue around the edges and tips. Light yellow-green spots form on the leaf. Plants are shortened with wilting and puckering distortion of new leaflets. Shrivelling of the leaf tip and aborted flowers.

Determine the copper status of the plant by tissue testing. Copper can be applied at seeding in fertiliser, by liquid injection on the seed or as a foliar application.³⁹



Figure 18: *Copper deficient (right) and copper adequate (left) new leaves of field pea.*

Photo: © A. Robson.

39 GRDC (2009) Field peas: The Ute Guide, Southern region. GRDC Ground Cover Direct

Weed control

Key points

- Growing field pea provides the opportunity to use different herbicide groups and to target grass weeds, including herbicide-resistant weeds. Preventing weed seedset is a priority for this pulse phase of the rotation.
- There are limited options for broadleaf weed control in field pea. They need to be targeted in the preceding crop or fallow. Pre-emergent herbicides will be required.
- Use pre-emergent herbicides carefully to prevent damage to emerging plants. Be wary of herbicide damage from herbicide residues in the soil, drift from outside the crop or spray tank contamination.
- Cutting weedy crops for hay, silage, or green or brown manuring can be a useful alternative for weed control.
- Crop-topping and desiccation can be used as part of an integrated weed management strategy with techniques such as seed capture at harvest to maximise the effectiveness.
- Crop-topping can be effective in early-maturing field pea varieties, with very low risk to damage to grain quality from the herbicide application.

7.1 Introduction

7.1.1 Impact and cost of weeds

Weeds cost Australian grain growers \$3.3 billion each year. That is, \$2.6 billion in control costs and another \$745 million in reduced yield. The cost to southern growers ranges from \$105 per hectare in the low-rainfall zones to up to \$184/ha in the medium to high-rainfall zones.

Reducing the cost of weed management is one of the grains industry's largest challenges as good weed control is vital for successful and profitable crop production.

Weed management is a challenge because weed situations are constantly evolving, with changes in weed types and their characteristics, such as herbicide resistance. The use of management techniques such as crop-topping, double-knockdown and narrow-windrow burning to reduce weed seedbanks have increased.

Grasses are the most costly weeds in the southern region (Table 1). Brome grass has increased in importance since the previous rankings were determined in 2000. Planting a pulse crop as a break crop between cereals provides an ideal opportunity to target grass weeds.

Table 1: Weeds in the southern region ranked by area, yield loss and revenue loss.

Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss
1	Ryegrass	3,419,170	Ryegrass	155,332	Ryegrass	\$38.9m
2	Wild oats	1,252,299	Wild oats	87,855	Wild oats	\$21.7m
3	Brome grass	1,122,207	Brome grass	86,683	Brome grass	\$21.0m
4	Wild mustard	822,497	Wild radish	37,169	Wild radish	\$10.4m
5	Wild radish	739,339	Wild mustard	15,711	Vetches	\$4.9m
6	Wild turnip	586,488	Vetches	11,517	Wild mustard	\$3.8m
7	Fleabane	189,422	Amsinkia / yellow burr weed	8253	Amsinkia / yellow burr weed	\$2.0m
8	Vetches	174,789	Wireweed	5555	Wireweed	\$1.4m
9	Barley grass	152,483	Barley grass	3661	Barley grass	\$1.0m
10	Cape weed	138,380	Skeleton weed	3302	Skeleton weed	\$866.7k
11	Cutleaf mignonette	137,131	Prickly lettuce / whip thistle	2979	Sow thistle / milk thistle	\$730.7k
12	Paterson's curse / salvation Jane	90,088	Doublegee	2768	Prickly lettuce / whip thistle	\$729.4k
13	Amsinkia / yellow burr weed	90,024	Brassica weeds	2367	Doublegee	\$588.9k
14	Doublegee	89,428	Lincoln weed	2268	Cape weed	\$577.0k
15	Wireweed	89,068	Cape weed	2082	Lincoln weed	\$533.7k
16	Skeleton weed	86,023	Sow thistle / milk thistle	2049	Brassica weeds	\$516.5k
17	Sow thistle / milk thistle	81,454	Paterson's curse/ salvation Jane	1834	Paterson's curse/ salvation Jane	\$422.8k
18	Prickly lettuce / whip thistle	77,518	Thistle species	1501	Cutleaf mignonette	\$406.1k
19	Thistle species	55,960	Cutleaf mignonette	1417	Bedstraw	\$400.8k
20	Brassica weeds	50,418	Wild turnip	1086	Thistle species	\$395.1k

Source: Llewellyn et al. (2016) <https://grdc.com.au/ImpactOfWeeds>

Weeds affect yield and management of broadacre crops across all seasons and sometimes the price received for grain.¹

Weeds may:

- lower crop yields by competing for soil moisture, nutrients, space and light;
- carry diseases and viruses that can infect crops;
- impede harvest;
- contaminate grain; and
- restrict cropping options due to limited herbicide options in pulse crops.²

7.1.2 Identifying weeds

The Grains Research and Development Corporation (GRDC) has developed an application (App) to assist in the identification of the most common weeds found in paddocks throughout Australia.

The App is called 'Weed ID: The Ute Guide'. Where possible, photos are shown for each stage of a weed's life cycle, from seed and seedling through to mature and flowering plants.

Weeds are categorised by plant type, and results for each can be refined by state and life cycle, and whether they are native, currently flowering or have a distinctive smell.

The Weed ID App allows users to search, identify and compare photos of weeds in their own paddock to weeds in the App.

MORE INFORMATION

Weed ID: The Ute Guide,
<https://grdc.com.au/apps>



Figure 1: *Weed ID: The Ute Guide* (GRDC 2016).

¹ R Llewellyn, D Ronning, M Clarke, A Mayfield, S Walker and J Ouzman (2016) Impact of weeds on Australian grain production: the cost of weeds to Australian grain growers and the adoption of weed management and tillage practices. GRDC, <https://grdc.com.au/ImpactOfWeeds>

² Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

7.1.3 Profiles of common weeds of cropping

Click on the weed name below to be taken to further information on this weed

- [Annual ryegrass \(*Lolium rigidum*\)](#)
- [Barley grass \(*Hordeum* spp.\)](#)
- [Barnyard grasses \(*Echinochloa* spp.\)](#)
- [Black bindweed \(*Fallopia convolvulus*\)](#)
- [Bladder ketmia \(*Hibiscus trionum*\)](#)
- [Brome grass \(*Bromus* spp.\)](#)
- [Capeweed \(*Arctotheca calendula*\)](#)
- [Doublegee \(*Emex australis*\)](#)
- [Feathertop Rhodes grass \(*Chloris virgata*\)](#)
- [Fleabane \(*Conyza* spp.\)](#)
- [Fumitory \(*Fumaria* spp.\)](#)
- [Indian hedge mustard \(*Sisymbrium orientale*\)](#)
- [Liverseed grass \(*Urochloa panicoides*\)](#)
- [Muskweed \(*Myagrum perfoliatum*\)](#)
- [Paradoxa grass \(*Phalaris paradoxa*\)](#)
- [Silver grass \(*Vulpia* spp.\)](#)
- [Sweet summer grass \(*Brachiaria ericuformis*\)](#)
- [Turnip weed \(*Rapistrum rugosum*\)](#)
- [Wild oats \(*Avena fatua* and *Avena ludoviciana*\)](#)
- [Wild radish \(*Raphanus raphanistrum*\)](#)
- [Windmill grass \(*Chloris truncata*\)](#)
- [Wire weed \(*Polygonum aviculare* and *Polygonum arenastrum*\)](#)

7.1.4 Alerting service for weeds

Growers can subscribe to a newsletter that provides local weed updates. The services listed below are all free:

Agriculture Victoria

General grains information is available on the twitter @VicGovGrains

Australia wide

The GRDC has a GrowNotes™ Alert for the latest weed, pest and disease issues in the users' area. The GrowNotes™ Alert is delivered via app, SMS, voice, email, social media or web portal (or a combination preferred methods). Subscription to the GrowNotes™ Alert is on the GRDC website.

MORE INFORMATION

For more information see the GRDC's Integrated Weed Management Hub & Integrated Weed Management Manual
<https://grdc.com.au/resources-and-publications/iwmhub>

VIDEO

Watch Harvest seed control for the high rainfall zone.
<https://youtu.be/RrvQQYqSmdE>



VIDEO

Watch Integrated weed management in 2017 by Peter Newman at the Bendigo Grains Research Update,
<https://youtu.be/Wh4ozniPCNQ>



7.2 Integrated weed management

An integrated weed management (IWM) system combining all available methods is the key to successful control of weeds. IWM includes both herbicide and non-herbicide options (Table 2).

Table 2: Weed control options for integrated weed management (IWM).

	Herbicide	Non-herbicide
Crop phase	<ul style="list-style-type: none"> • Crop topping in pulse/legume crops • Knockdown herbicides e.g. double-knock strategy before sowing • Selective herbicides before and/or after sowing but ensure escapees do not set seed • Utilising moderate resistance risk herbicides • Delayed sowing (as late as spring in some case) with weeds controlled several times before sowing • Brown manure crops 	<ul style="list-style-type: none"> • Rotate crops • Rotate varieties • Grow a dense and competitive crop • Use cultivation • Green manure crops • Cut crops for hay/silage • Burn stubbles/windrows • Delay sowing • Collect weed seeds at harvest and remove/burn • Destroy weed seeds harvested (Harrington Seed Destructor)
Pasture phase	<ul style="list-style-type: none"> • Spray-topping • Winter cleaning • Use selective herbicides and ensure escapee weeds do not set seed 	<ul style="list-style-type: none"> • Good pasture competition • Cut for hay / silage • Cultivated fallow • Grazing

Source: Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 5-2016.

7.2.1 Strategy – paddock choice and crop rotation

A well-managed rotation in each paddock, which alternates broadleaf crops with cereal crops, and may also include pastures, is a very useful technique for controlling weeds. For example, grass weeds are more easily and cheaply controlled chemically in broadleaf crops, whereas broadleaf weeds are much easier to control in cereal crops. Good crop rotation management can substantially reduce the cost of controlling weeds with chemicals.

Pulses grown in rotation with cereal crops offer opportunities to easily control grass weeds with selective herbicides that cannot be used when the paddock is sown to a cereal. An effective kill of grass weeds in pulse crops will reduce root disease carryover and provide a 'break crop' benefit in following cereal crops. Grass-selective herbicides can control most grass weeds in pulses, along with volunteer cereals.³

7.2.2 Good agronomic practice

Using weed-free seed and sowing on time with optimal plant populations and adequate nutrition will all contribute to good weed-control management.

Some crops and varieties are more competitive against weeds than others. Of the pulses, field pea and faba bean have a medium competitive ability, whereas lentil, lupin and chickpea have poor ability to compete with weeds in the paddock.⁴

³ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 5-2016

⁴ GRDC (2014) Integrated Weed Management Hub. GRDC, <https://grdc.com.au/resources-and-publications/iwmhub>

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FEEDBACK

VIDEO

Watch Over the Fence South: Summer weed control saves moisture for winter crops
<https://youtu.be/97gRnGHP2hM>



VIDEO

Watch AHRI Insight #70: Narrow row spacing: more crop, fewer weeds.
<https://youtu.be/qM-PI4vMliw>



MORE INFORMATION

See GRDC Videos in the Weed Management Manual
<https://grdc.com.au/resources-and-publications/iwmhub>

VIDEO

Watch IWM: Weed Seed Destruction
<https://youtu.be/a6b4SCmbqUA>



7.2.3 Pre-plant weed control

All weeds growing in a paddock should be controlled before the crop emerges. Large, advanced weeds not controlled before or during the sowing operation prove most difficult and often impossible to remedy with in-crop herbicides.

Tillage is a valuable method for killing weeds and preparing seedbeds. There are varying combinations of mechanical and chemical weed control to manage weeds in fallows or stubbles.

Knockdown herbicides are generally used instead of cultivation for fallow commencement, as well as for pre-planting weed control in the autumn. This improves soil structure through a reduction in cultivation. Knockdown herbicides also provide more timely and effective weed control. However, it is important to understand and manage the risk of herbicide resistance.⁵

Cultivation can spread grass weed seeds such as ryegrass, wild oat and brome grass through the soil profile and prolong their seedbank dormancy. For these weeds a light cultivation (1–3 cm deep) at autumn can encourage germination and assist in depleting the seedbank. This needs to be combined with delayed sowing.⁶

7.2.4 In-crop weed control

A wide range of pre-emergent and early post-emergent herbicides are available for grass weed control in field pea. 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 to minimise yield losses. Yield responses will depend on weed species, weed and crop density and seasonal conditions.

The growth stage of the weed and the crop are vital factors to consider when planning the successful use of post-emergent herbicides. The growth stages of field pea are detailed in [Section 5 Plant and growth physiology](#). Read herbicide labels carefully for these details and information on the best conditions for spraying.

The risk of crop damage from herbicide application should be balanced against the potential yield loss from weed competition. In heavy weed infestations, some crop damage can be tolerated, as it is easily offset by the yield loss avoided by reducing weed competition.

7.2.5 Managing weeds at harvest

Managing weeds at harvest is an effective way to reduce carryover of problem weeds, particularly those with herbicide resistance.

Most southern Australian cropping weeds have seed that does not shatter before harvest. This major biological weakness provides the possibility to collect the weed seed at harvest, for example using a chaff cart.⁷

Research by the Australian Herbicide Resistance Initiative (AHRI) (2014) found that ryegrass, wild radish, brome grass and wild oats all retained at least 75% of weed seeds at the first opportunity to harvest wheat.⁸ As field pea can be harvested before wheat this presents an excellent opportunity to reduce the weed seedset, particularly if used in conjunction with crop-topping.

These same weeds will shed between 0.8 and 1.5% of their seeds each day that harvest is delayed. To improve control of problem weeds, harvest weedy crops first and collect chaff containing the weed seeds.

5 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 5-2016

6 GRDC (2012) Herbicide resistance fact sheet, Southern Region, GRDC, May 2012, <https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance>

7 GRDC (2013) Herbicide Resistance. GRDC Ground Cover™ Supplement, Issue 104, May–June 2013, <https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104>

8 Australian Herbicide Resistance Initiative (2014) Rules of thumb. Australian Herbicide Resistance Initiative, <http://ahri.uwa.edu.au/rules-of-thumb/>

SECTION 7 FIELD PEA

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FEEDBACK

VIDEO

Watch GRDC video Weed Seed Capture
<https://youtu.be/x26mbIVV9F4>



VIDEO

Watch Ground Cover TV Harvest Weed Seed Control
https://youtu.be/8LPGaqHyF_s



VIDEO

Watch Capture Weed Seeds at Harvest – Harrington Seed Destructor
<https://youtu.be/wZUSmRdafAs>



Options for removing weed seeds in the chaff include:

- removing the weed-laden chaff via baling;
- tow a chaff cart and burn the heaps;
- concentrate the chaff into narrow windrows for burning;
- pulverise the chaff to crush and destroy the weed seeds before they exit the harvester; and
- in controlled-traffic farming: funnel chaff onto tramlines, confining weeds to a hostile environment separate from the crop.



Photo 1: The integrated Harrington Seed Destructor is not a silver bullet but allows growers to destroy weed seed at harvest, facilitating the use of non-chemical weed control as part of an IWM package.

Photo: WAHRI, GRDC (2012)

VIDEO

Harvest – the time to get on top of resistant weeds.

https://youtu.be/uURyKaaq-_I

A beginner's guide to harvest weed seed control.

<https://youtu.be/H5-yVmJ1pKs>

Burning Snails & Weed Seeds.

<https://youtu.be/zqQKFFqndKQ>

Reducing the seedbank

A weakness of weeds in southern Australia is that, for many, their seed does not remain viable in the soil for very many years, and seedbanks decline rapidly if not replenished each year.

Control methods for weed seed at harvest can lower a very large seedbank of more than 1,000 seeds per square metre to 100 seeds/m² in only 4 years. In paddocks with low ryegrass burdens, harvest weed seed methods reduced ryegrass emergence by as much as 90%. Paddocks with high ryegrass burdens (>2,000 seeds/m²) were less responsive, with 30–40% reduction in ryegrass emergence. This means that harvest weed seed management takes longer to lower ryegrass populations in highly infested paddocks where the residual seedbank is still being exhausted.

Trials in South Australia and New South Wales show that narrow windrow burning and the use of a chaff cart are as effective at removing ryegrass seed.⁹

7.2.6 Alternatives to harvesting the crop

Operations such as cutting hay or silage, or green or brown manuring provide an opportunity for improved weed control when compared with harvesting crops for grain. These techniques are particularly valuable where herbicide-resistant weeds are a problem. When timed well they can prevent almost all seedset.¹⁰

Additional benefits of manuring include boosting soil nitrogen and conserving soil moisture to benefit yield in subsequent years.¹¹

Green manuring uses cultivation and brown manuring uses chemical control to stop the growth of both crop and weed.

While green and brown manuring cost money without providing an income, the benefit for subsequent years can make it worthwhile. Manuring is usually suited to longer-seasoned forage crops, crop-topping for earlier-maturing grain crops. If income is important, crop-topping and grain harvest may be a more economically viable option even though yield may be reduced by crop-topping.¹²

The best crops for manuring are those with early vigour that are effective at suppressing weed growth. Total biomass is important to maximise the nitrogen benefit so choose a variety that is most likely to produce the highest biomass.¹³ (See Section 3 Pre-planting.)

Two varieties (PBA Hayman[®] and PBA Coogee[®]) have been released for suitability for forage (hay/silage) or green or brown manuring. Morgan[®] is also a dual-purpose field pea variety that is still grown.

7.2.7 Weed Seed Wizard

The Weed Seed Wizard helps growers understand and manage weed seedbanks on farms across Australia's grain-growing regions.

It is a computer simulation tool that uses paddock management information to predict weed emergence and crop losses. Different weed management scenarios can be compared to show how different crop rotations, weed control techniques, irrigation, grazing and harvest management tactics can affect weed numbers, the weed seedbank and crop yields.

9 <https://grdc.com.au/resources-and-publications/groundcover/groundcover129-july-august-2017/lesson-and-optimism-after-first-hshd-harvest>

10 A Glover, I Trevelan, L Watson, M Peoples, T Swan (2013) Research for the Riverine Plains 2013, Riverine Plains Inc., pp. 38-41, Online farm trials website, <http://www.farmtrials.com.au/trial/16519>

11 GRDC (2013) Manuring of pulse crops. GRDC Fact Sheet, September 2013, <https://grdc.com.au/Resources/Factsheets/2013/09/Manuring-of-Pulse-Crops>

12 E Armstrong (2015) Weigh up the risks, benefits of pulse harvest. Ground Cover™ Supplement, Issue 155: Profitable pulses and pastures, GRDC, <https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Weigh-up-the-risks-benefits-of-pulse-harvest>

13 GRDC (2014) Integrated Weed Management Hub. GRDC, <https://grdc.com.au/resources-and-publications/iwmhub>

The 'Wizard' uses farm-specific information and users enter their own farm management records, their paddock soil type, local weather and one or more weed species. The 'Wizard' has numerous weed species to choose from including annual ryegrass, barley grass, wild radish, wild oat, brome grass and silver grass in the southern states and liverseed grass, barnyard grass, paradoxa grass, feathertop Rhodes grass, bladder ketmia, fleabane, sow thistle, sweet summer grass, cowvine and bellvine in the north.¹⁴

A free download is available from: <https://www.agric.wa.gov.au/weed-seed-wizard-0>

7.3 Key points for managing weeds in field pea

Field pea have the greatest selection of herbicides of any pulse crop. There are more post-emergent herbicide options for field pea than for other pulses, as long as they are applied at the correct crop growth stage. However, field pea does not compete well with weeds, particularly early in the season. Despite field pea having more effective broadleaf weed control options than other pulses, it is important to understand potential weed problems in individual paddocks. Avoid paddocks with high weed seed loads or where weeds are unlikely to be controlled.¹⁵

Field pea provides valuable management strategies for integrated weed management and unique features to assist weed control in the cropping rotation. These include:

- a relatively late sowing window compared to other crops;
- the availability of competitive varieties such as Morgan[®], which compete well against weeds;
- the availability of earlier maturing varieties such as PBA Wharton[®], PBA Twilight[®], PBA Oura[®], PBA Gonyah[®], SW Celine and Maki, that enable 'crop-topping' for grasses to be undertaken when the crop is close to maturity but the weeds are not. (See Section 3 Pre-planting.)

There are a number of soil-applied residual herbicides registered that provide an opportunity to use alternative chemistries as part of a herbicide-resistance management program. They may also be more cost effective and cause less crop damage than post-emergent herbicide options for weed control. Some residual herbicides applied to the previous cereal crop can affect the establishment and growth of field pea. Refer to the current pesticide labels for further information on plant-back periods.¹⁶

7.4 Using herbicides

Herbicides that are registered for use in field pea can be found using the Australian Pesticides and Veterinary Medicines Authority (APVMA) database (<https://apvma.gov.au/node/10831>). An iOS app is also available. Seek the advice of your local agronomist or reseller.

Make sure you have the current information on the registration status, rates of application and warnings related to withholding periods, OH&S, residues and off-target effects before making decisions on which pesticide to use.

Herbicides must only be used if they are legally registered for the particular use in the particular crop at the listed label rates and timings. Using products off-label risks reduced efficacy, exceeding Maximum Residue Limits (MRLs) and litigation.

Always read the product label and Materials Safety Data Sheet (MSDS) before using herbicides.

¹⁴ DPIRD (2017) Weed Seed Wizard. <https://agric.wa.gov.au/n/1522>

¹⁵ Pulse Australia (2010) Northern Region Field Pea Management Guide. Pulse Australia, https://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

¹⁶ P Matthew, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015, NSW– DPI Management Guide. NSW Government Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

Residue limits in any crop are at risk of being exceeded or breached where pesticides are applied:

- at rates higher than the maximum specified;
- more frequently than the maximum number of times specified per crop;
- within the specified withholding period; and
- where they are not registered for the particular crop.

The National Residue Survey (NRS) is part of an Australian Government and industry strategy to minimise chemical residues and environmental contaminants in Australian food products. NRS programs support primary producers and commodity marketers by confirming Australia's status as a producer of clean food and facilitating access to key domestic and export markets. The compliance rate for pulses in 2013-14 was 99.5%.¹⁷

The NRS survey helps protect our export markets and Australian reputation.

7.4.1 Getting best results from herbicides

Successful results from herbicide application depends on careful planning and application of the herbicide treatment.

Annual weeds compete with cereals and broadleaf crops mainly when the crops are in their earlier stages of growth. Weeds should be removed no later than 6 weeks after sowing to minimise losses. Early post-emergent control nearly always results in higher yields than treatments applied after branching in broadleaf crops.

Points to remember for the successful use of herbicides:

- Plan the operation. Check paddock sizes, tank capacities, water availability and supply.
- Do not spray outside the recommended crop growth stages as damage may result.
- Carefully check crop and weed growth stages before deciding upon a specific post-emergent herbicide.
- Read the label. Check to make sure the chemical will do the job. Note any mixing instructions, especially when tank mixing two chemicals.
- Follow the recommendations on the label.

Conditions inhibiting plant cell growth, such as stress from drought, waterlogging, poor nutrition, high or low temperatures, low light intensity, disease or insect attack, or a previous herbicide application, are not conducive to maximum herbicide uptake and translocation.

- Use good quality water, preferably from a rainwater tank. Water quality is very important.
- Hard, dirty or muddy water can reduce the effectiveness of some herbicides.
- Use good equipment that has been checked for output.
- Use sufficient water to ensure a thorough, uniform coverage.
- Check boom height with spray pattern operation for full coverage of the target.
- Check accuracy of GPS or boom width marking equipment.
- Check wind speed.
- A light breeze helps herbicide penetration into crops.
- Do not spray when wind is strong (>15 km/h).
- Do not spray if rain is imminent or when heavy dew or frost is present.
- Calculate the amount of herbicide required for each paddock and tank load. Add surfactant where recommended.
- Select the appropriate nozzle type for the application.

¹⁷ National Residue Survey (2014) Residue results for 2013-14. Australian Government, Department of Agriculture and Water Resources, <http://www.agriculture.gov.au/ag-farm-food/food/nrs/nrs-results-publications/industry-brochures-2013-14/results-2013-14>

i MORE INFORMATION

APVMA webpage: Registration database
<https://portal.apvma.gov.au/pubcris>

APVMA webpage: Permits database
<https://portal.apvma.gov.au/permits>

APVMA app: Permit app for iOS
http://apvma.gov.au/node/10831#iphone_app

Pulse Australia webpage: Permits for pulses
<http://pulseaus.com.au/growing-pulses/crop-protection-products>

Grain Producers booklet: Safely managing risks with crop inputs and grain on-farm
<http://grainsguide.grainproducers.com.au/>

- Beware of compromising nozzle types when tank-mixing herbicides with fungicides or insecticides.
- Be aware of spray conditions to avoid potential spray drift onto sensitive crops and pastures, roadways, dams, trees, watercourses or public places.

Seek advice before spraying recently released field pea varieties as they may differ in their tolerance of herbicides. (See [Section 7.5.7 Specific guidelines for Group F herbicides](#))

Information on herbicide tolerance is available in the variety management package for the variety. PBA varieties and brochures are available here: <https://grdc.com.au/research/trials,-programs-and-initiatives/pba/varieties-and-brochures>

Keep appropriate spray records for each spray operation.¹⁸

7.4.2 Current minor use permits (MUP)

Some products may be available under permit, with conditions attached, until enough data is generated for full registration. In other cases, a temporary permit may be granted when there is a particular seasonal issue.

Pulse Australia holds several minor use permits on behalf of the pulse industry and is actively involved in the pursuit of new permits and label registrations to meet industry needs.¹⁹

7.5 Mode of action (MOA)

Herbicides have been classified into a number of groups. The group refers to the way a chemical works: different chemical make-up and mode of action (see [Section 7.5.2 Grouping by MOA and ranked by resistance risk](#), for a full list of options).

The main reason resistance has developed is because of the repeated and often uninterrupted use of herbicides with the same mode of action. Selection of resistant strains can occur in as little as 3–4 years if no attention is paid to resistance management. Remember that the resistance risk remains for products having the same MOA. If you continue to use herbicides with the same MOA and do not follow a resistance management strategy, problems will arise.

7.5.1 Mode-of-action labelling in Australia

In order to facilitate management of herbicide-resistant weeds, all herbicides sold in Australia are grouped by mode of action (MOA). The MOA is indicated by a letter code on the product label. The MOA labelling is based on the resistance risk of each group of herbicides. Australia was the first country to introduce compulsory MOA labelling on products, and the letters and codes used in Australia are unique. Labelling is compulsory and the letters and codes reflect the relative risk of resistance evolving in each group. Since the introduction of MOA labelling in Australia, other countries have adopted MOA classification systems; however, caution is advised if cross-referencing MOAs between Australia and other countries, as different classification systems are used. The herbicide MOA grouping and labelling system in Australia was revised in 2007. This is the first major revision of the classification system since its introduction.

The original groupings were made based on limited knowledge about MOAs. Groupings have been changed to improve the accuracy and completeness of the MOAs to enable more informed decisions about herbicide rotation and resistance management. The general intent of groups based on their risk has not changed. However, six additional herbicide mode of action groups were created to more accurately group herbicides.

¹⁸ GRDC (2016) Spray application manual GrowNotes™, GRDC, <https://grdc.com.au/resources-and-publications/grownotes/technical/spray-application-manual>

¹⁹ Pulse Australia (2016) Crop protection products. Pulse Australia website, <http://pulseaus.com.au/growing-pulses/crop-protection-products>

7.5.2 Grouping by MOA and ranked by resistance risk

Growers and agronomists are now better able to understand the huge array of herbicide products in the marketplace in terms of mode of action (MOA) grouping and resistance risk by reference to the mode of action chart

All herbicide labels now carry the mode of action group clearly displayed, such as:

GROUP	G	HERBICIDE
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Not all MOA groups carry the same risk for resistance development therefore specific guidelines for Groups E, O, P and R have not been developed to date because there are no recorded cases of weeds resistant to members of these groups in Australia.

Products represented in Group A and Group B are HIGH RESISTANCE RISK herbicides and specific guidelines are written for these products.

Specific guidelines are also included for the MODERATE RESISTANCE RISK herbicides, Groups C, D, F, G, I, J, K, L, M, N, Q and Z herbicides.

HIGH RESISTANCE RISK herbicides

Group A (mostly targeted at annual ryegrass and wild oats); and

Group B (broadleaf and grass weeds).

Specific guidelines are written for use of these products in winter cropping systems.

MODERATE RESISTANCE RISK herbicides

Group C (annual ryegrass, wild radish and silver grass);

Group D (annual ryegrass and fumitory);

Group F (wild radish);

Group I (wild radish and Indian hedge mustard);

Group J (serrated tussock and giant Parramatta grass);

Group L (annual ryegrass, barley grass, silver grass, square weed and capeweed);

Group M (annual ryegrass, barnyard grass, fleabane, liverseed grass and windmill grass);

Group Q (annual ryegrass); and

Group Z (wild oats and winter grass).

Group K

Specific guidelines have been developed for Group K due to the reliance on this MOA to manage annual ryegrass and prevent future resistance development.

Groups with no resistant weeds listed:

Group E

Group G

Group H

Group N

Group O

Group P

Group R

There are no recorded cases of weeds resistant to members of these groups in Australia.

7.5.3 Specific guidelines for Group A herbicides

The following charts have been compiled from chemical labels on the APVMA web site and PIRSA Spraying Charts and in consultation with chemical companies.²⁰

Group A herbicides

High resistance risk.

Group A resistance exists in Australia in the grass weeds, including annual ryegrass, wild oats, phalaris, brome grass, crab grass, goose grass and barley grass. Resistance has developed in broadacre and vegetable situations.

Research has shown that as few as six applications to the same population of annual ryegrass can result in the selection of resistant individuals. A population can go from a small area of resistant individuals to a whole-paddock failure in one season.

'Fops', 'Dims', and 'Dens' are Group A herbicides and carry the same high resistance risk. Where a Group A herbicide has been used on a particular paddock for control of any grass weed, avoid using a Group A herbicide to control the same grass weed in the following season, irrespective of the performance it gave.

Frequent application of Group A herbicides to dense weed populations is the worst scenario for rapid selection of resistance.

Where resistance to a member of Group A is suspected or known to exist, there is a strong possibility of cross-resistance to other Group A herbicides. Therefore, use other control methods and herbicides of other MOA groups in a future integrated approach.

The above recommendations should be incorporated into an integrated weed management (IWM) program. In all cases, try to ensure that surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies, including rotation of MOA groups.

Table 3: Active ingredients of Group A MOAs.

Chemical family	Active constituent (first registered trade name)
Group A	Inhibitors of acetyl co-enzyme A carboxylase (Inhibitors of fat synthesis/ACC'ase inhibitors)
Aryloxyphenoxypropionates (Fops)	clodinafop (Topik [®]), cyhalofop (Barnstorm [®]), diclofop (Cheetah [®] Gold*, Wildcat [®]), fluazifop (Fusilade [®] , Fusion [®]), haloxyfop (Verdict [®]), propaquizafop (Shogun [®]), quizalofop (Targa [®])
Cyclohexanediones (Dims)	butroxydim (Falcon [®] , Fusion [®] *), clethodim (Select [®]), profoxydim (Aura [®]), sethoxydim (Cheetah [®] Gold*, Decision [®]), tralkoxydim (Achieve [®])
Phenylpyrazoles (Dens)	pinoxaden (Axial [®])

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

²⁰ CropLife Australia Herbicide Resistance Management Strategies—September 2011. <https://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

7.5.4 Specific guidelines for Group B herbicides

Group B herbicides

High resistance risk.

Group B resistance exists in Australia in the grass weeds annual ryegrass, barley grass, brome grass, wild oats and crab grass, and in at least 16 broadleaf weeds including wild radish, common sowthistle, climbing buckwheat, turnip weed, wild mustard, Indian hedge mustard, prickly lettuce, wild turnip and African turnip weed. Resistance has developed in broadacre, rice and pasture situations. With respect to rice, three broadleaf weeds have been discovered: dirty dora, arrowhead, and starfruit.

Research has shown that as few as four applications to the same population of annual ryegrass can result in the selection of resistant individuals and as few as six applications for wild radish. A population can go from a small area of resistant individuals to a whole paddock failure in one season.

Avoid applying more than two Group B herbicides in any 4-year period on the same paddock.

Broadleaf weed control

If a pre-emergent application is made with a Group B herbicide for broadleaf weed control, monitor results and, if required, apply a follow-up spray with a non-Group B herbicide for control of escapes and to reduce seedset.

If a post-emergent application is made with a Group B herbicide for broadleaf weed control, it should preferably be as an APVMA-approved tank-mix with another MOA that controls or has significant activity against the target weed. If no APVMA-approved tank-mix is available, then monitor results and if required, apply a follow-up spray with a non-Group B herbicide for control of escapes and to reduce seedset.

A Group B herbicide may be used alone on flowering wild radish only if a Group B herbicide has not been previously used on that crop.

Grass-weed control

If there are significant escapes following the herbicide application, consider using another herbicide with a different mode of action or another control method to stop seedset.

Table 4: Active ingredients of Group B MOAs.

Chemical family	Active constituent (first registered trade name)
Group B	Inhibitors of acetolactate synthase (ALS inhibitors), acetohydroxyacid synthase (AHAS)
Imidazolinones (IMIs)	imazamox (Intervix [®] , Raptor [®]), imazapic (Bobcat I-Maxx [®] , Flame [®] , Midas [®] , OnDuty [®]), imazapyr (Arsenal Xpress [®] , Intervix [®] , Lightning [®] , Midas [®] , OnDuty [®]), imazethapyr (Lightning [®] , Spinnaker [®])
Pyrimidinylthiobenzoates	bispyribac (Nominee [®])
Sulfonylureas (SUs)	azimsulfuron (Gulliver [®]), bensulfuron (Londax [®]), chlorsulfuron, ethoxysulfuron, foramsulfuron (Tribute [®]), halosulfuron (Sempra [®]), iodosulfuron (Hussar [®]), mesosulfuron (Atlantis [®]), metsulfuron (Ally [®] , Stinger [®] , Trounce [®]), prosulfuron (Casper [®]), rimsulfuron (Titus [®]), sulfometuron (Oust [®] , Eucmix Pre Plant [®]), sulfosulfuron (Monza [®]), thifensulfuron, triasulfuron (Logran [®] , Logran [®] B Power [®]), tribenuron (Express [®]), trifloxysulfuron (Envoke [®] , Krismat [®])
Triazolopyrimidines (Sulfonamides)	florasulam (Paradigm [®] , Vortex [®] , X-Pand [®]), flumetsulam (Broadstrike [®]), metosulam (Eclipse [®]), pyroxsulam (Crusader [®] , Rexade [®])

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies. <https://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

7.5.5 Specific guidelines for Group C herbicides

Group C herbicides

Moderate resistance risk.

Group C resistance exists in Australia in the weeds annual ryegrass, wild radish, liverseed grass, silver grass, stinging nettles and barnyard grass. Resistance has developed in broadacre, horticultural and non-crop situations.

CropLife Australia gives specific guidelines for the use of Group C herbicides in triazine-tolerant (TT) canola and in winter legume crops, following increasing reports of resistance development.

Avoid using Group C herbicides in the same paddock in consecutive years. Growing TT canola in a paddock treated with triazine herbicides in the previous season is a high resistance risk and is not recommended.

Watch and record for weed escapes, especially in paddocks with a long history of Group C use.

Consult the 'Integrated Weed Management Strategy for TT Canola' for further details. The resistance status of the 'at-risk' weeds should be determined prior to sowing. Always use the label rate of herbicide, whether a single active ingredient (e.g. bromoxynil) or combination of active ingredients is applied (e.g. bromoxynil/MCPA, pyrasulfotole/bromoxynil). Apply to weeds at the labelled growth stage and ensure that no weeds set or shed viable seed. To prevent seedset, control survivors with a herbicide of different MOA from Group C, or use another weed-management technique.

Table 5: Active ingredients in Group C MOAs.

Chemical family	Active constituent (first registered trade name)
Group C	Inhibitors of photosynthesis at photosystem II (PS II inhibitors)
Amides	propanil (Stam®)
Benzothiadiazinones	bentazone (Basagran®, Basagran® M60*, Lawnweeder plus®*)
Nitriles	bromoxynil (Buctril® MA*, Eliminar C®*, Flight®*, Jaguar®*, Talinor®*, Triathlon®*, Velocity®*), ioxynil (Actril DS*, Totril®)
Phenylcarbamates	phenmedipham (Betanal®)
Pyridazinones	chlorthalozon (Pyramin®)
Triazines	ametryn (Amigan®*, Gesapax®Combi*, Krismat®), atrazine (Gesapax® Combi*, Gesaprim®, Primextra® Gold*), cyanazine (Bladex®), prometryn (Cotogard®*, Gesagard®), propazine, simazine (Gesatop®), terbutylazine (Terbyne®), terbutryn (Agtryne® MA*, Amigan®*, Igran®)
Triazinones	hexazinone (Bobcat I-Maxx®*, Velpar® K4*, Velpar® L), metribuzin (Aptitude®*, Sencor®)
Uracils	bromacil (Hyvar®*, Krovar®*), terbacil (Eucmix Pre Plant®*, Sinbar®)
Ureas	diuron (Krovar®*, Velpar® K4*), fluometuron (Cotogard®*, Cotoran®), linuron (Afalon®), methabenzthiazuron (Tribunil®), siduron (Tupersan®), tebuthiuron (Graslan®)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

7.5.6 Specific guidelines for Group D herbicides

Group D herbicides

Moderate resistance risk.

Resistance to Group D herbicides is known for an increasing number of populations of annual ryegrass and fumitory. Resistance has generally occurred after 10–15 years of use of Group D herbicides.

Where possible, avoid the use of Group D herbicides on dense ryegrass populations. Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

Rotate with herbicides from other MOA. For annual ryegrass, consider rotating trifluralin with products such as Boxer Gold®.

These recommendations should be incorporated into an IWM program. Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups.

Table 6: Active ingredients of Group D MOAs.

Chemical family	Active constituent (first registered trade name)
Group D	Inhibitors of microtubule assembly
Benzamides	propyzamide (Kerb®)
Benzoic acids	chlorthal (Dacthal®, Prethal™)
Dinitroanilines (DNAs)	oryzalin (Rout®*, Surflan®), pendimethalin (Stomp®), prodiamine (Barricade®), trifluralin (Jetti Duo®*, Treflan®)
Pyridines:	dithiopyr (Dimension®)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

7.5.7 Specific guidelines for Group F herbicides

Group F herbicides

Moderate resistance risk.

Resistance to Group F herbicides is known for a small number of populations of wild radish. Resistance has generally occurred after a long history of use of Group F herbicides. The number of populations with Group F resistance is increasing following increased use of these herbicides.

Group F includes herbicides that reduce carotenoid biosynthesis through inhibition of phytoene desaturase (PDS).

Avoid applying Group F herbicides in any two consecutive years unless one application is a mixture with a different MOA that is active on the same weed, or a follow-up spray is conducted (using a different MOA) to control escapes. Always use the label rate of herbicide, whether a single active ingredient (e.g. diflufenican) or combination of active ingredients is applied (e.g. diflufenican/MCPA, picolinafen/MCPA). Apply to weeds at the labelled growth stage and ensure that no weeds set or shed viable seed. To prevent seedset, control survivors with a herbicide of different MOA from Group F, or use another weed-management technique.

If applicable, apply a follow-up spray with a non-Group F herbicide for control of escapes and to reduce seedset. Aim to ensure that surviving weeds from any treatment do not set and shed viable seed.

These recommendations should be incorporated into an IWM program. Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies including rotation of MOA groups.

Table 7: Active ingredients for Group F MOAs.

Chemical family	Active constituent (first registered trade name)
Group F	Bleachers: Inhibitors of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)
Pyridazinones	norflurazon (Zoliar®)
Pyridinecarboxamide	diflufenican (Brodal®, Spearhead®*, Jaguar®*, Tigrex®*, Triathlon®*, Yates Pathweeder®*), picolinafen (Eliminar C®*, Flight®*, Paragon®*, Sniper®)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

7.5.8 Specific guidelines for Group H herbicides

Group H Herbicide

Moderate resistance risk.

There are currently no known weeds resistant to Group H herbicides in Australia. Resistance to Group H herbicides is known for a number of populations of *Amaranthus* species in the United States, which demonstrates the potential for weeds to develop resistance to this mode of action. Continuous usage of Group H herbicides in the US has resulted in resistance in *Amaranthus* species in a relatively short time.

1. **Broadacre cropping:** Of particular concern in Australia is the potential for development of Group H resistance in wild radish. In some areas, because of a lack of alternate herbicide options growers are heavily reliant on Group H herbicides for control of wild radish populations. It is essential to integrate additional cultural weed control techniques to reduce the seedbank and minimise seedset, thereby decreasing the selection pressure on Group H herbicides.
2. **Fallow:** In high summer rainfall areas, weed control in fallow is heavily reliant on herbicides. Multiple sprays are often required to maintain a clean fallow between winter crops. Integrated weed management principles should be incorporated wherever possible, including cultivation, the double-knock technique, grazing and combining more than one mode of action in a single application. To assist in delaying the onset of Group H resistance, rotate and/or tank mix with herbicides from other modes of action.
3. **Rice:** Where benzofenap has been applied to rice, a follow-up application of MCPA or bentazone and MCPA is recommended where appropriate to provide a secondary mode of action. To reduce the likelihood of resistant weeds developing it is recommended that products containing benzofenap (e.g. Taipan®, Viper®) not be used in consecutive rice crops.

Synergistic interactions have been documented for several Group H and Group C herbicide combinations. Where possible, apply a Group H herbicide in combination with a Group C herbicide to maximise efficacy. Always use the label rate of herbicide whether or not a single active ingredient (eg. isoxaflutole) or combinations of active ingredients are applied (eg. isoxaflutole + simazine, pyrasulfotole/bromoxynil).

The above recommendations should be incorporated into an integrated weed management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set or shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Where possible, rotate between products from different mode of action groups.

Table 8: Active ingredients for Group F MOAs.

Chemical family	Active constituent (first registered trade name)
Group H	Bleachers: Inhibitors of 4-hydroxyphenyl-pyruvate dioxygenase (HPPDs)
Isoxazoles	isoxaflutole (Balance®)
Pyrazoles	benzofenap (Taipan®), pyrasulfotole (Precept®, Velocity®)
Triketone	bicyclopyrone (Talinor®)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/>

7.5.9 Specific guidelines for Group I herbicides

Group I herbicides

Moderate resistance risk.

Resistance to Group I herbicides is known for a number of populations of wild radish and Indian hedge mustard. Resistance has occurred after a long history of use of Group I herbicides. The number of populations with Group I resistance is increasing.

It is of particular concern that in addition to Group I resistance in wild radish, which is the most important broadleaf weed in broadacre agriculture, some populations are cross-resistant to other MOAs, e.g. Group F herbicides, which can be important for control of wild radish in lupins where other selective, non-Group I options are limited. Because of the long soil life of wild radish seed, measures to reduce the return of seed to the soil would be useful for this weed. Wild radish seed that is confined to the top 5 cm of soil has a shorter life than seed buried deeper.

As a rule, in situations of high resistance risk:

- Avoid applying two applications of Group I herbicides alone onto the same population of weeds in the same season.
- Where possible, combine more than one MOA in a single application. Each product should be applied at rates sufficient for control of the target weed alone to reduce the likelihood of weeds resistant to the Group I herbicide surviving. These recommendations should be incorporated into an IWM program. Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups.

Table 9: Active ingredients of Group I MOAs.

Chemical family	Active constituent (first registered trade name)
Group I	Disruptors of plant cell growth (Synthetic Auxins)
Arylpicolinate	halauxifen (ForageMax [®] , Paradigm [®] , Rexade [®])
Benzoic acids	dicamba (Banvel [®] , Banvel M [®] , Barrel [®] , Casper [®] , Lawnweeder plus [®] , Mecoban [®] , Methar Tri-Kombi [®])
Phenoxyacetic acids: (Phenoxy)	2,4-D (Actril DS [®] , Amicide [®] , Fallow Boss Tordon [®] , Methar Tri-Kombi [®] , Pyresta [®] , Vortex [®]), 2,4-DB (Trifolamine [®]), dichlorprop (Lantana 600 [®]), MCPA (Agtryne [®] MA [*] , Basagran [®] M60 [*] , Buctril [®] MA [*] , Flight [®] , Lawnweeder plus [®] , MCPA, Midas [®] , Paragon [®] , Precept [®] , Silverado [®] , Spearhead [®] , Tigrex [®] , Triathlon [®]), MCPB, mecoprop (Methar Tri-Kombi [®])
Pyridine carboxylic acids: (Pyridines)	aminopyralid (FallowBoss Tordon [®] , ForageMax [®] , Grazon Extra [®] , Hotshot [®] , Stinger [®] , Vigilant II [®]), clopyralid (Lontrel [®] , Spearhead [®]), fluroxypyr (Hotshot [®] , Starane [®]), picloram (Fallow Boss Tordon [®] , Grazon Extra [®] , Tordon [®] , Tordon Regrowth Master [®] , Vigilant II [®]), triclopyr (Garlon [®] , Grazon Extra [®] , Tordon Regrowth Master [®] , Tough Roundup [®] Weedkiller [*])
Quinoline carboxylic acids:	quinclorac (Drive [®])

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies. <https://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/>

7.5.10 Specific guidelines for Group J herbicides

Group J herbicides

Moderate resistance risk.

There are isolated cases of weeds resistant to Group J in Australia. Two populations of serrated tussock and six populations of giant Parramatta grass are confirmed resistant to flupropanate.

To assist in delaying the onset of resistance, consider alternating with herbicides from other MOA.

The recommendations should be incorporated into an IWM program. Try to ensure surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups.

Table 10: Active ingredients of Group J MOAs.

Chemical family	Active constituent (first registered trade name)
Group J	Inhibitors of lipid synthesis (not ACCase inhibitors)
Benzofurans	ethofumesate (Tramat®)
Chlorocarbonic acids	2,2-DPA (Dalapon®), flupropanate (Tussock®)
Phosphorodithioates	bensulide (Exporsan®)
Thiocarbamates	EPTC (Eptam®), molinate (Ordram®), pebulate (Tillam®), prosulfocarb (Arcade®, Boxer® Gold*), thiobencarb (Saturn®), triallate (Avadex®, Jetti Duo*), vernolate

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

7.5.11 Specific guidelines for Group K herbicides

Group K herbicides

Moderate resistance risk.

Resistance to Group K herbicides is possible in Australia and may develop in broadacre situations.

Where possible, avoid the use of Group K herbicides on dense populations of ryegrass. Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

Rotate with herbicides from other modes of action. The recommendations should be incorporated into an IWM program. Try to ensure surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups.

Table 11: Active ingredients of Group K MOAs.

Chemical family	Active constituent (first registered trade name)
Group K	Inhibitors of cell division / inhibitors of very long chain fatty acids (VLCFA inhibitors)
Acetamides	napropamide (Devrinol®)
Chloroacetamides	dimethenamid (Frontier®-P, Outlook®), metazachlor (Butisan®), metolachlor (Boxer® Gold*, Dual® Gold, Primextra® Gold*), propachlor (Ramrod®)
Isoxazoline	pyroxasulfone (Sakura®)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

7.5.12 Specific guidelines for Group L herbicides

Group L herbicides

Moderate resistance risk.

Group L resistance exists in Australia in annual ryegrass, barley grass (two species), silver grass, cape weed and square weed. Most instances have occurred in long-term lucerne stands treated regularly with a Group L herbicide, but Group L-resistant barley grass has also occurred in no-till situations.

The following factors are common to all cases of Group L resistance:

- a Group L herbicide is the major or only herbicide used; and
- a Group L herbicide has been used for 12–15 years or more.

There has been minimal or no soil disturbance following application. The risk of resistance to Group L herbicides is higher in no-tillage broadacre cropping. Other situations of high resistance risk include irrigated clover pivots, orchards, vineyards or pure lucerne stands where frequent applications of a Group L herbicide are made each season, cultivation is not used and there is reliance on a Group L herbicide alone for weed control. Below are strategies to reduce the risk of Group L resistance developing in situations of high resistance risk.

No-tillage

Rotate Group L herbicides with other knockdown herbicides with a different mode of action.

Consider utilising the double-knock technique, with glyphosate sprayed first, followed within 1–7 days by a paraquat application. A full label rate for the weed size targeted should be used for the paraquat application for resistance management. Consider occasional mechanical cultivation to aid weed control.

Lucerne

If using a Group L herbicide for winter cleaning, where possible include another MOA, e.g. diuron (Group C).

Use alternative MOAs to selectively control grass and broadleaf weeds. Rotate Group L herbicides with other knockdown herbicides with a different MOA prior to sowing lucerne and prior to sowing future crops in that paddock.

Horticulture

Rotate Group L herbicides with other knockdown herbicides with a different MOA. Where possible, use residual herbicides (that are effective on the same weeds as the Group L herbicides) where applicable, either alone or in mixture with Group L herbicides. Where possible, use an alternative MOA to selectively control grass and broadleaf weeds. Consider using the double-knock technique, with glyphosate sprayed first, followed within 1–7 days by a paraquat application. A full label rate for the weed size targeted should be used for the paraquat application for resistance management.

These recommendations should be incorporated into an IWM program. Try to ensure surviving weeds from any treatment do not set and shed viable seed. Always try to apply herbicides to the smallest weed density. Use integrated strategies, including rotation of MOA groups.

Table 12: Active ingredients of Group L MOAs.

Chemical family	Active constituent (first registered trade name)
Group L	Inhibitors of photosynthesis at photosystem I (PSI inhibitors)
Bipyridyls	diquat (Reglone®, Spray.Seed®*), paraquat (Alliance®*, Gramoxone®, Spray.Seed®*)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/>

7.5.13 Specific guidelines for Group M herbicides

Group M herbicides

Moderate resistance risk.

Group M resistance occurs in Australia in annual ryegrass, awnless barnyard grass, fleabane, liverseed grass and windmill grass.

Herbicide resistance to glyphosate was first discovered in annual ryegrass in Australia in 1996. Since then, several new cases of glyphosate resistance in annual ryegrass, awnless barnyard grass, fleabane, liverseed grass and windmill grass have been confirmed.

The following factors are common to all cases of Group M resistance:

- a Group M herbicide is the major or only herbicide used;
- a Group M herbicide has been used for 12–15 years or more; and
- there has been minimal or no soil disturbance following application.

Given the important role of glyphosate in Australian farming systems, the Australian agricultural industry has developed strategies for sustainable use of glyphosate.

For more information, refer to the Australian Glyphosate Sustainability Working Group website (<http://www.glyphosateresistance.org.au>).

All cases of glyphosate-resistant weeds confirmed to date share three common factors:

- intensive (year-to-year) use of glyphosate;
- lack of rotation with other herbicide modes of action; and
- little or no tillage or cultivation following the application of glyphosate

Several cases of ryegrass resistance to glyphosate have occurred in horticultural and non-cropping situations (e.g. firebreaks, fence lines, driveways, irrigation ditches), with the balance occurring in no-till, broadacre cropping systems.

Given the demonstrated propensity of annual ryegrass to develop resistance to multiple herbicide classes, IWM principles should be incorporated wherever possible to minimise the risk of selecting for glyphosate-resistant ryegrass. Strategies may include the use of cultivation, the double-knock technique (using a full-cut cultivation OR the full label rate of a paraquat-based product (Group L) following the glyphosate (Group M) knockdown application), strategic herbicide rotation, grazing and baling.

Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Always try to apply herbicides to the smallest weed density. Use the integrated strategies mentioned, including rotation of MOA groups.

Table 13: Active ingredients of Group M MOAs.

Chemical family	Active constituent (first registered trade name)
Group M	Inhibitors of 5-enolpyruvyl shikimate-3 phosphate (EPSP) synthase
Glycines	glyphosate (Arsenal Xpress [®] *, Broadway [®] *, Illico [®] *, Resolva [®] Weedkiller*, Roundup [®] , Tough Roundup [®] Weedkiller*, Trounce [®] *, Yates Pathweeder [®] *)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/>

7.5.14 Specific guidelines for Group Q herbicides

Group Q herbicides

Moderate resistance risk.

Group Q resistance exists in Australia in annual ryegrass resistant to amitrole. This has only occurred in three populations and this type of resistance is rare in Australia.

To assist in delaying the onset of resistance, consider alternating Group Q herbicides with herbicides from other modes of action, e.g. Group L (e.g. paraquat), Group N (e.g. glufosinate) or Group M (e.g. glyphosate).

Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

All the above recommendations should be read in conjunction with the integrated weed management (IWM) strategies.

Table 14: Active ingredients of Group Q MOAs.

Chemical family	Active constituent (first registered trade name)
Group Q	Bleachers: Inhibitors of carotenoid biosynthesis unknown target
Isoxazolidinones	clomazone (Command [®])
Triazoles	amitrole (Alliance [®] *, Amitrole [®] , Illico [®] *)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/>

7.5.15 Specific guidelines for Group Z herbicides

Group Z herbicides

Moderate resistance risk.

Group Z resistance exists in Australia in wild oats resistant to flamprop. Many of these flamprop-resistant wild oats also show cross-resistance to Group A herbicides. Resistance to endothal is confirmed in winter grass.

To assist in delaying the onset of resistance, rotate with herbicides from other MOAs. Consider using alternative methods of weed control to reduce weed numbers before applying herbicides. These may include summer crop rotations, delayed sowing to control wild oats with a knockdown herbicide, higher seeding rates and brown manuring to stop seedset.

The recommendations should be incorporated into an IWM program. Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups.

Table 15: Active ingredients of Group Z MOAs.

Chemical family	Active constituent (first registered trade name)
Group Z	Herbicides with unknown and probably diverse sites of action
Arylamino propionic acids	flamprop
Dicarboxylic acids	endothal
Organoarsenicals	DSMA - disodium methylarsonate (Trinoc®*), MSMA - monosodium methylarsonate (Daconate®)

* This product contains more than one active constituent.

Source: CropLife Australia (2011). Herbicide Resistance Management Strategies, <https://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/>

Refer to the APVMA website to obtain a complete list of registered products from the PUBCRIS database (<https://apvma.gov.au/>).

7.6 Herbicide performance

Characteristics that determine herbicide performance and activity are:

- Herbicide uptake: how and where the chemical is taken up by the plant.
- Herbicide solubility: how readily it dissolves or leaches in soil water.
- Herbicide adsorption: how much is lost by binding to the soil.
- Herbicide persistence: how long it will last in the soil, affected by:
 - » volatilisation: loss to the atmosphere;
 - » leaching potential: how much is lost below the root zone; and
 - » decomposition by light: loss of product by decomposition.

Understanding these factors will assist in ensuring more effective herbicide use.

For best performance, pre-sowing and pre-emergent herbicides should be placed in the top 7.5 cm of soil. They must enter the germinating weed seedling in order to kill it. These herbicides can be mixed in by cultivation, rainfall or sprinkler irrigation, depending on the herbicide.

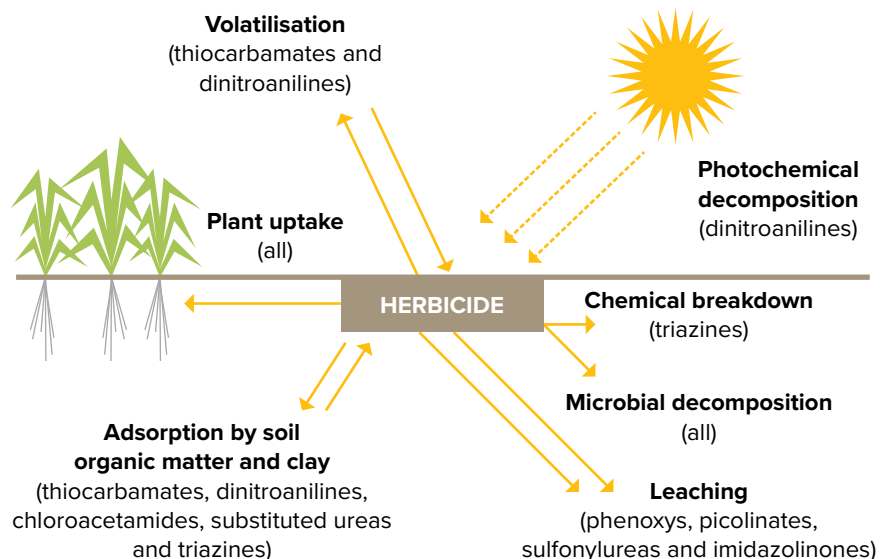


Figure 2: Fate of applied herbicides in soil, plants and sunlight.

Source: Shaner (2013) via Pulse Australia (2016). Southern Lentil – Best management practices training course, Module 5 – Weed management.

7.7 Herbicide types

7.7.1 Residual v. non-residual herbicides

Residual herbicides remain active in the soil for an extended period (months) and can act on successive weed germinations. Residual herbicides must be absorbed through the roots or shoots, or both. Examples of residual herbicides include imazapyr, chlorsulfuron, atrazine and simazine.

The persistence of residual herbicides is determined by a range of factors including application rate, soil texture, organic matter levels, soil pH, rainfall and irrigation, temperature and the herbicide's characteristics.

Persistence of herbicides will affect the choice of crop sequences (a rotation of crops, e.g. wheat–barley–chickpeas–canola–wheat).

Non-residual herbicides, such as the non-selective paraquat and glyphosate, have little or no soil activity and they are quickly deactivated in the soil. They are either

i MORE INFORMATION

GRDC Update paper: Optimising the impact of glyphosate
<https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Optimising-the-impact-of-glyphosate>

▶ VIDEO

GRDC Video: IWM: Double Knock Applications – a Grower’s Experience
<https://youtu.be/pEIEGsQDzBg>



▶ VIDEO

GRDC Video: Double-knock timing
<https://youtu.be/tNNRziB3MKc>



▶ VIDEO

GRDC Video playlist: Double-knock playlist
<https://youtu.be/1bfSRteU5SY?list=PL2PndQdkNRHGRIpNhkDYN2dJWAY1-oH9W>

broken down or bound to soil particles, becoming less available to growing plants. They also may have little or no ability to be absorbed by roots.

7.7.2 Knockdown herbicides

The most important part of the pulse weed control strategy is to control the majority of weeds before sowing, either by cultivation or with knockdown herbicides such as glyphosate (Group M) or Spray Seed® (Group L).²¹

Double knockdown refers to any two different weed-control tactics practised in close succession, where the second measure controls survivors of the first, e.g. any sequence that includes a herbicide and a non-chemical measure, such as heavy grazing or cultivation. It most commonly refers to two herbicide applications from different mode-of-action (MOA) groups, between 2 and 10 days apart. This is often glyphosate (Group M) or glyphosate plus 2,4-D (Group I) followed by paraquat or paraquat plus diquat (both Group L).²²

It may be necessary to delay sowing for up to 2 weeks after rain to enable a greater percentage of annual weeds to emerge. When the opening break is late this can compromise optimal sowing time.²³

7.7.3 Pre-emergent herbicides

Pre-emergent herbicides control weeds at the early stages of the life cycle, between radicle (root shoot) emergence from the seed and seedling leaf emergence through the soil.

Some pre-emergent herbicides also have post-emergent activity through leaf absorption and can be applied to newly emerging weeds.

The residual activity of a pre-emergent herbicide controls the first few flushes of germinating weeds while the crop is too small to compete. As a result, pre-emergent herbicides are often excellent at protecting the crop from early weed competition.²⁴

Pre-emergent herbicides offer the following advantages:

- Alternative modes of action to post-emergent and knockdown herbicides.
- Some are very effective on hard-to-kill weeds, such as annual ryegrass and barley grass.
- Herbicide resistance to pre-emergent herbicides is low for some chemicals or in some districts.
- Pre-emergent herbicides control weeds early in the crop’s life and potentially over several germinations, maximising crop yield potential.
- They suit a no-till sowing system with knife points and press-wheels and/or disc seeders, as well as conventional tillage systems.
- Can be cost effective.

These pre-emergent herbicides are primarily absorbed through the roots, but there may also be some foliar absorption.

When applied to soil, best control is achieved when the soil is flat and relatively free of clods and trash. While most pre-emergent herbicides are suitable for use in moderate stubble load paddocks, product labels will suggest adequate control with 50% groundcover.

Sufficient rainfall (20–30 mm) to wet the soil through the weed root zone is necessary within 2–3 weeks of application. The efficacy of most soil residual herbicides is greater where applied to moist soil rather than to dry soil. Best weed control is often

21 Pulse Australia (2016) Southern Lentil – Best management practices training course, Module 5 – Weed management, Pulse Australia Limited.
 22 GRDC (2012) Herbicide resistance Fact Sheet, Southern Region. GRDC, May 2012. <https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance>
 23 MJ Walsh and SB Powles (2007) Management strategies for herbicide-resistant weed populations in Australian dryland crop production systems. Weed Technology 21, 332–338
 24 GRDC (2014) Integrated Weed Management Hub. GRDC. <https://grdc.com.au/resources-and-publications/iwmhub>

VIDEO

Watch Pre-emergent Herbicides – Part 1 Solubility & Binding
<https://youtu.be/s63GYyflzw>



VIDEO

Watch the Webinar – Understanding pre-emergent herbicides.
<http://weedsmart.org.au/webinars/setting-crops-up-for-success/>

achieved from a post-sowing pre-emergent application because rainfall provides the best incorporation (compared to pre-sowing, which can occur without rainfall).

Mechanical incorporation of herbicides is less uniform than spraying after seeding and so weed control may be less effective. If applied pre-sowing and sown with minimal disturbance, then some of the incorporation will essentially be by rainfall after application. Weed control in the sowing row may be less effective because some herbicide will be removed from the crop row during the sowing operation.

Pre-emergent herbicides will not adequately control large weed populations by themselves. They need to be used in conjunction with paddock selection, crop rotation and pre-sowing weed control.

In no-till sowing systems, incorporation by sowing (IBS) is generally considered safer for the crop than post-sowing pre-emergent (PSPE). This is because there is little protection within the sowing row, unless there is potential for crop damage when soil is thrown into the sowing furrow.²⁵

To avoid PSPE damage sow deeper. Apply to moist soil, not dry, and do not apply if there is heavy rainfall forecast. Apply to a level soil surface to limit the possibility of herbicide concentrating in the furrow and causing damage to the crop. Use lower rates on lighter soils.²⁶

Use in field pea

Pre-emergent chemicals are the most effective tool in field pea crops to control broadleaf weeds and generally result in less crop damage than the in-crop options. Pre-emergents are becoming increasingly important in grass weed control, as they offer alternative chemical modes-of-action (MOA) to control herbicide-resistant weeds. Examples of this chemistry include trifluralin (Treflan®) and triallate (Avadex®).

Pre-emergent herbicides for use in field pea are generally registered for either incorporation by sowing (IBS) or use as a post-sowing pre-emergent (PSPE). Most of these chemicals are very dependent on rainfall for activation, therefore results are often limited under dry conditions or damage can be severe under heavy rainfall conditions.

Sufficient moisture and a level soil surface must be present at application for some soil-active broadleaf herbicides to be fully effective and to avoid crop damage. A ridged soil surface can cause problems if heavy rain falls between sowing and germination. The rain can wash the herbicide into the furrow and leave a concentrated band of chemical on top of the germinating seed, which can result in crop damage. Leave the soil surface flat to minimise herbicide damage. A flat surface can also assist harvest by ensuring clods or stones don't enter the harvester.²⁷

See NSW DPI Weed Control in Winter Crops 2017 guide, pages 96-97 (early post-emergence herbicides for field peas, tables 32-34) (<http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops>).

25 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 5-2016

26 B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, <http://www.dpi.nsw.gov.au/content/agriculture/farm/conservation/information/pre-emergent-herbicides>

27 GRDC (2015) Field pea Northern Region GrowNotes™, –Chapter 5, p 10, <https://asp-au.secure-zone.net/v2/index.jsp?id=1229/1381/7682&lng=en>

New pre-emergents for field pea: Groups J & K

Boxer Gold[®]

Apply as a pre-emergent to soil surface up to 7 days prior to sowing and incorporate mechanically by the sowing operation (IBS). Application should be made to a moist seedbed. Sufficient rain to thoroughly wet the top 3–4 cm of soil should occur within 10 days after spraying.

DO NOT:

- use in seeding/tillage systems that cannot ensure accurate seed placement and adequate spatial separation of seed and herbicide;
- apply to soils prone to waterlogging, sodic soils or soils affected by physical compaction; or
- apply if heavy rains or storms that are likely to cause run-off are forecast within 2 days of application.

Accuracy of seed placement is critical in ensuring crop selectivity. Unacceptable crop injury (reduction in crop vigour and yield loss) may occur where inadequate spatial separation of seed and herbicide occurs or where heavy rainfall occurs during the early stages of crop establishment. Avoid soil throw into adjacent seeding rows or sites where furrow walls may collapse. Shallow sowing is not recommended due to the greater potential for movement of herbicide within close proximity of the emerging crop, especially in sandy soils. Application of *Boxer Gold*[®] to crops sown in soils of high leaching potential and those low in clay or organic matter may result in crop damage. Avoid double spraying (overlapping) of the crop with herbicide.

Sakura[®]

Apply pre-sowing and incorporate by sowing (IBS) using knife points and press-wheels, or narrow points and harrows. For best results apply just before sowing. Avoid throwing treated soil into adjacent crop rows when sowing with knife points and press-wheels

DO NOT APPLY:

- if heavy rain has been forecast within 48 hours;
- unless incorporation by sowing (IBS) can be performed within 3 days of application; or
- to waterlogged soil.

Other factors that may adversely affect weed control include: uneven application, application to ridged or cloddy soil, stubble, plant residue or other groundcover, particularly where this exceeds 50%.

Terbyne Xtreme[®]

Use the lower rate on light soils (sandy loams to loamy sands) and the higher rate on heavier soils (loams, silt plus clay 40–60%). The soil should be free of excessive clods, trash and deep furrows. Sufficient rainfall (20–30 mm) to wet the soil through the weed root zone is necessary within 2–3 weeks of application. Ensure lupin seed is covered with at least 3 cm and preferably 5 cm of soil.

DO NOT APPLY:

- if heavy rains or storms that are likely to cause surface run-off are forecast within 2 days of application;
- to waterlogged soil; or
- at rates higher than 0.86 kg/ha on soils with pH 8.0 and above as unacceptable crop damage may occur.

NOTE: Some early crop phytotoxicity may be observed particularly on light soils. Heavy, intense rainfall following application may cause crop damage. At the higher rates, avoid overlapping sprays and spraying-out corners.

Outlook®

Outlook® only controls annual ryegrass in low weed populations only (<100 plants/m²). Use in higher weed populations will only yield suppression. Apply as late as possible before sowing and sow with a knife-point and press-wheel seeder before weeds germinate.

Weeds that have emerged or that emerge soon after application are unlikely to be controlled. A post-emergent herbicide to control annual ryegrass may be needed to control escapes and late germinations.

Ensure that soil throw during seeding is not into adjacent furrows. Apply to moist soil if possible. If applied to dry soil, rain must follow within 7 days for best results.

DO NOT APPLY:

- if heavy rain is expected within 48 hours; or
- to areas that may be prone to waterlogging.

7.7.4 Post-emergent herbicides

There are more post-emergent herbicide options for field pea than for other pulses.²⁸

Selective post-emergent herbicides give high levels of control (often >98%) when applied under recommended conditions on susceptible populations. When used early in crop development the yield benefit provides significant economic returns.

Application of post-emergent herbicides to stressed crops and weeds can result in reduced levels of weed control and increased crop damage.

Stress from waterlogging, frost or dry conditions can result in greater crop damage from the herbicide because crops cannot produce sufficient levels of the enzymes that normally break down the herbicide.²⁹

See NSW DPI Weed Control in Winter Crops 2017 guide, pages 96-97 (early post-emergence herbicides for field peas, Table 34) (<http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops>).

Know your nodes

Counting the number of nodes on the main stem of field pea is the key to safely applying herbicides (Table 16). It is the system researchers around the world use when testing new herbicides and the system most labels use.

Individual field pea plants will have a dominant main stem and several basal branches, with the main stem simply being the longest one you can find. All references to node number on labels and so on refer to the number of nodes on the main stem.

28 Pulse Australia (2010) Northern Region Field Pea Management Guide. Pulse Australia, https://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

29 GRDC (2014) Integrated Weed Management Hub. GRDC, <https://grdc.com.au/resources-and-publications/iwmhub>

Table 16: Post-emergent herbicides and field pea crop stage.

Herbicide	Crop stage (as per herbicide label)
Grass herbicides	From 2nd node
Metribuzin	3rd node
Imazamox	Do not apply beyond the 4th-node stage
Diflufenican	After 3rd node and before flowering
Flumetsulam	2nd node to 6th node, no later than 6 weeks after emergence
Cyanazine	Between 3rd node and 5th node stage
MCPA Na	6th node to 8th node, 10–15 cm tall. Do not apply if flowering has begun*
Paraquat	No specific crop guide on label. In practice, when 75% of the crop has brown pods
Diquat	As soon as crop has reached full maturity
Glyphosate	At or after crop maturity. When average seed moisture content is below 30%

* Varieties grown in Western Australia are unlikely to be at 6th to 8th node when flowering.

Source: M. Seymour (2016). A visual guide to key stages in the growth and maturity of field pea. <https://agric.wa.gov.au/n/369>

7.7.5 Weed control in wide-row cropping

With the shift to cropping pulses on wider rows, weed management tactics may include;

- inter-row tillage;
- shielded spraying; and
- band spraying.

In this system weeds can be given more time to become more established between the rows with greater scope for the use of inter-row, spraying.³⁰ This can also be combined with banding of fertiliser to favour the crop over the weed.

Shielded sprayers

Shielded sprayers are becoming increasingly common in or around the cotton-growing areas as they provide very cheap grass and broadleaf weed control with glyphosate, but the label does not list use for field pea.³¹

Some disadvantages of shielded spraying are the potential to damage crop plants, particularly the lower branches, and the ability of weeds within the row to escape control and set seed.³²

7.7.6 Crop-topping

Desiccation and crop-topping are well established techniques to improve the rotational fit, benefits and profitability of the pulse crop. While they are essentially the same physical operation of applying a desiccant herbicide close to final maturity of the pulse, they do achieve different objectives and must be applied with care.

Crop-topping aims to stop the seedset of survival weeds without substantially affecting crop yield and grain quality. Crop-topping is timed for the weed growth stage to control weed seedset from survivors of normal in-crop weed control. Crop-

30 GRDC (2014) Integrated Weed Management Hub. GRDC. <https://grdc.com.au/resources-and-publications/iwmhub>

31 Pulse Australia (2016) Draft Southern/western field pea best management practices training course, module 5-2016. Pulse Australia Limited

32 S Kleemann, G Gill (2012) Herbicide Application Strategies for the Control of Rigid Ryegrass (*Lolium rigidum*) in Wide-Row Faba Bean (*Vicia faba*) in Southern Australia. Weed Technology 26, 284-288

topping cannot be used in all pulses, but is effective in early-maturing species like field pea with very low risk of damage to grain quality from the herbicide application.

The ideal timing for crop-topping occurs when the field pea seeds have reached 30% moisture, or when the lower 75% of pods are brown with firm seeds and leathery pods.

Note: Field pea destined for seed or the sprouting market should not be desiccated or crop-topped using glyphosate. Germination percentage of normal seedlings is affected by glyphosate.

Crop-topping and desiccation should be used as part of an integrated weed management strategy with techniques such as seed capture at harvest to maximise the effectiveness.³³

Desiccation

Desiccation is the application of a non-selective herbicide to the crop to dry off green growth to reduce the time to harvest and improve efficiency of harvesting. It may or may not control weed seedset depending on the weed growth stage at application.

Further information is available in [Section 10 Pre-harvest treatments](#).

MORE INFORMATION

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

7.8 Herbicide residues

Herbicides applied to paddocks in previous years may not have broken down adequately due to insufficient rainfall. Summer rainfall is not necessarily as effective as growing-season rainfall in breaking down herbicide residues, so it needs to be substantial and to keep the soil wet for long enough. This detail is on the herbicide label. You will need to know the chemical type used, as well as the plant-back periods, and the soil pH, rainfall and other requirements for breakdown. Herbicides applied 2 years ago could still have an impact too, as could the presence of cereal stubble with herbicides like Lontrel® (clorpyralid).

Pulse types differ in their sensitivity to residual herbicides. While the largest selection of in-crop herbicides is available for use in field pea, out of all the pulse crops, it is still important to check each herbicide and its plant-back requirements prior to use.³⁴

Group B:

- Lentil, faba bean, broad bean and chickpea are most vulnerable to sulfonylurea residues (e.g. Lusta®, Logran®), while field pea is the least vulnerable. Residues persist longer in high pH soil.
- At low pH (<6.5) faba and broad bean are more sensitive to Monza® residues (sulfonylurea) than chickpea, lentil, lupin or field pea. All are sensitive at higher pH (>6.5).
- Faba bean, broad bean, lentil and lupin are more sensitive to sulfonamide residues (e.g. Broadstrike®), particularly on shallow duplex soils where breakdown is slower.
- Chickpea, field pea, faba bean and broad bean are least sensitive to the imidazolinones (IMIs e.g. Spinnaker®, Raptor®, Midas®). Lentil is extremely sensitive unless it is an 'XT' variety with herbicide tolerance. Lupin and vetch are intermediate.
- Raptor® (IMI) has no minimum re-cropping interval if field pea is being sown.
- Lentil cannot immediately follow after bean or field pea if IMIs (e.g. Spinnaker® or Raptor®) or sulfonamides (e.g. Broadstrike®) were used.

33 Pulse Australia (2016) Pulses: Desiccation and croptopping. Pulse Australia, <http://pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping>

34 Pulse Australia (2016) Field Pea: Residual herbicides and weed control. Australian Pulse bulletin, <http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides>

Group I:

- All pulses are vulnerable to pyridine residues (e.g. clopyralid/Lontrel®). Lontrel® is more likely to persist in stubble-retention systems.
- Spikes (i.e. dicamba) added to knockdown sprays may persist under dry conditions and can reduce pulse crop establishment. Dicamba plant-backs require 15 mm of rain. Faba bean and lentil are not listed on label.
- Picloram (e.g. Grazon Extra®) applied to previous summer fallows is more likely to persist and damage crops under dry conditions.

Group C:

- Triazine herbicides (e.g. cyanazine, terbuthylazine) applied in-crop can potentially cause crop damage in some circumstances.^{35 36}

7.8.1 Plant-back intervals

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

Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods (e.g. sulfonylureas (chlorsulfuron)). This is shown in [Table 18](#) and [Table 19](#) where known. Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the 'Protection of crops etc' heading in the 'General instructions' section of the label.

Part of the management of herbicide resistance includes rotation of herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonylurea, triazines etc) may be an issue in some paddocks. Remember that plant-back periods begin after rainfall occurs.³⁷

³⁵ P Matthews, D McCaffery, L Jenkins (2017) Winter crop variety sowing guide 2017, NSW DPI Management Guide, NSW Department of Primary Industries, <https://www.dpi.nsw.gov.au/about-us/media-centre/releases/2017/2017-winter-crop-variety-sowing-guide-now-available>

³⁶ Pulse Australia (2016) Field Pea: Residual herbicides and weed control. Australian Pulse bulletin

³⁷ 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

Table 17: Residual persistence of common pre-emergent herbicides and noted residual persistence in broadacre trials and paddock experiences.

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

Source: 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

Table 18: Minimum re-cropping intervals and guidelines. (NOTE: always read labels to confirm.)

Group and type	Product	pH (H ₂ O) or product rate (ml/ha) as applicable	Minimum re-cropping interval (months after application), and conditions
B, sulfonylurea (SU)	Chlorsulfuron e.g. Glean®, Seige®, Tackle®	<6.5	3 months
		6.6–7.5	3 months, minimum 700 mm
		7.6–8.5	18 months, minimum 700 mm
B, sulfonylurea (SU)	Triasulfuron, e.g. Logran®, Nugrain®	7.6–8.5	12 months, >250 mm grain, 300 mm hay
		>8.6	12 months, >250 mm grain, 300 mm hay
B, Sulphonamide	Flumetsulam e.g. Broadstrike®		0 months
B, sulfonylurea (SU)	Metsulfuron e.g. Ally®, Associate®	5.6–8.5	1.5 months
		>8.5	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area.
B, sulfonylurea (SU)	Metsulfuron + thifensulfuron E.g. Harmony® M	7.8–8.5 organic matter >1.7%	3 months
		>8.6 or organic matter <1.7%	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area.
B, sulfonylurea (SU)	Sulfosulfuron e.g. Monza®	<6.5	0 months
		6.5–8.5	10 months

Source: GRDC (2017) GrowNotes –Chickpea, southern, draft Chapter 6, p 51, <https://grdc.com.au/resources-and-publications/grownotes>

7.8.2 Rotational crop plant-back intervals for southern Australia

Where areas have received limited rain during the spring and summer months, there is potential for herbicide residues to still be present in the soil when sowing commences in autumn, unless there are mild temperatures and adequate moisture at least a month or more before sowing (Table 19).

Conditions required for breakdown

Warm, moist soils are required to break down most herbicides through the processes of microbial activity. For the soil microbes to be most active, they need good moisture and an optimum soil temperature range of 18°C–30°C. Extreme temperatures above or below this range can adversely affect soil microbial activity and slow herbicide breakdown. Very dry soil also reduces breakdown. To make matters worse, where the soil profile is very dry it requires a lot of rain to maintain topsoil moisture for the microbes to be active for any length of time.

Risks

In those areas that do not experience conditions which will allow breakdown of residues until just prior to sowing, it is best to avoid planting a crop that is sensitive to the residues potentially present in the paddock, and opt for a crop that will not be affected by the suspected residues. In most cases, cereals or canola would be better options as these crops are comparatively less affected by herbicide residues. If dry areas do get rain and the temperatures become milder, then they are likely to need substantial rain (more than the label requirement) to wet the subsoil, so the topsoil can remain moist for a week or more. This allows the microbes to be active in the topsoil where most of the herbicide residues will be found. Sensitive crops include

legume pastures (e.g. clovers, lucerne or forage legumes) and pulse crops (e.g. lentil, lupin, field pea, faba bean or vetch).³⁸

Table 19: Minimum re-cropping intervals and guidelines for common broadacre herbicides.

Product	Rate	Plant-back period	Wheat	Barley	Oats	Canola	Legume pasture	Pulse crops
2,4-D Ester 680*	0-510 ml/ha	(days)	1	1	1	14	7	7
	510–1,150 ml/ha		3	3	3	21	7	14
	1,150–1,590 ml/ha		7	7	7	28	10	21
Amicide Advance® 700*	0–500 ml/ha	(days)	1	1	1	14	7	7
	500–980 ml/ha		3	3	3	21	7	14
	980–1,500 ml/ha		7	7	7	28	10	21
Kamba® 500*	200 ml/ha	(days)	1	1	1	7	7	7
	280 ml/ha		7	7	7	10	14	14
	560 ml/ha		14	14	14	14	21	21
Hammer® 400 EC					No residual effects			
Nail® 420 EC					No residual effects			
Goal®					No residual effects			
Striker®					No residual effects			
Sharpen®	26 g/ha	(weeks)	–	–	–	16	–	–
Lontrel®	300 ml/ha	(weeks)	1	1	1	1	36	36
Garlon® 600		(weeks)	1	1	NS	NS	NS	NS
Ally®**		(weeks)	2	6	36	36	36	36
Logran®#		(months)	–	–	–	12	12	12
Glean®**		(months)	–	9	6	12	12	12
Grazon® Extra/Grazon® DS		(months)	9	9	NS	9	24	24
Tordon® 75D, Tordon® 242		(months)	2	2	NS	4	9	6
Tordon® Fallow Boss		(months)	9	9	NS	12	20	20

* 15 mm rainfall required to commence plant-back period

** Period may extend where soil pH is greater than 7

Assumes 300 mm rainfall between chemical application and sowing

NS Not specified

Source: GRDC (2017) GrowNotes™ – Chickpea, southern, draft Chapter 1, p 34, <https://grdc.com.au/resources-and-publications/grownotes>

7.9 Herbicide damage

The risk of herbicide damage needs to be weighed against potential yield losses from weed competition. In heavy weed infestations some herbicide crop damage can be tolerated as this is more than offset by the yield loss avoided by removing competing weeds.

If the herbicide is applied to dry soils, the risk of movement and crop damage is increased greatly after rainfall, particularly if the soil is left ridged and herbicide washes into the seed row. Incorporation by sowing (IBS) may be more appropriate in dry conditions, or, alternatively, a split application to minimise risk. Post-sowing

³⁸ Dow AgroSciences. Rotational crop plant-back intervals for southern Australia. http://msdssearch.dow.com/PublishedLiteratureDAS/dh_0931/0901b80380931d5a.pdf?filepath=au&fromPage=GetDoc

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 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 which have been left level and which are moist from recent rainfall.³⁹

Herbicide damage can result from:

- residues in the soil;
- drift from outside the crop;
- pre and post-emergent herbicides applied to the crop; and
- spray tank contamination.

Damage from pre and post-emergent herbicides can be minimised by careful application and by understanding the tolerance of field pea varieties.

Plants weakened by herbicide injury are more susceptible to diseases. The most common problems come from residual herbicides applied to previous cereal crops.⁴⁰ There are also cases where herbicides (such as metribuzin) used in field pea can increase disease severity.

Table 20: The relative leaching potential of some soil-active herbicides (1 indicates the least leaching).

Chemical	Example of product	Leaching index
pendimethalin	Stomp®	1
trifluralin	Treflan®	1
diuron	Diuron	2
prometryn	Prometryn	3-4
simazine	Simazine	5
s-metalochlor	Dual Gold®	6
terbutylazine	Terbyne®	8*
atrazine	Atrazine	10
metribuzin	Sencor®	14

* Estimated

Source: J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry: Chapter 5 – Weed control. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

Metribuzin leaches at seven times the rate of diuron. The relative tolerance of the crop type and variety will also affect crop damage from these herbicides. For example, lupin is more tolerant of simazine than other pulses.

7.9.1 Symptoms of herbicide damage

Symptoms of crop injury from herbicides do not always mean a grain yield loss will occur. Recognition of crop injury symptoms allows the cause of the injury to be identified and possibly prevented in future crops. The type of injury depends on how the herbicide works in the plant, the site and seasonal conditions.

Herbicide injury may be very obvious (e.g. scorched leaves) or it may be more subtle (e.g. poor establishment or delayed maturity). Herbicide crop injury symptoms can easily be confused with symptoms produced by other causes, such as frost, disease or nutrition.

39 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 5-2016

40 P Matthews, D McCaffery, L Jenkins (2017) Winter crop variety sowing guide 2017, NSW DPI Management Guide. NSW Department of Primary Industries, <https://www.dpi.nsw.gov.au/about-us/media-centre/releases/2017/2017-winter-crop-variety-sowing-guide-now-available>

i MORE INFORMATION

Field crop herbicide injury: The Ute Guide <https://grdc.com.au/resources-and-publications/all-publications/bookshop> or as an app

App: Field Peas: The Ute Guide <https://grdc.com.au/Resources/Apps>

App: Herbicide Injury: The Ute Guide <http://www.uteguides.net.au/UteGuides>

Care should be taken when using crop oils and penetrants with herbicides as these can increase the uptake of active chemicals and exceed crop tolerance. Always follow the herbicide label.⁴¹

For information on field pea variety response to herbicides see [Section 3.2.1 Characteristics of field pea varieties for southern Australia](#).

Group B – inhibitors of the enzyme ALS (e.g. chlorsulfuron, imazethapyr)

Sulfonylureas, imidazoliones and sulfonamides are systemic herbicides that are used for pre and/or post-emergent for grass and/or broadleaf weed control in cereals and most are damaging to field pea. Damage can be caused by soil residue or spray contact. Imazamox and imazethapyr are exceptions and are used for post-emergent broadleaf weed control in pea.

Group B soil-residual-herbicide damaged plants germinate normally but become stunted with pale to yellow new leaves. Residual damage is more likely on alkaline (sulfonylureas) or acidic (IMIs) soils.

Affected plants develop brown necrotic spots on leaves and the plant slowly dies. Excessive new shoots form to compensate for growing point death. Root systems are severely stunted.



Photo 2: Stunted field pea with chlorotic new growth that becomes necrotic.

Photo: DPIRD image <https://agric.wa.gov.au/n/4467>

Group C – inhibitors of photosynthesis (e.g. metribuzin)

Seedling emerges normally but tips and edges of older leaflets and tendrils become bleached, pale brown and shrivelled. These symptoms develop on successively younger leaves, as the plant becomes pale and stunted, until it recovers or dies.

41 GRDC (2015) Field pea Northern Region GrowNotes™, <https://grdc.com.au/GrowNotes>



Photo 3: *Metribuzin damage: typically scorched edges/ends of leaves and tendrils.*

Photo: DPIRD <https://www.agric.wa.gov.au/mycrop/diagnosing-group-c-herbicide-damage-field-peas>

Group D – inhibitors of cell division (e.g. trifluralin)

Group D herbicides can cause reduced plant numbers and delayed or poor seedling emergence. Stunted seedlings with thickened hypocotyl, stem and tendrils. Multiple hypocotyl shoots. Leaves are small, thickened and blotchy yellow-green.



Photo 4: *Stunted seedling with thickened hypocotyl, stem and tendrils.*

Photo: DPIRD <https://agric.wa.gov.au/n/4469>

Group F – inhibitors of carotenoid biosynthesis (e.g. diflufenican)

White/yellow spots/bands may develop within 3–4 days after application (2 days in bright sunny weather). Pea plants turn light green and whole leaves turn yellow to cream colour.



Photo 5: *Plants recover from damage.*

Photo: J Moore (2015) Diagnosing Group C herbicide damage in field peas. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/h/4468>

Group G – inhibitors of protoporphyrinogen (e.g. oxyflurfen)

Group G herbicide damage causes numerous white spots on the leaves from the droplets of herbicide contact within one or two days of application. It may lead to death in field pea, although grasses and cereals generally recover.⁴²

42 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC Ground Cover Direct

Group I – disruptors of plant cell growth (e.g. clopyralid)

The plants rapidly develop distorted and twisted growth after spray contact, growing points are pale and distorted and may die. Slightly affected plants can gradually recover.⁴³



Photo 6: Young growth twists rapidly after herbicide application.

Photo: DPIRD <https://agric.wa.gov.au/n/4471>

Group J – inhibitors of fat synthesis (e.g. triallate)

Visual symptoms appear underground or as the crop emerges with reduced or poor seedling emergence. Shoots, if emerged, are often swollen and bright green. Roots are often pruned, leaving stubby root knobs.

Group K – inhibitors of cell division and very long chain fatty acids (e.g. metolachlor)

Visual symptoms appear as the crop emerges with reduced or poor seedling emergence. In most cases weeds do not appear. Seedlings are malformed and twisted, with transitory crop yellowing.

Group L – inhibitors of photosynthesis (photosystem I) (e.g. paraquat)

Visual symptoms appear within hours of application, with spots of dead tissue on otherwise healthy leaves. There may also be wilting and interveinal yellowing, followed by browning and blackening of the leaf edges.

⁴³ S Peltzer (2015) Diagnosing Group I herbicide damage in field peas. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/4471>

Group M – inhibitors of amino acid synthesis (e.g. glyphosate)

Glyphosate symptoms are most obvious at growing points within 5–7 days of application. Plants are stunted (growth stopped until recovery or death) with leaves turning yellow to red, followed by browning. There may be some twisting of plants. Plants look flaccid and tend to lie on the soil surface.⁴⁴



Photo 7: Group M (glyphosate) damage first signs: yellowing/reddening and sometimes interveinal chlorosis of new growth.

Photo: DPIRD <https://agric.wa.gov.au/n/4466>



Photo 8: Group M (glyphosate) damage: tendrils and leaves become wilted and necrotic and the plant dies.

Photo: DPIRD <https://agric.wa.gov.au/n/4466>

44 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC Ground Cover Direct

7.10 Herbicide resistance

Herbicide resistance continues to develop and become more widespread. It is one of the biggest agronomic threats to the sustainability of our cropping systems.

As of October 2017, 49 weed species in Australia have populations that are resistant to at least one herbicide mode-of-action (MOA). Australian weed populations have developed resistance to 12 distinct MOAs.

The International Survey of Herbicide-Resistant Weeds website lists herbicide-resistant weeds by country, including the list of herbicide-resistant weeds in Australia (<http://www.weedscience.org/Summary/Country.aspx?CountryID=1>).⁴⁵

Resistance can be managed through good crop rotation, rotating herbicide groups, and by combining both chemical and non-chemical methods of weed control.

The WeedSmart App (<https://grdc.com.au/apps>) is a simple tool to assess the weed management for a specific paddock. By answering nine short questions about a paddock's farming system, the tool will assess herbicide resistance and weed seedbank risk. It is currently only available for iOS.



Figure 3: WeedSmart App

Source: <https://grdc.com.au/apps>

VIDEO

Watch GCTV video: Glyphosate Resistant Weeds,
<https://youtu.be/Ke8klYnQzI8>



Jane Drinkwater

7.10.1 Glyphosate (Group M)

Continued reliance on glyphosate is leading to increased resistance. The potential inability to use glyphosate due to resistant weeds will increase the cost of weed management. Glyphosate-resistant weeds have a lower fitness and are more able to be controlled using IWM techniques. Controlling weeds using IWM is more costly, but has long-term benefits in delaying resistance development and reducing weed seedbanks.

Resistance mainly occurs in situations where glyphosate has been used as the main weed control tactic, no other effective herbicides are used, and few other weed management practices are employed. These include chemical fallows, fence lines, irrigation channels, vineyards and roadsides.⁴⁶

Glyphosate resistance was first identified in 1996 in Victoria and since then has been confirmed in another 15 weed species. Resistance is known in 9 grass species and 7 broadleaf species of which 5 are winter-growing weed species and 11 are either non-seasonal or summer-growing weed species. Please see the Australian glyphosate resistance register for the most up-to-date information (http://glyphosateresistance.org.au/register_summary.html).

Growers are encouraged to use paraquat for crop-topping in pulses rather than rely on glyphosate, which is frequently used for topping in other crops. However,

⁴⁵ GRDC (2014) Integrated Weed Management Hub. GRDC, <https://grdc.com.au/resources-and-publications/iwmhub>

⁴⁶ C Preston (2012) UA00104 - Understanding and management of weed resistance to glyphosate. GRDC Final report, <http://finalreports.grdc.com.au/UA00104>

paraquat resistance is also increasing so weeds should be tested before planning a management strategy.⁴⁷

7.10.2 Paraquat (Group L)

In 2014, paraquat-resistant weeds included capeweed, northern barley grass, barley grass, annual ryegrass, small square weed and silvergrass.⁴⁸

Ryegrass that is resistant to both glyphosate and paraquat has been found in South Australia.⁴⁹

7.10.3 Other herbicides

Annual ryegrass in Australia is now resistant to eight different herbicide groups. The major herbicides are Group A (>20,000 sites in Australia), Group B (>20,000 sites) and Group D (>5,000 sites).⁵⁰ Resistance to trifluralin (Group D) and the Dims (Group A) is increasing in southern Australia.⁵¹

Clethodim (Group A) resistance is a major issue in pulse production. Clethodim is the last Group A herbicide that provides effective control of Group A herbicide-resistant ryegrass.⁵²

In wild oats there is a high rate of resistance to all of Group A (Fops, Dims and Dens).⁵³

7.10.4 WeedSmart

WeedSmart's mantra has evolved to 'The Big 6' to help make winning the battle against crop weeds simple to follow and apply.

The WeedSmart plan is all about the grower – and not the weeds – calling the shots.

1. Rotate crops and pastures
2. Double knock – to preserve glyphosate
3. Mix and rotate herbicides
4. Stop weed seed set
5. Crop competition
6. Harvest weed seed control – the holgy grail.

Please see <https://weedsmart.org.au/the-big-6> for further details

MORE INFORMATION

WeedSmart: www.weedsmart.org.au

Australian Herbicide Resistance Initiative: www.ahri.uwa.edu.au

Australian Glyphosate Sustainability Working Group: <http://glyphosateresistance.org.au>

GRDC: www.grdc.com.au

47 C Preston (2012) UA00104 - Understanding and management of weed resistance to glyphosate. GRDC Final report, <http://finalreports.grdc.com.au/UA00104>

48 GRDC (2014) Integrated Weed Management Hub. GRDC, <https://grdc.com.au/resources-and-publications/wmhub>

49 C Preston (2012) UA00104 - Understanding and management of weed resistance to glyphosate. GRDC Final report, <http://finalreports.grdc.com.au/UA00104>

50 CropLife Australia (2017) Herbicide-resistant weeds. CropLife website, <http://www.croplife.org.au/resistance-strategy/2017-herbicide-resistant-weeds-list>

51 G Brooke, C McMaster (2016) Weed control in winter crops 2016. NSW Department of Primary Industries, <http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops>

52 C Preston, P Boutsalis, S Kleemann, R Saini and G Gill (2015) Managing resistant ryegrass in break crops and new herbicides for resistant ryegrass. GRDC Update Papers, 28 July 2015, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Managing-resistant-ryegrass-in-break-crops-and-new-herbicides-for-resistant-ryegrass>

53 G Brooke, C McMaster (2016) Weed control in winter crops 2016. NSW Department of Primary Industries, <http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops>

i MORE INFORMATION

CropLife webpage: Herbicide mode of action table

<http://www.croplife.org.au/resistance-strategy/2017-herbicide-moa-table/>

CropLife webpage: Herbicide resistant weeds in Australia

<http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistant-weeds-list/>

GRDC Fact Sheet: Herbicide resistance <https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance>

CropLife Booklet: Herbicide resistance management strategies <http://www.croplife.org.au/resistance-strategy/2017-herbicide-resistance-management-strategies/>

Webpage: Weedsmart The Big 6 <https://weedsmart.org.au/the-big-6/>

Website: Australian Glyphosate Sustainability Working Group <http://www.glyphosateresistance.org.au/>

App: WeedSmart to estimate paddock risk (iOS only) <https://grdc.com.au/apps>

AHRI decision-support tool: Ryegrass Integrated Management (RIM) <http://ahri.uwa.edu.au/research/rim/>

GRDC Updates: Herbicide resistance management, a local, in-field perspective <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Herbicide-resistance-management-a-local-infield-perspective>

7.10.5 Annual ryegrass

Annual ryegrass has higher levels of resistance than any other weed. Preventing ryegrass from setting seed and removing weed seeds at harvest before they fall to the ground is the top priority. Aim for 3 years with no weed seedset.⁵⁴

Techniques to manage resistant ryegrass include:

- Know your resistance status. What herbicides is the ryegrass resistant to?
- Use crop rotation to access different treatment options.
- Avoid cultivation that will bury ryegrass seed. Seed on the soil surface is more likely to be burnt, rot naturally or be controlled by pre-emergent herbicide. Cultivation is more suited to large mature weeds in fallow.
- Use double knockdowns before sowing.
- Consider crop-topping even if yield will be reduced.
- Consider green or brown manuring or cutting for hay.
- Capture and destroy weed seeds at harvest.
- Control ryegrass in non-crop areas such as fence lines, channel banks.⁵⁵

Ryegrass Integrated Management (RIM) (<http://ahri.uwa.edu.au/research/rim/>) is a decision-support tool to evaluate the long-term profitability of strategic and tactical ryegrass control methods. It allows growers to test ideas to reduce ryegrass populations while improving profitability.

7.10.6 Herbicide-resistance testing

There are two types of commercial tests for herbicide resistance:

Seed testing is suitable for pre- and post-emergent herbicides and takes 4–5 months. This requires 3,000 seeds of each weed, which is approximately 1 cup of annual ryegrass seed or 6 cups of wild radish pods. The **quick-test** for post-emergent herbicides only uses live plant seedlings and results are available within 6 weeks. This requires 50 plants (or 20 large tillering plants) for each herbicide tested.

There are two testing services in the southern region:

Plant Science Consulting offers both seed testing and the quick-test.

22 Linley Avenue, Prospect, SA 5082.
Ph: 0400 66 44 60
Email: info@plantscienceconsulting.com.au
<http://www.plantscienceconsulting.com.au/>

Charles Sturt University offers the seed test only.

Herbicide Resistance Testing, School of Agricultural and Wine Sciences, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW, 2678.
Ph: John Broster 02 6933 4001 or 0427 296 641
Email: jbroster@csu.edu.au
<https://www.csu.edu.au/weedresearchgroup/herbicide-resistance>

54 L Pearce (2015) Herbicide-resistance management: a local, in-field perspective. GRDC Update Papers, 30 July 2015, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Herbicide-resistance-management-a-local-infield-perspective>

55 GRDC (2012) Herbicide resistance Fact Sheet, Southern Region, GRDC, May 2012, <https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance>

7.11 Spraying Issues

Watch Spray Application Workshop <https://youtu.be/UskthCWjeug>

7.11.1 Water quality for herbicide application

Good quality water is important when mixing and spraying herbicides. It should be clean and of a good irrigation quality. Poor quality water can reduce the effectiveness of some herbicides and damage spray equipment (Table 21).

Table 21: Herbicide tolerance to water qualities.

Herbicide	Water quality				
	Muddy	Saline	Hard	Alkaline (pH>8)	Acidic (pH<5)
2,4-DB			X	NR	
2,4-D or MCPA amine	✓	✓	X	NR	
2,4-D or MCPA ester	✓	test	test	✓	✓
Associate®	✓	✓	✓	Marginal	X
Brodal®		✓	✓	X	
Dicamba	✓	✓	NR	NR	
Diuron	✓	test	✓	✓	
Diuron + 2,4-D amine	✓	test	X	NR	
Diuron + MCPA amine	✓	test	X	NR	
Fusilade® Forte	✓	✓	✓	NR	X
Tackle®	✓	✓	✓	marginal	X
Glyphosate	X	✓	X		✓
Gramoxone®	X	✓	✓	✓	✓
Logran®B-Power	✓	✓	✓	marginal	X
Lontrel™ Advanced	✓	✓	X	X	
Simazine	✓	X	✓	NR	
SpraySeed®	X	✓	✓	✓	✓
Elantra® Xtreme®	✓	✓	✓	✓	✓
Tigrex®	✓	X	X	NR	
Trifluralin		✓	✓	✓	✓
Verdict™	✓	✓	✓	NR	✓

✓= OK X = Do not use NR = Not recommended but use quickly if there is no alternative test = Mix herbicides and water in proportion and observe any instability marginal = Not ideal, but acceptable.

Source: Weed control in winter crops 2017, (2017), NSW Department of Primary Industries, <http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops>

i MORE INFORMATION

Weather essentials for pesticide application, <https://grdc.com.au/GRDC-Booklet-WeatherEssentials>

Spray application manual for grain growers GrowNotes™, Module 4, 'Drift management strategies: minimising and managing spray drift risk', <https://grdc.com.au/resources-and-publications/grownotes/technical/spray-application-manual>

7.11.2 Spray drift

All pesticides are capable of drifting from neighbouring paddocks. Pulses are particularly vulnerable to damage from volatile phenoxy ester herbicides (Group I) that are more prone to drift as a vapour during or after application.⁵⁶

7.11.3 Spray tank contamination

Traces of sulfonylurea herbicides (Group B, e.g. chlorsulfuron, metsulfuron or triasulfuron) and carfentrazone (Group G, e.g. Affinity®) in spray equipment can cause severe damage to pulses when activated by grass-control herbicides.

It is vitally important to properly clean and decontaminate spray equipment before applying herbicides. See product labels for specific product recommendations on decontamination.⁵⁷

7.12 Selective sprayer technology

As a result of an increase in the use of no-till cropping and the incidence of summer weeds many growers have adopted a spray fallow system that predominantly uses glyphosate over summer to remove weeds and conserve moisture for the next crop.

To reduce the risk of glyphosate resistance developing in fallow weeds some growers are using weed-detecting technology to detect individual weeds that have survived the glyphosate application and spraying these with an alternative knockdown herbicide.

The key to successful resistance management is killing the last few individuals, but this becomes rather difficult on large-scale properties. Left uncontrolled, these last few weeds result in significant seed production and a resetting of the weed seedbank. The introduction of weed-detecting technology is timely as it is well suited to detecting patches of weeds across large areas.

The technology uses optical sensors to turn on spray nozzles only when green weeds are detected, greatly reducing total herbicide use per hectare. The units have their own light source so can be used day or night.

Rather than spraying a blanket amount of herbicide across a paddock, the weed-detecting technology enables the user to apply higher herbicide rates (per plant), which results in more effective weed control as well as saving on herbicide costs.



Photo 9: Selective sprayer technology uses optical sensors to turn on spray nozzles only when green weeds are detected.

Photo: McIntosh Distribution (2016) <http://www.mcintoshdistribution.com.au/machinery/show/weedseeker-australia>

56 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 5-2016

57 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 5-2016

7.12.1 Permits for herbicides using weed detectors

Weed-detecting technology (via WeedSeeker®) is being used to manage glyphosate-resistant grasses in fallows with the aid of a minor use permit (MUP). This allows growers to use selective grass herbicides and higher rates of paraquat and diquat (bipyridyl herbicides, Group L). The permit (PER11163) (<http://permits.apvma.gov.au/PER11163.PDF>) is in force until 28 February 2019 and is for all Australian states.

This permit allows the use of about 30 different herbicides from groups with seven modes of action. Additional modes of action are likely to be added to the permit over time.

Some herbicide rates have been increased to enable control of larger or stressed weeds. For example, glyphosate (450 grams of glyphosate per litre) rates range from 3 to 4 L/ha (using a set water rate of 100 L/ha), which far exceeds the label blanket rates of 0.4–2.4 L/ha. Similar increases in rate have also been permitted for paraquat (e.g. Gramoxone®).

The WeedSeeker® permit system is a great help for zero- and minimum-tillage systems battling glyphosate-resistant weeds as it represents a more economical way to carry out a double knock and avoids the need to cultivate for weed seed burial. It also results in significant savings in chemical costs.

The new technology also has the potential to map troublesome weed patches so that these areas can be targeted with a pre-emergent herbicide before sowing.⁵⁸

58 T Cook (2013) Selective spraying to cut costs. GRDC Ground Cover™ Supplement, 6 May 2013, <https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104/Selective-spraying-to-cut-costs>

Pest management

Key points

- The key pests of field pea across southern Australia are native budworm (*Helicoverpa punctigera*), pea weevil (*Bruchus pisorum*), snail, slugs, aphids, mites, lucerne flea and lucerne seed web moth (*Etiella behrii*).
- Integrated pest management (IPM) is an ecological approach aimed at significantly reducing use of pesticides while managing pest populations at an acceptable level.
- IPM involves planning, monitoring and recording, identification, assessing options, controlling/managing and reassessing.
- Monitoring for beneficial species is important.
- Exotic bruchids and leaf miners pose a biosecurity threat.

i MORE INFORMATION

GRDC Fact Sheet Integrated pest management:
<https://grdc.com.au/resources-and-publications/all-publications/bookshop/2009/12/integrated-pest-management-fact-sheet-national>

IPM Guidelines,
<http://www.ipmguidelinesforgrains.com.au>

8.1 Integrated pest management (IPM)

Integrated pest management (IPM) is an integrated approach of crop management to reduce chemical inputs and solve ecological problems. Although originally developed for agricultural insect pest management, IPM programs are now developed to encompass diseases, weeds and other pests that interfere with the management objectives of sites.

IPM is performed in three stages: prevention, observation and intervention. It is an ecological approach aimed at significantly reducing the use of pesticides while managing pest populations at an acceptable level. IPM therefore uses an array of complementary methods including mechanical and physical devices, as well as genetic, biological, cultural and chemical management. The reduction in cost, contamination, residues and resistance to the pesticide are all benefits.

An IPM system is designed around five basic components:

1. Acceptable pest levels

Emphasis is on control, not eradication. Wiping out an entire pest population is often impossible, and can be economically expensive and environmentally unsafe. IPM programs work to establish acceptable pest levels (action thresholds) and then apply controls if those thresholds are exceeded. Thresholds are pest and site specific. What is acceptable at one site may not be acceptable at another site or crop.

2. Preventive cultural practices

Using varieties best suited to local growing conditions, and maintaining healthy crops, is the first line of defense, together with plant hygiene and crop sanitation (e.g. removal of diseased plants to prevent spread of infection). Should an insect pest reach an unacceptable level, mechanical methods may be possible. For example, burning, rolling or cabling for snail control. Note that mechanical controls only work out of season as pests are unlikely to reach an unacceptable level when there is no crop.

3. Monitoring

Regular observation is the key to IPM. Observation is broken into inspection and identification. Visual inspection, insect traps and other measuring tools are used to monitor insect pest levels. Accurate pest identification is critical to a successful IPM program.

For insects, monitoring for beneficial organisms and predators is important too. These are important to assist in controlling the pest. Record-keeping is essential, as is a thorough knowledge of the behaviour and reproductive cycles of target pests.

Insects are cold-blooded and their physical development is dependent on temperatures in their environment.

Many insects have had their development cycles modelled in terms of degree days (e.g. etiology, pea weevil). Monitor the degree days of an environment to determine the optimal time for a specific insect outbreak.

4. Biological controls

Biological processes and materials can provide control, with minimal environmental impact, and often at low cost. The main focus is on promoting beneficial insects that eat target pests. In broadacre crops the best strategy is currently to preserve those that are naturally occurring. Biological insecticides, derived from naturally occurring microorganisms, also fit this category (e.g. *Bt* (*Bacillus thuringiensis*)). Unlike broad-spectrum chemical pesticides, *Bt* toxins are selective and negative environmental impact is very limited. *Bt* has been highly efficacious in pest management of corn and cotton, drastically reducing the amount of broad-spectrum chemical insecticides used while being safe for consumers and non-target organisms. *Bt* entomopathogenic fungi and entomopathogenic nematodes).

5. Responsible pesticide use

Synthetic pesticides are generally only used as required and often only at specific times in a pest's life cycle. Many newer pesticide groups are derived from plants or naturally occurring substances. Examples are nicotine, pyrethrum and insect juvenile hormone analogues. The active component may be altered to provide increased biological activity or stability. Further 'biology-based' or 'ecological' techniques are under evaluation.¹

8.1.1 Problems with pesticides

IPM does not mean abandoning pesticides – they are still the basis for pest control – but the impact on natural enemies must be considered when selecting a pesticide. Regular monitoring is needed to observe pest and beneficial species dynamics. Beneficial species can provide control of most pests if they are present. By reducing the use of non-selective pesticides, the aim is to foster predators and parasites to stabilise pest populations and reduce the need to spray.

Overuse of pesticides can hasten pesticide resistance developing. It can also lead to a resurgence of pests, create new pests, potentially increase pesticide residues in grain and lead to off-target contamination, including of wildlife reserves and waterways.²

8.1.2 IPM, organics and biological control

IPM is not the same as organic pest management, although many organic options are compatible with IPM. IPM is sometimes confused with classic biological control. While they are not the same, IPM plays an important role in maximising the success of biological control by reducing the use of non-selective sprays, boosting the survival of biological control agents.³

Native remnant vegetation can support beneficial predatory insects. Pest-suppressive landscapes are those that have the right mix of habitats that support beneficial insects and allow them to move into crop fields, while discouraging the build-up of pest insect species.⁴

8.1.3 Soft v. hard pesticides

The terms 'soft' and 'selective' are terms used to describe pesticides that kill target pests but have minimal impact on parasites and predators attacking these pests. Parasites and predators are often called 'beneficials'.

Pesticides that impact on beneficial species are termed 'hard', 'non-selective' or 'broad-spectrum'.

In practice, there are varying degrees of softness, and many products may be hard on one group of beneficial species but relatively soft on another.

(See Section 8.16 Beneficial species.)

Insecticides that are less toxic to beneficial insects should be used where possible; for example, using pirimicarb for aphid control may mean fewer repeat applications compared with the use of synthetic pyrethroids because beneficial insects are preserved.⁵

MORE INFORMATION

GRDC Fact Sheet Pest-suppressive landscapes: pest management using native vegetation:

<https://grdc.com.au/GRDC-FS-PestSuppressiveLandscapes>

1 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

2 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp

3 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp

4 GRDC (2014) Pest-suppressive landscapes: pest management using native vegetation. Fact Sheet, Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-PestSuppressiveLandscapes

5 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp

8.2 IPM process

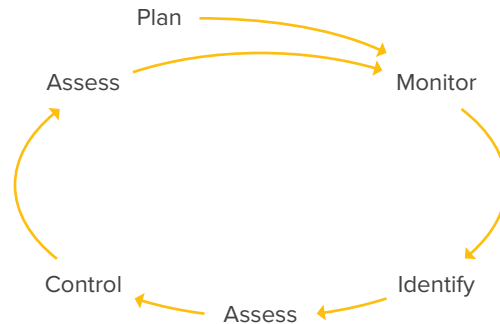


Figure 1: A summary of the pest management process.

Source: Pulse Australia (2016) Faba & Broad Bean – Best Management Practices Training Course, module 7-2016. Pulse Australia Limited

Planning

Be aware of which pests are likely to attack the crops in your region and become familiar with when to monitor for particular pests, what the pests look like and damage symptoms. Assess sampling protocols and plan how you will cope with the logistics of sampling. Discuss this with your consultant/clients, and their attitude towards management. Be aware of the latest management options, pesticide permits and registrations in field pea, and any use and withholding period restrictions.

Monitoring

Scout crops thoroughly and regularly during ‘at risk’ periods using the most appropriate sampling method. Record insect counts and other relevant information using a consistent method to allow comparisons over time. Also monitor any nearby crops that may be harbouring pests, e.g. aphids, that could rapidly build up and then take flight into a neighbouring pea crop. For more information see [Section 8.2.1 Pest monitoring methods](#).

Identification

It is important to be able to identify the various insects present in your crop, whether they are pests or beneficial species, and their growth stages. It is important to be able to identify the different larval instars of *Helicoverpa* (very small, small, small–medium, medium–large, large). Other minor pests of field pea include: aphids, pea weevil, cutworms, thrips, loopers, lucerne fleas and mites. For more information see [Section 8.2.2 Identify pests](#).

Assess options

Use the information gathered from monitoring to decide what sort of control action (if any) is required. Make spray decisions based on a combination of any available economic threshold information and your experience. Other factors such as insecticide resistance and area-wide management strategies may impact on spray recommendations.

Control

If a control operation is required, ensure application occurs at the appropriate time of day. Record all spray details including rates, spray volume, pressure, nozzles, meteorological data (relative humidity, temperature, wind speed and direction, inversions and thermals) and time of day.

Re-assess and document results

Assess crops after spraying and record data for future reference. Post-spray inspections are important in assessing whether the spray has been effective.⁶

⁶ Pulse Australia (2016) Faba & Broad Bean – Best Management Practices Training Course, module 7-2016. Pulse Australia Limited

8.2.1 Pest monitoring methods

Knowing when field pea crops are susceptible to pest attack is the first step in good pest management. For example, *Helicoverpa* do most damage during pod-set through to maturity. Seedling insect pests, such as cutworm, can attack field pea early. Regular monitoring of the crop for the presence of insects pests and/or damage is necessary in order to make timely decisions on control, especially when it is important to be targeting small larvae.

See individual pest species descriptions for best monitoring methods.

Pest monitoring will save money

Routine spraying without checking pest levels or spray effectiveness is a hit-and-miss process that may or may not be effective, and is likely to result in increased levels of resistance. It is also likely to take more time and money than necessary and give poor results.

Effective pest management depends on identifying changes in pest and beneficial insect activity in and around the crop in time to keep damage levels low.

Setting up a suitable monitoring program is probably the most complex and time-intensive component of an IPM program, but it is an essential risk-management tool for protecting all other investments made in the business.

A monitoring program will cut crop losses and unnecessary chemical costs and identify hidden weaknesses in the pest control program. Crop monitoring is absolutely essential if you want to also incorporate beneficial insects into your pest control program.

Record the results from monitoring

Successive records of crop inspections will show you whether pest numbers are increasing or decreasing, and help in deciding whether a spray is necessary.

As well as recording pest insect numbers, there are other key details that are important to both observe and record.

Insect checking records should include, as a minimum:

- date and time of day;
- crop growth stage and susceptibility;
- change in the number of insects present (pest and beneficial) and their stage of development over time;
- type of checking method used and number of samples taken per paddock;
- control recommendation if any; and
- post-spray counts.

When to monitor

All field pea crops should be scouted for insects at regular intervals, usually once per week prior to pod-set and 2–3 times a week from pod-set onwards.

Sweep net monitoring

The easiest and quickest way to determine the number of grubs in a crop is to ‘sweep’ the crop with an insect sweep net. It is impossible to accurately determine numbers by simply looking in the crop.

A standard sized net (380 mm in diameter) can be purchased from most chemical suppliers.

Follow these steps:

- Take 10 sweeps of the net through the crop canopy while walking slowly through the paddock. A standard sweep of the net needs to be about 2 m in length.

- Empty the contents into a tray or bucket and count the caterpillars of various sizes. It is important to look very carefully for small caterpillars as these have the most potential to cause damage.
- Repeat this process in at least 12 places throughout the paddock to obtain an average insect density.

Crop inspection

Sampling flowers and leaves in the crop can tell you much more than a sticky trap including:

- presence or absence and levels of non-flying juvenile stages (eggs, larvae, pupae);
- presence/absence and levels of non-flying adult insects (mites, snails etc); and
- early stages and extent of pest damage.

This information is much more powerful for assessing pest levels, accurately predicting trends and checking the effectiveness of control measures. It is essential for making decisions and following up on the results. It will also reveal a lot about the behaviour of pests and beneficial insects that will help you to manage problem pests. Depending on the pest, where it feeds, hides and breeds, you will need to check flowers, leaves, fruit etc. The pattern, frequency and level of sampling depend on the crop, pests of concern and beneficial insects of interest and the time of year.

Weeds near to your farm/crop will build up large numbers of pests in spring. Inspecting the weeds can keep you in touch with how the local pest pressure is building up. Better still, remove the weeds before the pests build up on them.

Yellow sticky traps or cards

Sticky traps are useful as a way of monitoring flying pests like thrips, whitefly and aphids. They attract these insects because of their colour. Yellow traps attract thrips, whitefly and aphids. They are also a useful way of sending samples away for identification of thrips species. However, they do not give a complete picture of pest dynamics in the crop. Adult insects may settle into the crop after flying in and juvenile non-flying stages may survive spray applications but will not show up on the traps.

Sticky traps should be changed or checked at least weekly. They need to be placed just above the growing tips of the plants to catch insects hovering above them and to avoid getting stuck and lost in the crop.

Quadrats

Use quadrats to sample snails. See [Section 8.7.4 Monitoring snails](#).

Tiles, hessian bags and slug traps

Use either a tile, hessian bag or slug trap left in the paddock over night to count snail or slug numbers.⁷

⁷ Pulse Australia (2016) Faba & Broad Bean – Best Management Practices Training Course, module 7-2016. Pulse Australia Limited

8.2.2 Identify pests

It is important to be able to identify the various insect present in your crop, whether they are pest or beneficial species, and their growth stages.

Sending insect samples for diagnostics

SARDI Entomology Unit provides free insect diagnostic services for subscribers of PestFacts South Australia and western Victoria newsletter.

CESAR (University of Melbourne), SARDI and NSW DPI will identify insects for a fee. For more information: contact CESAR (03 9349 4723 or www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/insect-identification-service/) or SARDI (www.pir.sa.gov.au/research/services/crop_diagnostics/insect_diagnostic_service/) (prices available on application).

Agriculture Victoria does not offer a routine insect identification service.⁸

8.2.3 Insect ID: The Ute Guide

While many resources are available, the primary insect-identification resource for grain growers is 'Insect ID: The Ute Guide', a digital guide (App) for smartphones and tablets that is progressively updated as new information becomes available.



Figure 2: *Insect ID: The Ute Guide App.*

Source: GRDC

Insect ID: The Ute Guide is a comprehensive reference guide for insect pests commonly affecting broadacre crops and growers across Australia, and includes the beneficial insects that may help to control them.

Photos have been provided for multiple life-cycle stages, and each insect is described in detail, with information on the crops it attacks, how it can be monitored and other pests that it may be confused with.

Not all insects found in field crops are listed in this App, so further advice may be required before making management decisions.

⁸ Pulse Australia (2016) Agronomy, Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

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Field peas: The Ute Guide, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

PestFacts, <https://grdc.com.au/resources-and-publications/apps>

iPhone Screenshots

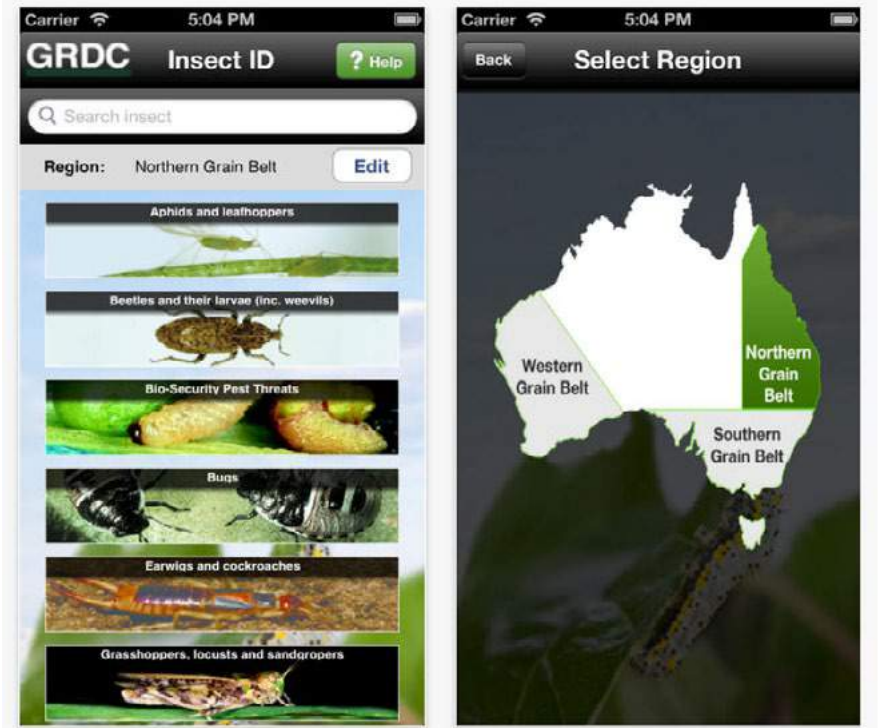


Photo 1: Screen shots from the iOS edition of *Insect ID: The Ute Guide App*.

Source: iTunes store, <https://itunes.apple.com/au/app/insect-id-the-ute-guide/id667842983>

8.2.4 GrowNotes™ Alerts

GrowNotes™ Alerts is a free, early-warning system that notifies growers of any emerging disease, pest and weed threats, specific to the user's chosen area. It provides real-time information from experts across Australia.

A GrowNotes™ Alert can be delivered via App, SMS, voice, email, social media or web portal (or a combination of preferred methods). The urgency with which the alerts are delivered can help reduce the impact of weed, pest and disease costs. GrowNotes™ Alerts improves the relevance, reliability, speed and coverage of notifications on the incidence, prevalence and distribution of weed, pest and diseases. To subscribe go to: <https://grdc.com.au/grownotesalert>

8.3 Key pests of field pea

The key pests of field pea in southern Australia are: native budworm (*Helicoverpa punctigera*), pea weevil (*Bruchus pisorum*), snail, slugs, aphids, mites, lucerne flea and lucerne seed web moth (*Etiella behrii*). Table 1 shows the timing of damaging effects of the key and other pests in field pea crops.

Table 1: Incidence of insect pests in field pea.

Pest	Crop stage				
	Emergence/ seedling	Vegetative	Flowering	Podding	Grain-fill
Earth mites	Damaging	Present	Present		
Lucerne flea	Damaging	Present			
Cutworms	Damaging				
Slugs and snails*	Damaging	Damaging			
Aphids	Damaging	Damaging	Present	Present	
Thrips		Present	Present		
Pea weevil		Present	Damaging	Damaging	Damaging
Helicoverpa		Present	Damaging	Damaging	Damaging
Etiella		Present	Present	Damaging	Damaging

Source: NPI & field pea IPM: <http://ipmguidelinesforgrains.com.au/crops/winter-pulses/field-peas/>

MORE INFORMATION

Insect ID: The Ute Guide

<https://grdc.com.au/resources-and-publications/apps/insect-id-the-ute-guide>

8.4 *Helicoverpa* species: native budworm and corn earworm (*Helicoverpa punctigera* and *H. armigera*)

The main insect pest of field pea late in the season in southern and western Australia is the larvae of native budworm (*Helicoverpa*), sometimes known as Heliothis.

Helicoverpa punctigera is not the species *H. armigera*, which is commonly known as corn earworm or cotton bollworm.

8.4.1 Distribution of *Helicoverpa* spp.

Most *Helicoverpa* across southern Australia from September to early November will be *H. punctigera*.⁹ *H. punctigera* (native budworm) breeds over winter in the arid inland regions of Queensland, South Australia, Western Australia and New South Wales on desert plants before migrating into southern agricultural areas in late winter or spring. They can migrate as far south as Tasmania.¹⁰

H. armigera may become more problematic in summer crop irrigation areas. It rarely occurs in significant numbers in Victorian crops.¹¹ It is a major pest of chickpea and other pulses in northern Australia.¹²

While significant numbers of *H. armigera* are rare in Victoria, it is still an important pest when it does occur in large numbers as it may be resistant to many of the commonly used insecticides.¹³

9 Pulse Australia (2016) Southern/western field pea best management practices training course, module 7-2016, Draft. Pulse Australia Limited

10 G McDonald (2015) Native budworm. Pest Notes Southern. CESAR and South Australian Research and Development Institute, http://www.pirsa.gov.au/_data/assets/pdf_file/0005/274181/Native_Budworm.pdf

11 G McDonald (1995) Native budworm. Agnote Ag0417. Agriculture Victoria, June 1995, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/native-budworm>

12 Pulse Australia (2016) Faba & Broad Bean – Best Management Practices Training Course, module 7-2016. Pulse Australia Limited

13 G McDonald (1995) Native budworm. Agnote Ag0417. Agriculture Victoria, June 1995, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/native-budworm>

8.4.2 Identification of *Helicoverpa* spp. moths

Adult moths are nocturnal, so are rarely seen during the day. They vary in colour from grey-green to pale cream and have a wingspan of 3–4.5 cm (Photo 2).



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

Photo: Photo from northern field pea GrowNote, chapter 7, Figure 1

For native budworm (*H. punctigera*), the forewings are buff-olive to red-brown with numerous dark spots and blotches. The hind wings are pale grey with dark veins and a dark band along the lower edge. The hind wings have a dark, broad band on the outer margin (Figure 3).

H. armigera has a small light or pale patch in the dark section of the hindwing while the dark section is uniform in *H. punctigera* (Figure 3).¹⁴

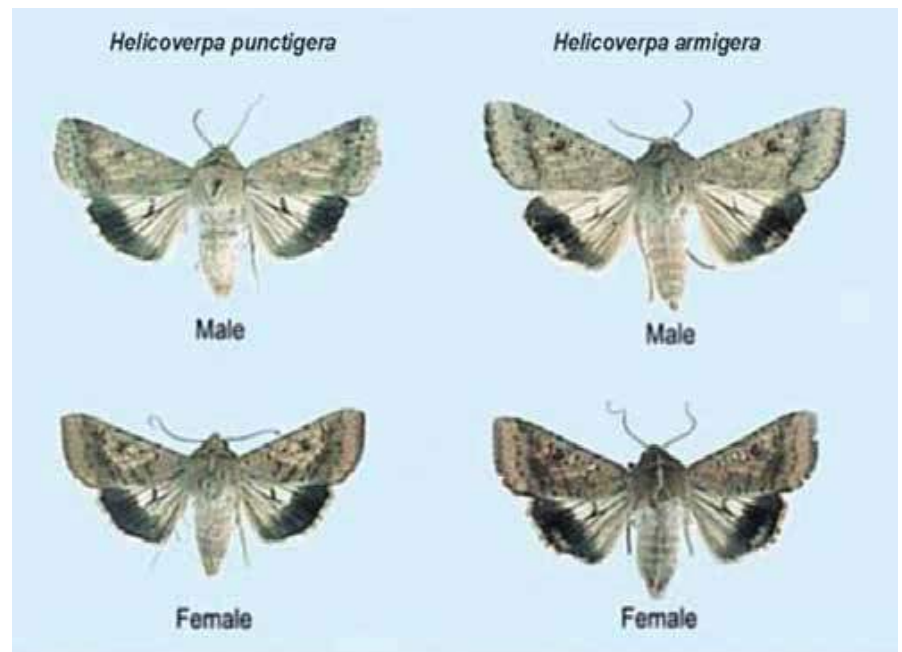


Figure 3: *Helicoverpa punctigera* and *H. armigera* moths are distinguished by the presence of a pale patch in the margin of the hindwing of *H. armigera*.

Photo: GRDC Resources Ute-Guide, <https://grdc.com.au/Resources/Ute-Guides/Insects/Butterflies-moths-larvae/North/Heliothis>

8.4.3 Identification of *Helicoverpa* spp. eggs and larvae

Determining which species of *Helicoverpa* are present in the crop is essential, because of the differing susceptibility of the two species to synthetic pyrethroids and carbamates. *H. armigera* is resistant to some insecticide groups, whereas *H. punctigera* is susceptible to all products.

As the larvae of *Helicoverpa* are the main insect pest of field pea, it is important to be able to identify the different larval instars (very small, small, medium, large) of *Helicoverpa* spp. (Figure 4).







Instar	Larval appearance	Actual larval length (mm)	Size category
First		1-3	very small
Second		4-7	small
Third		8-13	small medium
Fourth		14-23	medium large
Fifth		24-28	large
Sixth		29-30+	large

Figure 4: Guide to *Helicoverpa* spp. larval instars and size categories.

Source: QDPI&F, Understanding *Helicoverpa* ecology & biology in southern Queensland: Know the enemy to manage it better, https://www.daf.qld.gov.au/_data/assets/pdf_file/0005/72689/Insects-Helicoverpa-ecology-biology.pdf

The adult moths lay round eggs (0.5 mm in diameter), singly on the growing tips and buds of host plants. They are white when first laid but change colour from yellow through to brown just before hatching (Photo 3).



Photo 3: (From left) black larval head in nearly hatching egg, brown ring and fresh laid white eggs of *Helicoverpa* spp.

Photo: GRDC <https://grdc.com.au/Resources/Ute-Guides/Insects/Butterflies-moths-larvae/North/Heliothis>

Newly hatched caterpillars (larvae) are very small (approximately 1.5 mm), light in colour with dark brown heads and can easily be missed when inspecting a crop. They will pass through six or seven growth stages or instars until they are up to 40 mm long (Photo 4).

When fully grown, they can have considerable colour variation, from green, buff yellow, red or brown to almost black, with a broad yellow-white stripe down each side of the body and a dark stripe down the centre of the back (Photo 5).



Photo 4: Developmental stages of *Helicoverpa* spp. eggs and larvae. Newly laid egg (white and mature egg (black) with six larval instars.

Photo: Gabriella Caon, SARDI, GRDC Resources Ute-Guide, <https://grdc.com.au/Resources/Ute-Guides/Insects/Butterflies-moths-larvae/North/Heliothis>



Photo 5: Large *Helicoverpa* larvae showing colour variation.

Photo: D. Ironside, Queensland DAF, GRDC Resources Ute-Guide, <https://grdc.com.au/Resources/Ute-Guides/Insects/Butterflies-moths-larvae/North/Heliothis>

The two species of *Helicoverpa* look similar and it is important to identify them and develop an understanding of the likely presence and population mix of the two species, particularly when making control choices as *H. armigera* has developed resistance to the commonly used pyrethroid chemical group (e.g. Decis Options®, Karate®) and to the carbamate group (e.g. Lannate L®). Separate pheromone traps can be deployed to trap both species and is an indicator of their presence and the likely mix other than identifying the moths or larvae that are present.

While both species of *Helicoverpa* have four pairs of abdominal prolegs (grasping appendages) in addition to a pair of anal prolegs, *H. armigera* caterpillars have a saddle on the fourth abdominal segment (Photo 6) at the 3rd instar stage (approximately 1 cm long), and white hairs on the segment directly behind the head (Photo 8) at the 5th instar stage (approximately 2 cm long) and dark legs compared to black hairs on native budworm *H. punctigera*, which has no saddle and light-coloured legs (Photo 7 and Photo 8).¹⁵

15 Pulse Australia (2016) Managing native budworm in pulses. Australian Pulse Bulletin, <http://www.pulseaus.com.au/growing-pulses/publications/native-budworm>



Photo 6: Medium larvae of *Helicoverpa armigera* with saddle on fourth segment.

Photo: IPM guidelines for grains, <http://ipmguidelinesforgrains.com.au/pests/helicoverpa/>



Photo 7: Medium larvae of *Helicoverpa punctigera* (no saddle).

Photo: IPM guidelines for grains, <http://ipmguidelinesforgrains.com.au/pests/helicoverpa/>

In larger larvae (5th and 6th instar), hair colour on the segment immediately behind the head is a good species indicator. These hairs are white on *H. armigera* and black on *H. punctigera* (Photo 8).



Photo 8: Large larvae of *H. punctigera* (left) with black hair behind head and *H. armigera* (right) with white hair behind head.

Photo: GRDC

Helicoverpa punctigera larvae can be identified, despite the colour variations, by a broad yellow stripe along the body. The young larvae (<10 mm) prefer to feed on foliage. Older larvae prefer to feed on pods. Insecticides are more effective on smaller larvae.

Other larvae, which look like native budworm, may be found in a pulse crop, e.g. southern armyworm and pink cutworm. These are primarily grass feeders and rarely do any damage to pulses.¹⁶

8.4.4 Life cycle of *Helicoverpa* spp.

In southern Australia, native budworm may produce up to five generations a year. The spring generation causes the most damage, especially to grain legume crops. The late summer generation usually attacks lucerne seed crops.

During winter, native budworm enters a resting period as a pupa in the soil. Adult moths emerge from these overwintering pupae in August and September and live for about 2–4 weeks. The moths are capable of laying up to 1,000 eggs each.

The eggs hatch 1–2 weeks after laying in spring and the larvae feed in crops for 4–6 weeks. The mature larvae leave the host plant to pupate in the soil. During spring, summer and early autumn the pupae develop quickly and a new generation of moths emerges after about 2 weeks. Native budworm eggs and holes on soursob (oxalis) petals are signs of native budworm activity in the area.¹⁷

Diapause in *Helicoverpa* spp.

Both species of *Helicoverpa* survive winter as pupae in the soil, when host plants and thus food sources are scarce. *H. punctigera* are capable of overwintering in southern cropping regions, but only a few are ever found. By contrast, substantial numbers of overwintering *H. armigera* pupae can be found under late summer crops, particularly when *Helicoverpa* activity has been high late into March.

Not all pupae that form in late summer go into diapause; a proportion continue to develop, perhaps emerging during winter, or early in spring.

Overwintering pupae can be killed without the use of chemicals. Pupae in the soil are susceptible to soil disturbance and disruption of the emergence tunnel. Cultivation is enough to create this disturbance.¹⁸

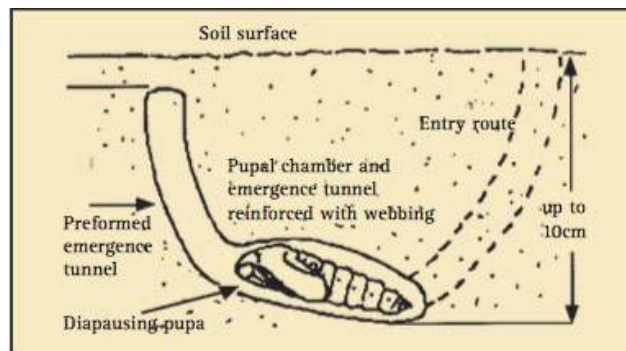


Figure 5: *Helicoverpa* pupa in pupal chamber showing the entry and exit tunnels formed before the larvae pupated.

Source: DPI & F, QLD, Insects understanding *Helicoverpa* ecology & biology in southern Queensland: Know the enemy to manage it better, https://www.daf.qld.gov.au/_data/assets/pdf_file/0005/72689/Insects-Helicoverpa-ecology-biology.pdf

¹⁷ Pulse Australia (2016) Faba & Broad Bean – Best Management Practices Training Course, module 7-2016. Pulse Australia Limited

¹⁸ Queensland DAF, Insects understanding: *Helicoverpa* ecology & biology in southern Queensland: know the enemy to manage it better, https://www.daf.qld.gov.au/_data/assets/pdf_file/0005/72689/Insects-Helicoverpa-ecology-biology.pdf

8.4.5 Damage by *Helicoverpa* spp.

Field pea is very susceptible to all sizes of caterpillars (larvae) during the formation and development of pods. Tiny larvae enter emerging pods and damage developing seed or devour the entire contents of the pod (Photo 9). Some growers have had unexpected losses from native budworm damage in semi-leafless field peas like Kaspas[®] as these are more difficult to sample with their intertwined tendrils.¹⁹



Photo 9: Field pea pod with entire contents eaten by native budworm.

Photo: DAWFA, <https://agric.wa.gov.au/n/2685>



Photo 10: Mature field pea with large budworm.

Photo: T. Bray, formerly Pulse Australia

The larvae bore into the pods and usually destroy the seeds in each pod. One larva may attack four to five pods before reaching maturity. The amount of damage to each seed varies considerably, but the damaged area has jagged edges (Photo 11). This contrasts with damage from pea weevil (in field pea), which leave a cylindrical, smooth, circular exit-hole.²⁰

Direct losses are usually associated with yield through grain being wholly or partially consumed by the caterpillar. However, indirect losses from quality issues can result in downgrading or even rejection from high levels of damaged grain, weathering or fungal infections from holes in pods, discolouration or odour.²¹

¹⁹ P Mangano, S Micic (2016) Management and economic thresholds for native budworm control. Department of Agriculture and Food, Western Australia, www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

²⁰ Pulse Australia (2016) Southern/western field pea best management practices training course, module 7- 2016, Draft. Pulse Australia Limited

²¹ Pulse Australia (2016) Managing native budworm in pulses. Australian Pulse Bulletin, Pulse Australia, <http://www.pulseaus.com.au/growing-pulses/publications/native-budworm>



Photo 11: *Native budworm larvae leave holes in field pea pods.*

Photo: Pulse Australia (2016) Managing native budworm in pulses. Pulse Australia, <http://www.pulseaus.com.au/growing-pulses/publications/native-budworm>

8.4.6 Monitoring

The use of pheromone traps (which attract male moths) provides an early warning of moth arrival and abundance, following their migration from inland regions. These should be set up in late winter or early spring. Observing the activity of moths in the crop and the presence of eggs may also be indicative of future larval activity. However, egg and early larval mortality of native budworm through natural courses can be very high. In Queensland chickpea, this has been estimated to be up to 70%. Eggs and very small larvae can be dislodged and will die after heavy rain or wind.²²

All crops should be scouted weekly during flowering for moth activity and eggs, then at least twice a week during pod-fill for eggs and larvae. The main egg-laying period is often around the flowering period when moths can be quite abundant. Eggs can often be found on the vegetative or floral growing points, new leaves, stems, flowers, flower buds and young pods. They may not be obvious to the untrained eye unless there is a heavy egg lay or until small larvae can be found.

Crop types can vary in attractiveness to moths for egg laying and as a general rule lentil is the most attractive crop, followed by field pea, vetch, faba bean, chickpea and lupin. Crop health, density and growth stages (flowering and podding) will generally affect the number of eggs laid, with moths mostly preferring the more advanced dense and succulent areas.

Feeding behaviour of caterpillars also changes according to the pulse type, with field pea, chickpea, lentil and faba bean crops being more susceptible to all sizes of caterpillars during pod formation and development. While tiny caterpillars will usually foliage feed, there are times, such as in hot, dry conditions, that they will burrow into emerging pods as they become more palatable than the wilting foliage.²³

²² G McDonald (2015) Native budworm. Pest Notes Southern. CESAR and South Australian Research and Development Institute, http://www.pir.sa.gov.au/_data/assets/pdf_file/0005/274181/Native_Budworm.pdf

²³ Pulse Australia (2016) Managing native budworm in pulses. Australian Pulse Bulletin, Pulse Australia, <http://www.pulseaus.com.au/growing-pulses/publications/native-budworm>

VIDEO

See video How to use a sweep net to sample for insect pests.

<https://youtu.be/DGgqRMwprY8>



VIDEO

Watch video Using a beatsheet to sample *Helicoverpa* in chickpeas

https://youtu.be/_Z457Cc1fig



8.4.7 Sampling methods

Either a sweep net (for e.g. field pea, lentil) or beat sheet (for e.g. chickpea, lupin, bean) should be used to monitor larval activity in crops. For field pea, monitor larval activity from budding and flowering development through to maturity.²⁴

Sweep net sampling

The quickest and easiest way to sample most crops is with a standard sweep net (380 mm diameter) and taking 2-metre-long sweeping arcs in multiples of 10 sweeps in several parts of the crop, keeping the lower edge of the sweep net slightly forward to catch any dislodged grubs.

This roughly equates to a sampled area of one square metre. This method works well in short and thin crops such as field pea, lentil and vetch, but may be less efficient in tall dense crops such as faba bean, lupin and chickpea.

Trials conducted in WA have found that semi-leafless field peas (e.g. Kaspas[®]) with intertwined tendrils make the netting efficiency only half that of the conventional trailing types (e.g. Parafield, Sturt) and 10 sweeps is usually sufficient to provide estimates that only equate to numbers present over 0.5 m².²⁵

To monitor for native budworm larvae in field pea:

- Semi-leafless field pea crops – use grub counts based on 20 sweeps of a sweep net.
- Trailing type field pea crops – use counts based on 10 sweeps of a sweep net.²⁶

Beat sheet sampling

A beat sheet is a good alternative monitoring technique for taller or more rigid crops, especially wide row chickpea and faba bean (Photo 12). A standard beat sheet (plastic or canvas) is about 1.3 metres wide and 1.5 m long, with a heavy dowel to weigh it down. One edge should be placed at the base of a row and the sheet spread out across the inter-row space. If rows are narrow then it can be draped over the adjacent row. Using a 1-metre-long rod, vigorously shake the row 10 times over the sheet to dislodge and catch larvae.²⁷

An alternative approach is to gently cut plants from an area such as 0.25 m² (0.5 x 0.5 m) and shake larvae into a large basin or onto a white sheet or poly bag. This is very simple and more accurate, with less plant and flower material than the sweep net, but it is more time consuming as at least five separate sites need to be sampled within a crop and the numbers averaged.

Misleading conclusions can result from inadequate sampling as grub numbers can vary greatly within a crop and sampling needs to be conducted at five or more randomly spaced locations and then averaged.²⁸

24 G McDonald (2015) Native budworm. Pest Notes Southern. CESAR and South Australian Research and Development Institute, http://www.pir.sa.gov.au/_data/assets/pdf_file/0005/274181/Native_Budworm.pdf

25 Pulse Australia (2016) Managing native budworm in pulses. Australian Pulse Bulletin, Pulse Australia, <http://www.pulseaus.com.au/growing-pulses/publications/native-budworm>

26 P Mangano, S Micic (2016) Management and economic thresholds for native budworm control. Department of Agriculture and Food, Western Australia, www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

27 G McDonald (2015) Native budworm. Pest Notes Southern. CESAR and South Australian Research and Development Institute, http://www.pir.sa.gov.au/_data/assets/pdf_file/0005/274181/Native_Budworm.pdf

28 Pulse Australia (2016) Managing native budworm in pulses. Australian Pulse Bulletin, Pulse Australia, <http://www.pulseaus.com.au/growing-pulses/publications/native-budworm>

i MORE INFORMATION

Integrated pest management: combating serial pests, <https://grdc.com.au/resources-and-publications/all-publications/bookshop/2009/12/integrated-pest-management-fact-sheet-national>



Photo 12: A beat sheet used in sampling a wide row chickpea crop.

Photo: Pulse Australia (2016) Managing native budworm in pulses. Australian Pulse Bulletin, Pulse Australia website, <http://www.pulseaus.com.au/growing-pulses/publications/native-budworm>

8.4.8 Control thresholds for *Helicoverpa* spp.

An economic threshold is the number of caterpillars that will cause more financial loss than the cost of spraying. The thresholds used are based on yield loss rather than quality.

The control thresholds used in the southern region are those developed for Western Australia in DPIRD trials. This threshold is the only one used in Australia that is derived from research. It assumes 50 kg/ha yield loss per larva in 10 sweeps from conventional field pea types and 100 kg/ha yield loss per larva in 10 sweeps from semi-leafless types (Table 2).

Table 2: Economic thresholds (ET) for native budworm (*Helicoverpa*) on various crops in WA.

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 (>15 mm) per m ²
Field pea - trailing type e.g. Helena, Dundale	200	10	50	1.0	5	-
Field pea - semi-leafless e.g. Kasper [Ⓛ]	200	10	100	0.5	2.5	-
Chickpea	420	10	30	0.8	4	-
Faba bean	280	10	90	0.4	2	-
Lentil	420	10	60	0.4	2	-
Canola	270	10	6	6.2	31	-
Lupin	175	10	7	-	-	8.2

Source: P Mangano, S Micic (2016) Management and economic thresholds for native budworm control. Department of Agriculture and Food, Western Australia, www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

To use the table, you need to substitute:

- control costs with your own actual costs; and
- expected grain price per hectare based.

This will calculate the economic threshold or the number of caterpillars that will cause more financial loss than the cost of spraying.²⁹

IN FOCUS

Example

This is an example of how to calculate the economic threshold (ET) or the number of caterpillars that will cause more financial loss than the cost of spraying.

The on-farm value of field pea is \$185 per tonne (t).

The cost of control is \$12 per hectare (ha).

$$ET = C \div (K \times P)$$

Where:

ET = economic threshold (number of grubs in 10 sweeps)

C = control cost (includes price of chemical + application) (\$ per ha)

K = kilograms per hectare (ha) eaten for every one caterpillar netted in 10 sweeps or per square metre (see Table 2)

P = price of grain per kg (price per tonne \div 1000)

Therefore, economic threshold for field pea = $12 \div (50 \times (185 \div 1000)) = 1.3$ grubs per 10 sweeps

Note that the Western Australian thresholds are only a guide for the southern region.

8.4.9 Management options

Biological

A key component to any IPM strategy is to maximise the number of beneficial organisms and incorporate management strategies that reduce the need for pesticides. Correct identification and monitoring is the key when checking for build-up or decline of beneficials. There are many natural enemies that attack native budworm. The egg stage is susceptible to the parasite *Trichogramma ivalae*, a minute wasp that has been recorded in up to 60% of eggs, along with egg predators such as ladybird beetles, lacewings and spiders. Beneficials attacking larvae include shield bugs, damsel bugs, assassin bugs, tachinid flies (their larvae prey on caterpillars), orange caterpillar parasite, two-toned caterpillar parasite, orchid dupe, lacewings and spiders. Naturally occurring fungal diseases and viruses also play an important role in some seasons.

Cultural

Desiccating pulse crops such as field pea may be an option to advance the drying of crops when small-medium size larvae are present near crop maturity.

²⁹ P Mangano, S Micic (2016) Management and economic thresholds for native budworm control. Department of Agriculture and Food, Western Australia, www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

i MORE INFORMATION

Native budworm Pest Notes
Southern, CESAR:
<http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/native-budworm>

Chemical

There are several insecticides registered for the control of native budworm. Timing and coverage are both critical to achieving good control. Try to target small larvae (up to 7 mm in length) and apply insecticides before larvae move into flowering pods. IPM options include the use of *Bt* (*Bacillus thuringiensis*) and nuclear polyhedrosis virus (NPV) based biological insecticides. Small larvae are generally easier to control because they are more susceptible to insecticides, and leaf feeding makes them susceptible to ingestion of active residues on the plant surface. Larvae entrenched in buds and pods will be more difficult to control and chemical residual will be important in contacting them.

The crop should be re-inspected 2–4 days after spraying to ensure enough caterpillars have been killed to prevent future damage and economic loss. In years of very high moth activity and extended egg lays, a second spray may be required.

In choosing a registered product, be aware of the withholding period for harvest or windrowing/swathing, which is the same as harvest. Residue testing is routinely conducted on grain destined for export and domestic stock-feed markets.³⁰

8.5 Pea weevil (*Bruchus pisorum*)

The pea weevil (*Bruchus pisorum*) is actually a beetle as opposed to a weevil and should really be called the pea beetle, however industry refer to *B. pisorum* as 'pea weevil'. The Australia pea weevil is one of the most damaging pests of the field pea industry. Not only does this beetle reduce yields but it can also reduce germination rates of seed and affect grain quality to the point that it is not saleable for human consumption.

8.5.1 Identification of pea weevil

The pea weevil is a chunky, 5–6 mm long, brownish beetle, flecked with white, grey and black patches (Photo 13). The white tip of the abdomen is marked with two black, oval spots.



Photo 13: Adult pea weevil.

Photo: DPIRD (2016) <https://agric.wa.gov.au/n/2815>

³⁰ G McDonald (2015) Native budworm. Pest Notes Southern, CESAR and South Australian Research and Development Institute. http://www.pir.sa.gov.au/_data/assets/pdf_file/0005/274181/Native_Budworm.pdf

Eggs are bright yellow, cigar-shaped and about 1.5 mm long, and attach individually to the developing pods (Photo 14). The larva is C-shaped, up to 6 mm long, legless, brown-headed and cream coloured (Photo 15). Larvae burrow directly into pods to feed on cotyledons and remain protected in the seed until the adult emerges. Once eggs are laid it is too late for field control.



Photo 14: A bright yellow, cigar-shaped pea weevil egg, about 1.5 mm long, attached individually to a developing pod.

Photo: W Smith (2014) <https://agricwa.gov.au/n/4477>

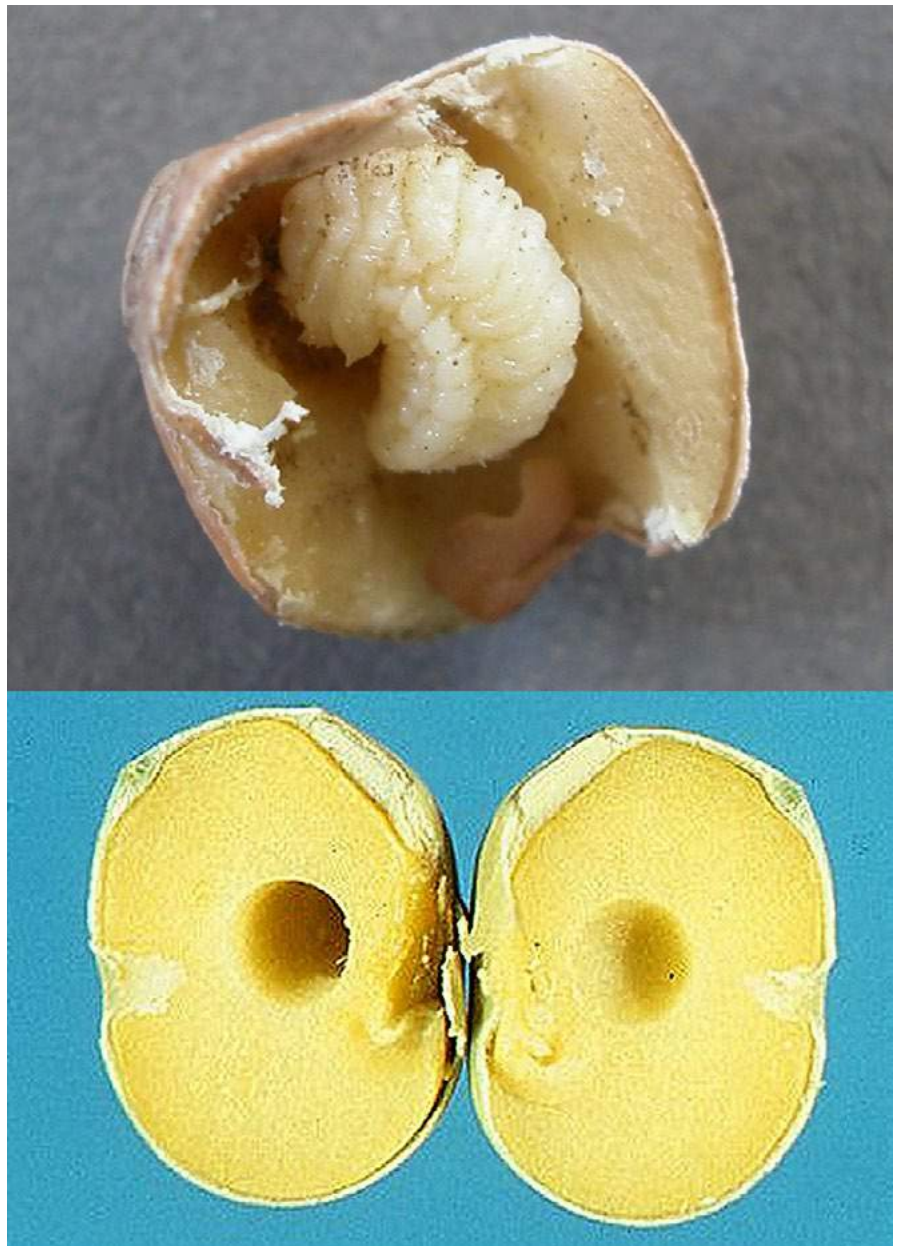


Photo 15: *Developing pea weevil larva (top) and split infested seed at early harvest (below).*

Photo: DPIRD (2014) <https://agric.wa.gov.au/n/4477>

8.5.2 Life cycle of pea weevil

Adult beetles hibernate during summer, autumn and winter in sheltered positions, e.g. under the bark of trees or in cracks and crevices of fence posts.

When spring temperatures reach about 20°C, the beetles become active and are attracted to crops. Even though pea weevil can travel up to 5 km, infestations usually occur from infested seed from the previous season.

The female beetles are sexually immature when they leave hibernation and first arrive in the pea crop. They require a feed of pollen and further time for ovarian development to take place.

Approximately 2 weeks after arrival in the pea crop the females lay eggs on the developing pods. Female beetles lay eggs individually on the surface of pods.

Small larvae hatch from the eggs in about 6–13 days. The larvae bore through the wall of the pod and into the soft, developing seed.

After about 40 days of feeding inside the pea seed the larva prepares a 2–3 mm exit hole by chewing partially through the seed coat. The larva then pupates and after about 14 days is ready to emerge as an adult beetle.

By this time the seed has generally been harvested and some beetles will emerge from the seeds to find suitable hibernation sites, others can remain concealed in grain for many months or when the grain is next sown.

The pea weevil will not reproduce in stored grain.³¹

8.5.3 Damage by pea weevil

Pea weevil reduce yield by:

- consuming seed – as much as 30% of individual seed weight is lost from larval feeding;
- feeding damage – which also increases the amount of seeds that split during sowing, harvesting and seed cleaning.

Many food consumption markets have a nil tolerance for live or dead adult pea weevil contamination or peas damaged by larval feeding.

The stockfeed market has nil tolerance for live pea weevil.

Pea-weevil-infested seed should be fumigated prior to sowing to prevent this pest spreading to new growing areas and to reduce the impact of this species on the pea crop later in the season.

Peas heavily damaged by pea weevil should not be sown without a germination test as the seed may not be viable or produce weak seedlings.³²



Photo 16: Holes created in pea seed by mature pea weevil adults (3 mm).

Photo: QDAF, The Beatsheet, http://thebeatsheet.com.au/wp-content/uploads/2014/11/C-maculatus-field-peas-IMG_2994.jpg

³¹ D Hardie, S Micic (2015) Management of pea weevil. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/2815>

³² D Hardie, S Micic (2015) Management of pea weevil. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/2815>

8.5.4 Monitoring

Where

Pea weevil movement in early spring within a flowering crop is generally restricted to the crop's edge, especially if adjacent to over-wintering sites such as trees and sheds.

When

Monitor the crop edges every 3–4 days from the start of flowering. Monitor when average temperatures are above 20°C as this is when pea weevil are active.

If sprays are applied, monitor crops about 10 days after spraying.

How

To monitor crops use a sweep net. It should be dragged across the tops of the plants in a horizontal, 160° arc with a one-metre stride between each sweep.

Take 25 sweeps within 1–5 m of crop edge. Repeat this at 6 or more sites.



Photo 17: Sampling pea crop using sweep net for pea weevil.

Photo: DPIRD (2016) <https://www.agric.wa.gov.au/pest-insects/management-pea-weevil>

8.5.5 Control

A 40 m border spray will control pea weevil that is moving into a crop. Spray with synthetic pyrethroids at registered rates.

Insecticides are only effective on adult pea weevil, so apply sprays only after adults first appear but before egg lay commences and before small pods are visible.

In early crops, beetle flights may occur over an extended period, so more than one spray application may be necessary.

If heavy infestations are detected or if seed infested with live weevil was sown, the entire paddock needs to be sprayed.³³

8.6 Aphids and viruses

Aphids can damage field pea crops by spreading viruses or through direct damage when feeding on plants. Feeding damage generally requires large populations, but virus transmission can occur before aphids are noticed.³⁴

Direct aphid feeding rarely causes major damage to broadacre field pea crops, and control measures are generally unnecessary, as parasitoids and predators keep populations in check. Exceptions occur when aphid populations are extreme (particularly early) or the compensatory ability of the crop is compromised by stress (particularly moisture stress), and aphid impact on flowering or pod-set/fill may be significant.³⁵

The main species affecting pea are the pea aphid (*Acyrtosiphon pisum*), green peach aphid (*Myzus persicae*), bluegreen aphid (*Acyrtosiphon kondoi*) and occasionally cowpea aphid (*Aphis craccivora*). It is unusual for aphids to colonise field pea, typically as winged aphids move through the crop they may spread viruses.³⁶

8.6.1 Aphids and virus transmission

Aphids are small, soft-bodied insects that grow up to 4 mm in length. Adult aphids can be winged or wingless; all immature aphids are wingless. Some aphid species will colonise individual plants, while other aphid species will move through a crop and be difficult to detect.

Different aphid species transmit different viruses to particular crop types; species identification is important because management strategies can vary.

Aphids can spread viruses persistently or non-persistently (Table 3). Once an aphid has picked up a persistently transmitted virus, it carries the virus for life, infecting every plant where it feeds. Aphids carrying non-persistently transmitted viruses, such as Cucumber mosaic virus (CMV), carry the virus temporarily and only infect new plants in the first one or two probes.

MORE INFORMATION

GRDC Fact Sheet Aphids and viruses in pulse crops,
<https://grdc.com.au/GRDC-FS-AphidsandVirusesinPulses>

33 D Hardie, S Micic (2015) Management of pea weevil. Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/pest-insects/management-pea-weevil>

34 GRDC (2010) Aphids and viruses in pulse crops, Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

35 Department of Agriculture & Fisheries (2016) IPM guidelines for grains, Aphids, <http://ipmguidelinesforgrains.com.au/pests/aphids/>

36 S Micic (2015) Diagnosing aphid damage in field peas. <https://agric.wa.gov.au/n/4458>

Table 3: Examples of transmission of one persistent and two non-persistent viruses for four aphid species.

Aphid	Cucumber mosaic virus (CMV)	Pea seed-borne mosaic virus (PSbMV)	Beet western yellows virus (BWYV)
	Non-persistent	Non-persistent	Persistent
Green peach aphid	Yes	Yes	Yes
Pea aphid	Yes	Yes	No
Cowpea aphid	Yes	Yes	Yes
Bluegreen aphid	Yes	No	No

Source: GRDC (2010) https://grdc.com.au/_data/assets/pdf_file/0019/205642/aphidsvirusesfactsheets.pdf.pdf

VIDEO

Green peach aphids and Beet western yellows virus
<https://youtu.be/1MIRtsfydkc>



MORE INFORMATION

For more information on viruses, refer to [Section 9 Diseases](#)

Green peach aphids, www.grdc.com.au/GPAResistanceStrategy

Russian wheat aphid: tactics for future control, <https://grdc.com.au/rwa-tacticsfuturecontrol>

Persistently transmitted aphid-borne viruses

The common virus in this category is Beet western yellows virus (BWYV). Persistent transmission means that when an insect vector feeds on an infected plant, the virus has to pass through its body and lodge in its salivary glands before it can be transmitted to a healthy plant, a process that takes more than a day. Once the insect is infectious it remains so for the rest of its life. Important aphid vectors such as the green peach aphid tend to colonise the hosts they transmit the virus to. Because acquisition of the virus is slow, insecticides that kill aphids work well in suppressing virus spread. Luteoviruses are not seed-borne and require a continuous ‘green bridge’ of host plant material, such as an infected lucerne pasture or broadleaved weeds surviving in isolated wet spots over summer, in order to pass from one crop to the next.

Non-persistently transmitted aphid-borne viruses

These viruses are also seed-transmitted to varying extents. Pea seed-borne mosaic virus (PSbMV) is the most common and economically damaging virus that reduces yield and seed quality in pea.

Non-persistent transmission means that the insect vector can land on a virus-infected plant, make a brief probe, acquire the virus on its mouth parts within seconds and then transmit it immediately when probing on a healthy plant. The aphid loses the virus after it probes a healthy plant one or two times. After this, the insect does not infect further plants. The whole process is so quick that insecticides do not act fast enough to prevent transmission, and can make things worse by making the aphids hyperactive, causing them to flit from plant to plant. Many aphid species are vectors of this type of virus, including some that do not colonise legumes but just land and probe pulse crops while searching for their preferred hosts, such as oat and turnip aphids.

Close proximity to a substantial external virus reservoir, seed infection, and high summer and autumn rainfall before the growing season are the most important factors that predispose pea crops to severe virus infection. Summer and autumn rainfall stimulate early growth of pastures, weeds and crop volunteers upon which aphids build up before the growing season starts. This results in early aphid flights to newly emerged crops and early virus infection. The infected plants then act as reservoirs for further spread of infection within the crop so the final virus incidence is high. In contrast, dry starts to the season and minimal virus sources result in little virus spread and absence of any economic losses.³⁷

³⁷ B Coutts (2015) Diagnosing virus damage in field peas. Department of Agriculture & Food, Western Australia, <https://agric.wa.gov.au/n/4489>

i MORE INFORMATION

For more information see
 Crop Aphids: The Back Pocket Guide
<https://grdc.com.au/CropAphidsBackPocketGuide>

8.6.2 Aphid types

The pea aphid (Photo 18) 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 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 (Photo 19). They can be similar in colour to young unfurled field pea leaves. Green pea aphid has a wide host range including canola, lupin 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 (Photo 19). 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 (Photo 19), it is not typically found on field pea, but often colonises lupin and faba bean plants.

Russian wheat aphid (RWA) is one of the world’s most economically important and invasive pests of wheat, barley and other cereal grains. Since first being discovered in South Australia in 2016, RWA has been found widespread in cereal-growing regions of South Australia, Victoria, New South Wales and Tasmania.

Their small size, green colour, elongate shape, very short antennae and apparent lack of siphuncles readily distinguish RWA from other pest aphids found in Australian cereal crops. Russian wheat aphid injects salivary toxins during feeding that cause rapid, systemic phytotoxic effects on plants, resulting in acute plant symptoms and potentially significant yield losses.

Please see <http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Russian-wheat-aphid> for more details.



Photo 18: *Pea aphid.*

Photo: DPIRD (2014) <https://www.agric.wa.gov.au/mycrop/diagnosing-aphid-damage-field-peas>



Photo 19: Green peach aphid (top), bluegreen aphid (centre) and cowpea aphid (bottom).

Photo: DPIRD (2015) <https://www.agric.wa.gov.au/mycrop/diagnosing-aphid-damage-field-peas>

8.6.3 Management strategies

Aphid colonies do not usually develop on field pea; control is only warranted if aphid colonies are impacting on the growth of plants.

Correct identification of the aphids is critical. Green peach aphids are resistant to organophosphorus, carbamate and synthetic pyrethroid insecticides, and can be difficult to control. Green peach aphids are easily identified: they tend to be found on the underside of leaves and vary in colour from bright green to pink.

Spraying insecticides to stop virus spread is unlikely to be of any benefit because insecticides do not act fast enough to prevent the rapid spread of the virus by aphids and may increase rather than reduce virus spread because aphids move around more on sprayed plants.³⁸

³⁸ S Micic (2015) Diagnosing aphid damage in field peas. <https://www.agric.wa.gov.au/mycrop/diagnosing-aphid-damage-field-peas>

Practices that minimise virus damage are:

1. Where the virus source is internal, especially with Pea seed-borne mosaic virus (PSbMV), sow healthy seed stocks to minimise initial infection sources within the crop.
2. Where the virus source is external, sow non-host barrier-crop strips and spray pastures adjacent to the crop. These measures decrease virus spread into the crop from an external source.
3. Sow at high seeding rates to generate high plant densities and promote early crop canopy development. These measures minimise virus infection sources (seed-infected and/or early infected plants), diminish aphid landing rates and dilute numbers of infected plants.
4. Sow at narrow row spacing and maximise retained stubble. These measures diminish aphid landing rates before the crop canopy develops.
5. Do not plant pea after another pulse to avoid volunteer seed-borne pulse infection sources within the crop.
6. Maximise weed control to minimise potential weed virus infection sources within the crop.
7. Sow early maturing varieties to decrease final infection incidence, especially in prolonged growing seasons.³⁹

Studies indicate that both Maki and Yarrum have a high level of resistance to PSbMV and useful levels of resistance to Bean leaf roll virus (BLRV).⁴⁰



Photo 20: *Planting field pea into standing stubble can disrupt aphids' flight and deter them from landing on the ground.*

Photo: Wayne Hawthorne, formerly Pulse Australia

³⁹ B Coultts (2015) Diagnosing virus damage in field peas. Department of Agriculture & Food, Western Australia, <https://agric.wa.gov.au/n/4489>

⁴⁰ S Moore, G Cumming, L Jenkins, J Gentry (2010) Northern Region Field Pea Management Guide. Pulse Australia, http://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

8.7 Snails

Snails are a significant problem in field pea crops across the southern region. Snails cause damage to emerging crops and contamination at harvest. This means monitoring and managing snails regularly throughout the year (Figure 6).

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Life cycle	Inactive		Becoming active			Actively breeding and feeding				Inactive		
	Egg laying – multiple hatchings						Juveniles hatching					
Integrated management	Summer weed control											
	Stubble – rolling, cabling, slashing											
			Stubble burning – most effective early in season when dry and before weeds germinate									
				Early baiting of paddocks and fencelines			Broadacre and fenceline baiting – finish 2 months before harvest					
	Grain cleaning											Modify header
Monitor snail numbers	Both before and 7 days after each management action										Pre-harvest assessment	

Figure 6: Integrated snail management calendar.

Source: GRDC (2011) Snail Identification and Control: The Back Pocket Guide. GRDC, <https://grdc.com.au/Resources/Publications/2011/03/Snail-Identification-and-Control-The-Back-Pocket-Guide>

Comprehensive information on snail management is available in the publications:

GRDC Snail Management Fact Sheet;
www.grdc.com.au/GRDC-FS-SnailManagement

GRDC Snail Bait Application Fact Sheet
<https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application>

Snail Identification and Control: The Back Pocket Guide
www.grdc.com.au/BPG-SnailIdentificationAndControl

Bash 'Em, Burn 'Em, Bait 'Em: Integrated snail management in crops and pastures
www.grdc.com.au/GRDC-Snails-BashBurnBait

8.7.1 Types of pest snails

In Australia there are both native and introduced snail species. The four species of introduced snails are the pests of grain crops and pastures in the southern region. These can be divided into two distinct groups: round or white snails, and conical or pointed snails.

Species are found across southern Australia but not always in pest proportions. Numbers continue to rise and new areas are colonised.

Snails are proficient hitchhikers, moving between regions on transport. Farm machinery and produce such as hay should be inspected and cleaned of snails before transport.⁴¹

⁴¹ GRDC (2011) Snail Identification & Control: The Back Pocket Guide, <https://grdc.com.au/Resources/Publications/2011/03/Snail-Identification-and-Control-The-Back-Pocket-Guide>

White (round) snails (*Ceruella virgata* and *Theba pisana*)

Two species of white (or round) snails exist: the vineyard or common white snail (*Ceruella virgata*) and the white Italian snail (*Theba pisana*).⁴² They are found throughout the agricultural districts of South Australia, and the Victorian Mallee and Wimmera. They also occur in Western Australia, New South Wales and Tasmania.

Both species have similar shapes: white, coiled shells up to 20 mm diameter, which may have brown bands around the spiral.⁴³ The common white snail has an open umbilicus, whereas the umbilicus of the Italian snail is partly closed.⁴⁴ The umbilicus of a white snail is the hollow space on the underside of the shell.



Photo 21: Vineyard or common white snail. Note the umbilicus (hollow space) is open.

Photo: SARDI Southern/western field pea best management practices training course, module 7-2016



Photo 22: White Italian snail. Note the umbilicus (hollow space) is partly closed.

Photo: SARDI Southern/western field pea best management practices training course, module 7-2016

⁴² Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

⁴³ GRDC (2011) Snail Identification & Control: The Back Pocket Guide, www.grdc.com.au/BPG-SnailIdentificationAndControl

⁴⁴ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

Conical (pointed) snails (*Cochlicella acuta* and *C. barbara*)

Two species of conical snails exist: conical snails (*Cochlicella acuta*) and small conical snails (*C. barbara*).

Conical snails are also known as pointed snails (Photo 23). They have fawn, grey or brown shells. Mature conical snails have shells 12–18 mm long, whereas the shells of small conical snails are 8–10 mm long.

Highest numbers of conical snails (*C. acuta*) are found on the Yorke Peninsula in South Australia. Isolated populations are also present in other parts of SA, Victoria, NSW and WA.

The small conical snail, *C. barbara* (Photo 24), occurs throughout SA, but is most abundant in the higher-rainfall areas (>500 mm). It is also widely spread in Victoria, NSW and WA.⁴⁵



Photo 23: Conical snail, also known as pointed snail.

Photo: SARDI Southern/western field pea best management practices training course, module 7-2016



Photo 24: Small conical snail, also known as small pointed snail.

Photo: SARDI Southern/western field pea best management practices training course, module 7-2016

⁴⁵ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

8.7.2 Damage by snails

White snails mainly damage crops during establishment and harvest. Both common white and Italian snails may feed on young crops and destroy substantial areas, which then need re-sowing. In late spring, snails climb plants.

Conical snails contaminate grain at harvest, especially cereals and canola. They feed mostly on decaying plant material but can damage cereal and canola seedlings. The small conical snail feeds on growing plants and can contaminate grain. Lucerne is a favourite plant.

The contaminated grain may be downgraded or rejected and live snails in grain pose a threat to exports.⁴⁶ Grain will be rejected if more than half a dead or one live snail is found in a 0.5-litre wheat sample or 200-gram pulse sample (Grain Trade Australia). Check with your buyers for specific regulations.⁴⁷

8.7.3 Life cycle of snails

Snails appear to build up most rapidly in canola, field pea and faba bean. However, they can feed and multiply in all crops and pastures.⁴⁸ White snails are dormant in summer. Young snails hatch about 2 weeks after eggs are laid. They feed and grow through the winter and spring and then climb fence posts or plants in late spring or summer where they go into summer dormancy. Snails live for 1–2 years, and move only short distances. They are spread in hay or grain, or by machinery or vehicles.

Conical snails have a similar life cycle to white snails. Conical snails may over-summer under stones, as well as on posts and plants.

Small conical snails over-summer on the ground in the leaf litter and under stones and stumps.⁴⁹

8.7.4 Monitoring snails

Early baiting before eggs are laid is critical for snail control.⁵⁰

Monitor snails regularly to establish their numbers, type(s) and activity, as well as success of controls.

Look for snails early in the morning or in the evening when conditions are cooler and snails are more active.

The key times to monitor snail populations are:

- summer to pre-sowing – check numbers in stubble before and after rolling, slashing or cabling;
- 3–4 weeks before harvest, to assess need for harvester modifications and cleaning; and
- after summer rains – check if snails are moving from resting sites.⁵¹

A wide range of snail sizes in an area indicates that snails are breeding there; if most snails are the same size, snails are moving in from other areas.⁵² Size range of snails is important as juveniles don't take baits.⁵³

46 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

47 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

48 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

49 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

50 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

51 NIPI & field pea IPM: Snails in seedling crops, <http://ipmguidelinesforgrains.com.au/pests/slugs-and-snails/snails-in-seedling-crops/>

52 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

53 Pulse Australia (2016). Southern/western field pea best management practices training course, module 7-2016, Draft. Pulse Australia Limited

Monitoring technique:

- Sample a 30 x 30 cm quadrat at 50 locations across the paddock.
- If two snail groups are present (round and conical), record the number of each group separately.
- To determine the age class of round snails, place into a 7 mm sieve box, shake gently and they will separate into two sizes: >7 mm (adults) and <7 mm (juveniles).
- Sieve boxes can be constructed from two stackable containers e.g. sandwich boxes. Remove the bottom from one and replace by a punch-hole screen. Suggested screen size is 7 mm, round or hexagonal.
- Five sampling transects should be taken in each paddock. One transect is taken at 90° to each fence line, while the fifth transect runs across the centre of the paddock.
- Take five samples, 10 metres apart along each transect.

Record the size and number of the snails in each sample. Average the counts for each transect and multiply this figure by 10 to calculate the number of snails per square metre in that area of the paddock.⁵⁴

When looking for snails, check under weeds, and shake and thresh samples of mature crops onto a small tarp or sack, to see if snails are in the portion of crop that will enter the harvester.⁵⁵

Record live snails before and 7 days after baiting or the paddock operation and calculate the reduction in numbers.⁵⁶

If pulse crops have more than 5 snails/m², growers are likely to have grain contamination at harvest.⁵⁷

8.7.5 Control

The keys to snail management and control are:

- Stubble management:
 - » cabling or rolling in summer;
 - » slashing in summer; and
 - » burning in autumn.
- Summer weed control.
- Baiting in autumn.
- Harvest and delivery:
 - » reducing snail intake during harvest (windrowing, brushes, bars);
 - » header settings; and
 - » cleaning after harvest.

Snail control starts in the summer before sowing. The best control is achieved by stubble management on hot days, or burning, followed by baiting, in autumn before egg-laying.

Rolling, harrowing or dragging a cable over stubble on hot days reduces snail numbers by knocking snails to the ground to die in the heat (air temperature >35°C). Some snails may also be crushed by rollers.

Burning in autumn can reduce snail numbers by up to 95%, provided there is sufficient stubble for a hot and even burn. Note that wind or water erosion become a risk on burnt stubble.

54 NIPI & field pea IPM: Snails in seedling crops, <http://ipmguidelinesforgrains.com.au/pests/slugs-and-snails/snails-in-seedling-crops/>
 55 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement
 56 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016
 57 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Fact Sheet. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

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FEEDBACK

VIDEO

Burning Snails and Weed Seeds
<https://youtu.be/zqQKFFqndKQ>



MORE INFORMATION

For more information on managing snails at harvest see [Section 11.5](#)
[Managing snails](#)

While control measures for conical snails are the same as those used on white snails, they are generally less effective as conical snails can shelter in cracks in the ground or under stones. Dragging harrows or a cable before burning improves the control of conical snails by exposing more snails to burning.

It is important to understand the factors that determine baiting efficacy. 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 reinfestation of the paddock. Do not bait within 2 months of harvest.

Three bait types are available for snail control: methiocarb, metaldehyde and iron chelates. They are comparable in their effectiveness. Standard rate is 5 kg/ha of bait. If there are more than 80 white snails (>7 mm in diameter) per square metre then the rate should be 8–10 kg/ha. For conical snails, repeat applications of 5 kg/ha rate are more efficient than a single application of 10 kg/ha.

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.

Grain can be cleaned on-farm where snail contamination is so high that grain will be downgraded or rejected.

Biological controls are not yet available for white snails.⁵⁸ Native nematode species have shown promise against the four pest snail species but commercially trialled with limited success.⁵⁹

8.8 Slugs

Slugs are a growing problem in the high-rainfall zones with zero-till and stubble-retention. No single control method will provide complete protection; an integrated approach is best.

Slug populations are regulated by moisture. Cool, wet summers and heavy stubble provide ideal conditions for slugs, as they need moisture and shelter to thrive.

The two main pest species are the grey field slug, or reticulated slug (*Deroceras reticulatum*) and the black keeled slug (*Milax gagates*).

Details of other species can be found in *Slugs in Crops: The Back Pocket Guide* (<https://grdc.com.au/resources-and-publications/all-publications/publications/2011/03/slugs-in-crops-the-back-pocket-guide>).

Slugs have caused major damage in emerging canola, pulse and wheat crops, especially in high-rainfall areas, but have also caused damage in lower-rainfall areas in wetter years. Damage is usually greater in cracking clay soils.

Slugs will attack all plant parts. Seedlings are the most vulnerable and can suffer major economic damage.

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 down the soil to depths of 20 cm or more in dry periods and reappear when conditions improve.

Cultivation and rolling, and burning stubble after weeds are controlled will reduce slug populations. Rolling the soil after seeding can also reduce slug damage.

Bait after seeding if crop damage from slugs is expected. Buried bait is less effective than bait on the soil surface.

⁵⁸ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

⁵⁹ M Nash (2013) Slug control – new insight. GRDC Update paper, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Slug-control-new-insights>

i MORE INFORMATION

Redlegged Earth Mite Agnote
<http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite>

Redlegged earth mite resistance management strategy – NSW, SA, Tasmania and Victoria
<https://grdc.com.au/resources-and-publications/all-publications/factsheets/2016/08/redlegged-earth-mite-rms>

Crop Mites: The Back Pocket Guide
www.grdc.com.au/BPG-CropMites

▶ VIDEO

Watch GCTV9: Redlegged Earth Mites
<https://youtu.be/tMnUVGOUXU8>



The most effective baits are metaldehyde and iron chelates. Metaldehyde damages the mucus-producing cells and is therefore less affected by cold and wet conditions. Rates of up to 10 kg/ha may be necessary.

Baiting will generally only kill 50% of the slug population at any one time.⁶⁰

For more information:

Slug control: slug identification and management
<https://grdc.com.au/GRDC-FS-SlugControl>

Slugs in Crops: The Back Pocket Guide
<https://grdc.com.au/GRDC-BPG-Slug>

Slug control: new insights
<https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Slug-control-new-insights>

New insights into slug and snail control
<https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/New-insights-into-slug-and-snail-control>

Field Peas: The Ute Guide Available as an Android™ app on Google play and for the iPhone and iPad on the App Store

Identification and control of pest slugs and snails for broadacre crops in Western Australia
<https://agric.wa.gov.au/n/2671>

8.9 Redlegged earth mite (*Halotydeus destructor*)

Redlegged earth mites (RLEM) are active from autumn to late spring and are found in southern Australia.

8.9.1 Identification of RLEM

Adults and nymphs of RLEM have a 'velvety' black body. Adult RLEM are 1 mm long with 8 red-orange legs. Newly hatched mites are only 0.2 mm long and pinkish-orange with only 6 legs.



Photo 25: Adult redlegged earth mite (RLEM).

Photo: GRDC The Ute Guide, Southern region. GRDC Ground Cover Direct, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

60 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016



Photo 26: RLEM feeding causes leaves to first turn silvery, then brown and shrivelled, so that plants look scorched.

Photo: GRDC The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide/>

8.9.2 RLEM damage

The RLEM is called an earth mite because it spends 90% of its time on the soil surface, rather than on the foliage of plants. The mites feed on the foliage for short periods and then move around before settling at another feeding site. Other mites are attracted to volatile compounds released from the damaged leaves.

Typical RLEM damage appears as silvering or whitening of the attacked foliage. RLEM are most damaging to emerging crops, greatly reducing seedling survival and development.

In severe cases, entire crops may need re-sowing following RLEM attack. RLEM feed on a wide range of plant species.⁶¹

8.9.3 RLEM life cycle

RLEM are usually active between April and November. During this period, RLEM may pass through 2–3 generations, with each generation surviving 6–8 weeks. Long, wet springs favour the production of over-summering eggs.

Autumn rains trigger hatching in 3–9 days. False autumn breaks can cause large losses in mite numbers. Mites take 20–25 days from hatching to mature and start laying eggs.⁶²

8.9.4 RLEM monitoring

Inspect field pea crops from autumn to spring for mites and their damage, particularly in the first few weeks after sowing.

Mites feed on the leaves in the morning or on overcast days. In the warmer part of the day RLEM tend to gather at the base of plants, sheltering in leaf sheaths and under debris. They crawl into cracks in the soil to avoid heat and cold. When disturbed during feeding they will drop to the ground and seek shelter.⁶³

61 P Umina (2007) Redlegged earth mite. Agnote AG0414, January 2007, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite>

62 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

63 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

i MORE INFORMATION

GRDC Fact Sheet Resistance management strategy for the redlegged earth mite
<https://grdc.com.au/FS-RLEM-Resistance-strategy-South>

i MORE INFORMATION

TIMERITE® information package
<https://www.wool.com/globalassets/start/woolgrower-tools/timerite/timeriteinformationpackage.pdf>

8.9.5 RLEM control and insecticide-resistance management

Control strategies that only target RLEM may not entirely remove pest pressure. Other pests can fill the gap, and this is particularly evident after chemical applications which are generally more effective against RLEM than other mite pests.

Non-chemical options are becoming increasingly important due to evidence of resistance in RLEM populations and concern about long-term sustainability. If using a chemical spray, choose one that has least environmental impact and aim to reduce the number of chemical applications. Pesticide groups exist with low to moderate impacts on many natural enemies, such as cyclodienes.⁶⁴

Insecticide resistance in RLEM is presently confined to Western Australia. High levels of resistance to pyrethroids exist within WA populations. Resistance to organophosphates has also evolved. A strategy to manage insecticide resistance in RLEM populations is available for use by grain growers and their advisers.⁶⁵

8.9.6 Chemical control of RLEM

While insecticides are registered for control of active RLEM, none currently registered are effective against RLEM eggs.⁶⁶ Commonly used insecticides registered for use on RLEM are shown in [Table 4](#) with details in [Table 5](#).

Four chemical sub-groups are registered to control RLEM in grain crops: organophosphates (Group 1B); synthetic pyrethroids (Group 3A); phenylpyrazoles (Group 2B); and neonicotinoids (Group 4A). The latter two are registered only for use as seed treatments.⁶⁷

If spraying in autumn, control the first generation of mites before they lay eggs. Pesticides used at or after sowing should be applied within 3 weeks of the first appearance of mites, before adults begin to lay eggs. Rotate products with different modes of action, to reduce the risk of insecticide resistance.

Autumn insecticide application includes:

- pesticides with persistent residual activity used as bare earth treatments to protect seedlings;
- foliage sprays applied after crop emergence, which are generally an effective control; and
- systemic pesticides applied as seed dressings, which act by maintaining the pesticide at toxic levels within the seedling. Note: if mite numbers are high, plants may suffer significant damage before the pesticide has much effect.

A correctly timed spray in spring can reduce populations of RLEM the following autumn. Use climatic variables and tools such as TIMERITE® (<http://ipmguidelinesforgrains.com.au/pests/earth-mites/earth-mites-autumn-sown-crops-and-pasture/timerite/>) to determine the optimum date for spraying. While TIMERITE® has less relevance in pulse cropping, it has an important role in pastures and RLEM population management.⁶⁸ Research in southern Australia has shown the use of a TIMERITE® spring spray is effective in reducing RLEM populations by 93%.⁶⁹

Users need to be mindful of its limitations and the issues around repeated insecticide applications according to this approach.

Spring RLEM sprays will generally not be effective against other pest mites.⁷⁰

64 Pulse Australia (2016) Southern/western field pea best management practices training course, module 7-2016, Draft. Pulse Australia Limited

65 GRDC (2016) Resistance Management Strategy for the Redlegged earth mite in Australian Grains and Pastures, Southern Region, <https://grdc.com.au/FS-RLEM-Resistance-strategy-South>

66 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

67 GRDC (2016) Resistance Management Strategy for the Redlegged earth mite in Australian Grains and Pastures, Southern Region, <https://grdc.com.au/FS-RLEM-Resistance-strategy-South>

68 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

69 TJ Ridsdill-Smith, C Pavri (2015) Controlling redlegged earth mite, *Halotydeus destructor* (Acari: Penthalaeidae), with a spring spray in legume pastures. *Crop and Pasture Sci.*, 66: 938–946

70 Pulse Australia (2016) Southern/western field pea best management practices training course, module 7-2016, Draft. Pulse Australia Limited

i MORE INFORMATION

Blue oat mite Pest Notes Southern
http://www.pir.sa.gov.au/_data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

Blue Oat Mite Agnote
<http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite>

Crop Mites: The Back Pocket Guide
www.grdc.com.au/BPG-CropMites

Insect ID: The Ute Guide app
<https://grdc.com.au/resources-and-publications/apps/insect-id-the-ute-guide>

8.9.7 Biological control of RLEM

At least 19 predators and one pathogen are known to attack earth mites in eastern Australia, particularly other mites, although small beetles, spiders and ants also play a role. Benefits of a predatory mite (*Anystis wallacei*) that has been released are yet to be demonstrated.

Natural enemies of RLEM residing in windbreaks and roadside vegetation need to be protected also, so avoid pesticides with residual activity applied as border sprays to prevent mites moving into a crop or pasture.

8.9.8 Cultural control of RLEM

Cultural control measures include:

- rotating crops or pastures with non-host crops, such as cereals;
- cultivating, which can also help reduce RLEM populations;
- clean fallowing and controlling weeds around crop and pasture perimeters; and
- controlling weeds, especially thistles and capeweed, to remove breeding sites for RLEM.⁷¹

8.10 Blue oat mite (*Penthaleus* spp.)

8.10.1 Identification of blue oat mites (BOM)

Adult blue oat mites (BOM) are 1 mm long and have 8 red-orange legs. They can be identified by their dark blue-black bodies with a distinct oval red/orange spot on the back (Photo 27), which distinguishes them from the redlegged earth mite. They generally feed singularly and are active from autumn to late spring. BOM are distributed widely across southern Australia.



Photo 27: Adult blue oat mites have a dark blue-black body with distinct oval red/orange spot on the back.

Photo: CESAR, Field Peas: The Ute Guide, Southern region. GRDC Ground Cover Direct, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

There are three species of BOM in Australia, which complicates identification and control. These are *Penthaleus major*, *P. falcatus* and *P. tectus*. Two of these species (*P. major* and *P. falcatus*) have been found on field pea and cause feeding damage.⁷² The BOM species differ in their distribution, pesticide tolerance and crop plant preferences. BOM are often misidentified and treated as RLEM, which means the damage caused by BOM has been under-represented.⁷³ Spring spraying using TIMERITE® against BOM is not recommended as it is largely ineffective.⁷⁴

71 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

72 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

73 P Umina (2007) Blue Oat Mite. Agnote AG1300, July 2007, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite>

74 P Umina, S Hangartner (2015) Blue oat mite, Pest Notes Southern, cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/_data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

8.10.2 Blue oat mite damage

Feeding causes a silver or white discolouration of leaves and distortion or shrivelling if severe (Photo 28). Mites are most damaging to emerging crops, greatly reducing seedling survival and development.



Photo 28: *Blue oat mite feeding damage.*

Photo: PIRSA, Blue oat mite, PestNotes, southern, http://www.pir.sa.gov.au/_data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

8.10.3 Blue oat mite life cycle

BOM are active during cooler, wetter parts of the year (April to late October), and over-summer as eggs. Autumn rains trigger hatching in 3–9 days. False breaks in the season can cause large losses in mite numbers. Mites take 20–25 days from hatching to mature and start laying eggs.⁷⁵

8.10.4 Blue oat mite monitoring

Check paddocks prior to sowing in autumn and throughout winter. It is important to monitor germinating pulse crops.

Examine plants for damage and search for mites on leaves and the ground, especially in late-sown crops.⁷⁶

BOM spend most of their time on the soil surface, rather than on the foliage. They are most active during the cooler parts of the day, feeding in the mornings and in cloudy weather. They seek protection during the warmer part of the day on moist soil surfaces or under foliage, and may even dig into the soil under extreme conditions.⁷⁷

8.10.5 Chemical control

Each species of BOM differs in its distribution, pesticide tolerance and crop plant preferences.

BOM is often misidentified as RLEM⁷⁸ and some BOM species are more tolerant than RLEM to a range of synthetic pyrethroid and organophosphate insecticides.⁷⁹

All current pesticides are only effective against the active stages of mites, and do not kill mite eggs.

Different tolerance to chemical levels between species complicates management of BOM. *P. falcatus* has a high natural tolerance to a range of pesticides registered against earth mites in Australia and is responsible for many control failures involving earth mites. The other BOM species, including *P. major*, have a lower level of tolerance to pesticides and are generally easier to control with chemicals in the field.

⁷⁵ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

⁷⁶ GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

⁷⁷ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

⁷⁸ P Umina (2007) Blue Oat Mite. Agnote AG1300, July 20017, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite>

⁷⁹ GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

Control first generation mites before they can lay eggs to avoid a second spray. Pesticides used at or after sowing should be applied within 3 weeks of first appearance of mites, as adults will then begin laying eggs.

Spraying in spring using the TIMERITE® program is not a recommended strategy with BOM.

Pesticides with persistent residual effects can be used as bare-earth treatments. If applied by sowing, these treatments can protect the plants throughout their seedling stage.

Systemic pesticides applied as seed dressings maintain the pesticide at toxic levels within the seedlings as they grow. This can help minimise damage to plants during the sensitive establishment phase, however, if mite numbers are high, significant damage may still occur before the pesticide has much effect.

Commonly used insecticides registered for use on BOM are shown in [Table 4](#) with details in [Table 5](#).

8.10.6 Biological and cultural control

A number of predator species are known to attack earth mites in Australia. The most important predators of BOM appear to be other mites, although small beetles, spiders and ants may also play a role. The French anystis mite is an effective predator but is limited in distribution. Snout mites will also prey upon BOM, particularly in pastures. The fungal pathogen *Neozygites acaracida* is prevalent in BOM populations during wet winters and could be responsible for observed 'population crashes'.

Preserving natural enemies when using chemicals is often difficult because the pesticides generally used are broad spectrum and kill beneficial species as well as the pests.⁸⁰

Cultural controls such as rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival, decreasing the need for chemical control. Non-preferred crops are:

- *P. major* – canola;
- *P. tectus* – chickpea; and
- *P. falcatus* – wheat, barley.

Pre- and post-sowing weed management (particularly broadleaf weeds) is important.⁸¹

⁸⁰ P Umina (2007) Blue Oat Mite. Agnote AG1300, July 20017, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite>

⁸¹ P Umina, S Hangartner (2015) Blue oat mite, Pest Notes southern. CESAR and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/_data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

i MORE INFORMATION

Lucerne flea, Pest Notes southern:
<http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-flea>

8.11 Lucerne flea (*Sminthurus viridis*)

8.11.1 Lucerne flea identification

Lucerne flea is an introduced pest commonly found in Victoria, South Australia, Tasmania, New South Wales and Western Australia. The insect is 3 mm in length, green-yellow globular shaped and wingless (Photo 29). It is commonly found on loam and clay soils in broadleaf crops and pastures. Lucerne fleas have a furcula underneath their abdomen that acts like a spring and enables them to 'spring off' vegetation when disturbed.⁸²



Photo 29: Lucerne flea with eggs. Adults are green-yellow and may have dark markings.

Photo: Grain Legume Handbook (2008), chapter 7

8.11.2 Lucerne flea damage

Lucerne flea works up plants from ground level leaving distinctive transparent 'window' damage on the leaves (Photo 30). A severe infestation may remove all green material. They are present from autumn to spring with numbers tending to peak in late spring.

Crops are most susceptible to damage immediately following seedling emergence, however, they can also damage older crops.⁸³



Photo 30: Leaf damage caused by lucerne flea feeding, resulting in a distinctive transparent 'window' appearance.

Photo: Grain Legume Handbook (2008), chapter 7.

82 P Umina, S Hangartner, G McDonald (2015) Lucerne flea, Pest Notes southern. CESAR and South Australian Research and Development Institute, <http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-flea>

83 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

8.11.3 Lucerne flea life cycle

Female lucerne fleas lay their eggs in the ground in batches of 20–60.

Depending on temperature and moisture availability, lucerne fleas can have up to six generations per year between autumn and spring. The length of each generation can be from 3–5 weeks. The first generation often hatches from over-summering eggs in March–April after soaking autumn rainfall. In mid to late spring lucerne fleas die off from the onset of warmer weather, leaving over-summering eggs on the soil surface.

The rate of growth of lucerne flea populations is very moisture-dependent; they do well in moist conditions or under dense canopies of pasture.⁸⁴

8.11.4 Monitoring

Pulse crops should be inspected for damage from autumn to spring, and frequently at and immediately following emergence, when they are most susceptible to damage.

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 and check the soil surface, where insects may be sheltering.

Monitoring lucerne flea populations for growth stage as well as numbers can also be important for accurate timing of some sprays.

8.11.5 Chemical control of lucerne flea

Insecticides provide the most effective means of control.

In southern Australia, the standard recommendation is to spray 4 weeks after the first significant autumn rain of the season.

Spring spraying can reduce the number of insects in the following autumn by preventing the laying over-summering eggs. A planned program of timely spring and autumn sprays with effective chemicals over 2–3 years can reduce populations to very low levels.

There are no formal spray thresholds for lucerne flea damage in crops. However, the key is early control because of the impact of seedling vigour on crop performance. Damage levels can be used to determine whether or not spraying is necessary.⁸⁵

It is important to assess the complex of pests present before deciding on the most appropriate control strategy. When both lucerne flea and redlegged earth mite are present, control strategies should consider both pests.

Avoid ‘insurance sprays’, which select for insecticide resistance, and rotate insecticide groups to avoid resistance developing.

Spray immature lucerne fleas before they have a chance to reproduce. Organophosphates (OPs) are recommended for lucerne flea and *Bryobia* mite control.

Most synthetic pyrethroids are not effective on lucerne flea as well as *Bryobia* or *Balaustium* mites.

Several chemicals registered for redlegged earth mite are not effective against lucerne flea: synthetic pyrethroids such as alpha-cypermethrin and imidacloprid seed dressings.

If spraying, use an organophosphate insecticide, for example, omethoate. A border spray may be sufficient to stop invasion from neighbouring pastures or crops. Spot spraying, rather than blanket spraying, may be all that is required.

⁸⁴ P Umina, S Hangartner, G McDonald (2015) Lucerne flea, Pest Notes southern, CESAR and South Australian Research and Development Institute, <http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-flea>

⁸⁵ G Jennings (2002) Knowledge, timing, key to lucerne flea control. Grains Research Advice, November 2002, Grains Research and Development Corporation

If warranted, treat the infested area approximately 3 weeks after lucerne flea has been observed on a newly emerged crop. This will allow for the further hatch of over-summering eggs but will be before lucerne flea reaches maturity and begins to lay winter eggs.⁸⁶

8.11.6 Biological and cultural control of lucerne flea

Several predatory mites, for example, snout mites, various ground beetles and spiders prey on lucerne flea.

Clean fallows and control of weeds within crops and around pasture perimeters, especially capeweed, helps reduce lucerne flea numbers.

Cultivation using trap, border crops and mixed cropping can help reduce the overall infestation levels, particularly when used in conjunction with other measures. Grasses and cereals are less favourable to lucerne flea and as such can be useful for crop borders.⁸⁷

8.12 Australian plague locust

Locusts and grasshoppers will cause damage to field pea in the same way that they will cause damage to any green vegetation when in plague numbers. Native to Australia, most locust plagues occur primarily in inland breeding areas, including parts of Queensland, New South Wales, South Australia and Western Australia. Outbreaks occur in some seasons when favourable conditions in inland breeding areas result in extensive population build-up over sequential generations. Up-to-date advice can be obtained from the Australian Plague Locust Commission, and SA, Victorian or NSW state departments of primary industries.⁸⁸

8.12.1 Australian plague locust identification

Adults of the Australian plague locust have a characteristic black spot on the tip of the hind wing. Nymphs or hoppers are more difficult to identify. If swarming in a large band, then it is likely to be the Australian plague locust.

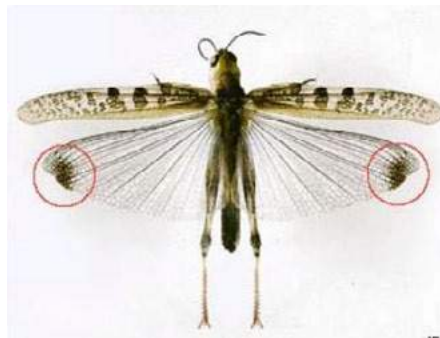


Photo 31: *Australian plague locust.* Note the black spot on the tip of the hind wing.

Photo: APLC via PIRSA, Pulse Australia (2016) Southern/western field pea best management practices training course, module 7-2016. Pulse Australia Limited, Page 41, Image 7.38

i MORE INFORMATION

Plague Locust Control – Fact Sheet:
<https://grdc.com.au/resources-and-publications/all-publications/factsheets/2010/08/plague-locust-control-factsheet>

Australian plague locust Pest Notes southern:
<http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/australian-plague-locust>

86 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

87 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

88 P Umina (2015) Australian plague locust, PestNotes southern. CESAR and South Australian Research and Development Institute, <http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/australian-plague-locust>

8.12.2 Australian plague locust damage

Pulses are susceptible to attack while they remain green; the susceptibility of drying pulse crops is unknown. Early harvesting of pulse crops should be considered in high-risk situations.⁸⁹ Rejection at grain delivery can occur if adult locust or parts of them are present in the sample, or objectionable stains and odours exist.

8.12.3 Australian plague locust life cycle

Most locust plagues originate in south-west Queensland and adjacent areas of SA, NSW and the Northern Territory. Populations develop following rainfall in this area.

With suitable conditions, autumn swarms may migrate 200–500 km into pastoral and adjacent agricultural areas. On arrival, they lay millions of eggs in bare ground, which can produce the spring outbreak.

8.12.4 Control

The Australian Plague Locust Commission (APLC) undertakes surveillance threat assessments, forecasting and control measures when locust populations in outbreak areas have the potential to cross into agricultural locations.

In the event of a plague, local government may undertake some spraying operations within their own area. Where significant problems are expected, government agencies may undertake large-scale control in pastoral and adjacent agricultural areas.

Effective locust suppression can only be achieved by landowners, and local government and government agencies working cooperatively, together with ongoing APLC activities.

Cultivating egg beds will destroy the eggs. Use approved insecticides to target the bands of nymphs before they take flight. Advice on timings and chemicals can be obtained from state government departments or local chemical resellers. Often Australian Veterinary Medicines Authority (APVMA) Permits are required for chemical use.⁹⁰

89 GRDC (2010) Plague locust control: a coordinated approach to control plague locusts. Fact Sheet, September 2010, Grains Research and Development Corporation and Australian Plague Locust Commission, <https://grdc.com.au/Resources/Factsheets/2010/08/Plague-Locust-Control-Factsheet>

90 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

8.13 Etiella or lucerne seed web moth (*Etiella behrii*)

The lucerne seed web moth, also referred to as *Etiella* is widespread throughout Australia. Although they only occur sporadically, when present they are potentially a very serious pest of crops (field pea, lentil, lupin, soybean) in South Australia, Victoria, Western Australia, New South Wales and Queensland (peanuts).

8.13.1 Lucerne seed web moth identification

Adult moths are 10–15 mm long, greyish-brown in colour and when at rest they are long and slender in appearance. They have a tan-coloured band that runs across the forewings and a white strip that runs their full length along the outer edge of the forewings (Photo 32).



Photo 32: Adult lucerne seed web moth.

Photo: SARDI, The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

8.13.2 Lucerne seed web moth lifecycle

Lucerne seed web moth or *Etiella* can have up to three generations per year occurring from spring to autumn. Larvae from the previous autumn overwinter in the soil and adults emerge from September. Adult females are capable of laying approximately 200 eggs. These are laid on the surface of leaves, stems and flowers, and hatch in between 1–14 days depending on temperature. Shortly after larvae hatch they bore into seed pods, where they feed as they grow (Photo 33). First moth flights usually take place during September.



Photo 33: *Etiella* larva in a pea pod with damaged peas.

Photo: SARDI, <http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-seed-web-moth-or-Etiella>

i MORE INFORMATION

Lucerne seed web moth or *Etiella*, <http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-seed-web-moth-or-Etiella>

i MORE INFORMATION

For more details on identification, see: Insects the Ute Guide. <https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/West/Cutworms-Bogong-Moth-Black-Cutworm-Pink-Cutworm-And-Herringbone-Cutworm>

8.13.3 Monitoring

Start to monitor crops in spring during early pod development. This will coincide with the first moth flights, which usually take place during September. There are various monitoring tools:

- Use the degree-day model produced by SARDI to help identify the predicted onset of moth flights and when critical crop monitoring will be required. (The model requires that you add local maximum and minimum temperatures, beyond 21 June, to the spreadsheet.)
- Use pheromone traps to monitor moth flights in paddocks by placing a minimum of 2 traps 25 cm above the crop. Light traps are another means of monitoring moth numbers.
- A sweep net can be used to monitor larval activity, and seed pods should be checked visually for the presence of grubs. A minimum of three groups of 20 sweeps taken randomly across the paddock will be required to accurately check for pest activity.

8.13.4 Biological and cultural control of lucerne seed web moth

There are several parasitic wasps and flies that attack the larvae of lucerne seed web moths. Predatory bugs such as the glossy shield bug and spined predatory shield bug also prey upon larvae.

Time of sowing and variety selection (early-maturing varieties) can result in crops flowering and setting pods prior to peak activity of the moths.⁹¹

8.13.5 Chemical control of lucerne seed web moth

Chemical control of *Etiella* is only effective on adult moths. Once larvae are in pods they cannot be controlled by insecticides.

Successful control relies on thorough crop monitoring in order to time insecticide applications to target adult moths prior to egg lay.

Continue to monitor for 1 week after chemical applications.⁹²

8.14 Occasional pests of field pea

The pests listed below are seldom seen in field pea crops, but have been known to occur over the years and under ideal conditions may occasionally represent an economic threat. See more specific publications for full details.

8.14.1 Cutworms: common cutworm or Bogong moth, black cutworm, brown or pink cutworm, and herringbone cutworm (*Agrotis infusa*, *Agrotis ipsilon*, *Agrotis munda* and other *Agrotis* species)

Cutworm identification and life cycle

Cutworm larvae are hairless with dark heads and, usually, dark bodies. They live in the soil and grow to 50 mm long. They curl up and remain still if disturbed.

Female moths lay eggs in soil in lightly vegetated or bare areas. Larvae have six growth stages (instars).

91 P Umina, B Kimber (2015) Lucerne seed web moth or *Etiella*, Pest Notes southern. CESAR and South Australian Research and Development Institute, <http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-seed-web-moth-or-Etiella>

92 Department of Agriculture & Fisheries (2016) IPM guidelines for grains, *Etiella*. <http://ipmguidelinesforgains.com.au/pests/etiella/>

i MORE INFORMATION

For more details on identification, see: Insects the Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Mites/South/Balaustium-Mite>

Crop mites: the back pocket guide
www.grdc.com.au/BPG-CropMites

i MORE INFORMATION

For more details on identification, see: Insects the Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Mites/South/Clover-Mite>

Cutworm monitoring, damage and control

Cutworm is a sporadic emergence pest. It attacks all crops and pastures including field pea.

Large larvae (20–40 mm long) ringbark or cut off seedlings at ground level; the final 6th stage larvae eat 86% of food.⁹³

Check crops from emergence to establishment. Damage is often patchy. Larvae are usually just beneath the surface; check the base of healthy or recently damaged plants adjoining damaged, bare or thin areas.

Control by selective spraying. Treat affected patches with a standard insecticide (synthetic pyrethroid). Commonly used insecticides registered for use on cutworm are shown in [Table 4](#) with details in [Table 5](#).

Biological controls include a number of parasites, disease, spiders.⁹⁴

8.14.2 Balaustium mite (*Balaustium medicagoense*)

Balaustium mite identification and life cycle

Correct identification is critical for control. *Balaustium* mite adults grow to 2 mm long and may be variable in colour but are mainly dark red to brown. They are slow moving and have characteristic short hairs covering the body. They also have a ‘pad’-like structure on the forelegs. Newly hatched nymphs have 6 bright orange legs, while adults have 8 red legs.

Balaustium mite activity is from March to November in a Mediterranean climate. The mite requires autumn rainfall for over-summered eggs to hatch.

Balaustium mite monitoring, damage and control

Check crops throughout the growing season, particularly in paddocks with a history of chemical treatments for redlegged earth mite.

Most synthetic pyrethroids are not effective on *Balaustium*, or *Bryobia* mites and lucerne flea.

Balaustium mite is also more tolerant of organophosphate insecticides than RLEM.^{95 96}

8.14.3 Clover mite or Bryobia mite (*Bryobia* spp.)

Bryobia mite identification and life cycle

Adults are 0.75–1 mm long with pale orange legs and a dark grey-brown to fawn-orange coloured body, which is oval and flattened. Their front legs are 1.5 times their body length. *Bryobia* mite leave distinct feeding trails.

Bryobia mite is highly active during warm conditions in autumn, spring and early summer. They are found in low numbers in winter when they are unlikely to cause problems. Summer rains followed by a warm autumn increases their survival.

Bryobia mite monitoring, damage and control

Control summer weeds early in paddocks to be cropped. Before sowing, look for damage and their presence on clover and *Brassica* weeds.

Monitor during crop establishment. Mites are difficult to find in wet conditions; check during the warmer part of the day.

93 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

94 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

95 Pulse Australia (2016). Southern/western field pea best management practices training course, module 7-2016, Draft. Pulse Australia Limited

96 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

Spray only when necessary – avoid insurance sprays and rotate insecticide groups to reduce the risk of insecticide resistance. Faba bean is not a good break crop against *Bryobia* mite.

Most synthetic pyrethroids are not effective on *Bryobia* mites, lucerne flea or *Balaustium* mites. Organophosphates are recommended for *Bryobia* mites and lucerne flea. Insecticide rates commonly used for redlegged earth mite are generally ineffective against *Bryobia* mite.^{97 98}

8.14.4 Earwigs – European earwig and native earwig (*Forficulina auricularia* and *Labidura truncata* plus other species)

For more details on identification, see: Insect ID: The Ute Guide <https://grdc.com.au/Resources/Ute-Guides/Insects/Earwigs/South/European-Earwig-and-Native-Earwig>

For information on management, see: GRDC Fact Sheet European earwigs, www.grdc.com.au/GRDC-FS-Earwigs

8.14.5 Mandalotus weevil (*Mandalotus* spp.)

For more details on identification, see: Insect ID: The Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/Mandalotus-Weevil>

8.14.6 Onion thrips, plague thrips and western flower thrips (*Thrips tabaci*, *Thrips imaginis* and *Frankliniella occidentalis*)

For more details on identification, see: Insect ID: The Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Thrips/South/Onion-Thrips-Plague-Thrips-and-Western-Flower-Thrips>

8.14.7 Brown pasture looper (*Ciampa arietaria*)

For more details on identification, see: Insect ID: The Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/South/Brown-Pasture-Looper>

8.14.8 Looper caterpillar (*Chrysodiexis* spp.)

For more details on identification, see: Insect ID: The Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/South/Looper-Caterpillar>

8.14.9 Bronze field beetle (*Adelium brevicorne*)

For more details on identification, see: Insects the Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/Bronzed-Field-Beetle>

8.14.10 False wireworm (*Gonocephalum misellum*)

For more details on identification, see: Insect ID: The Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/False-Wireworms>

97 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

98 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

8.14.11 Onion seedling maggot (*Delia platura*)

For more details on identification, see: Insect ID: The Ute Guide: <https://grdc.com.au/Resources/Ute-Guides/Insects/Flies/South/Onion-Maggot>

8.15 Exotic field pea insects

8.15.1 Exotic seed beetles/bruchids

(Coleoptera: Family: *Chrysomelidae*, sub-family: *Bruchinae*)

Seed beetles, also known as bruchids, are a group of relatively small beetles that attack ripe or ripening seeds, especially legumes. There are over 200 species of bruchids world-wide from several genera that are important primary pests with significant economic impact on pulses.

Several pest bruchid species occur in Australia, such as the pea weevil (*Bruchus pisorum*) that attacks field pea, and cowpea weevils (*Callosobruchus* spp.) that attack a range of pulses.

For more information see [Section 8.5 Pea weevil \(*Bruchus pisorum*\)](#)

Infestation commonly starts in the field, where eggs are laid on maturing pods before harvest and carry over into storage, where substantial losses can occur (species dependent). Surveillance should include field monitoring for adults and pod infestations, as well as seed sampling of stored product.

The presence of damaged seed (round holes) in stored grain is an indication of bruchids. The general form of bruchids and their association with pulses make it unlikely to be confused with other beetle pests associated with stored product. It is suggested that any bruchids found in the field or in storage should be sent in for further identification. Call the Exotic Pest Hotline (1800 084 881).

8.15.2 Exotic leafminers (*Diptera*: family *Agromyzidae*)

The Agromyzidae are a group of small flies whose larvae feed internally on living plant tissue, often as leaf and stem-miners. Key exotic Agromyzid species for field pea include the American serpentine leafminer (*Liriomyza trifolii*) and pea leafminers (*Chromatomyia horticola*, *Liriomyza huidobrensis*).

Leaf-mining (tunnelling) is the most obvious symptom that can be seen and surveyed for in the field. Leaf-mining damage caused by exotic Agromyzidae species can be confused with native leafminer species and moth larvae. Any suspect mining should be sent in for identification. Call the Exotic Plant Pest Hotline (1800 084 881).

Control of *Liriomyza* is difficult. Economic impacts could be highly significant in most crops and across most cropping regions if eradication is not achieved.⁹⁹

MORE INFORMATION

Exotic leafminers fact sheet:
<http://www.planthealthaustralia.com.au/wp-content/uploads/2014/02/Exotic-leaf-miners-FS-Grains.pdf>

99 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

8.16 Beneficial species

All pest populations are regulated to some degree by the direct effects of other living organisms. Beneficial organisms include a range of wasps, flies, bugs, mites, lacewings, beetles and spiders that can reduce insect pest populations through predation and parasitisation. Viruses and fungal diseases also provide control.

A wide range of beneficial organisms can be grouped into three categories:

- **Parasites** – organisms that feed on or in the body of another host. Most eventually kill their host and are free-living as an adult (parasitoids), e.g. aphid wasp parasites.
- **Predators** – mainly free-living insects that consume a large number of prey during their lifetime, e.g. shield bugs, lacewings, hoverflies, spiders, predatory mites and predatory beetles.
- **Insect diseases** – including bacterial, fungal and viral infections of insects.

Inappropriate use of an insecticide that reduces the number of beneficial species can result in a more rapid build-up of insect populations and reliance on further use of insecticide.

Integrated pest management (IPM) in its simplest form is a management strategy in which a variety of biological, chemical and cultural control practices are combined to provide stable, long-term pest control.¹⁰⁰ See [Section 8.1 Integrated pest management \(IPM\)](#)



Photo 34: A pea aphid being consumed by the seven-spotted lady beetle (*Coccinella septempunctata*).

Photo: Brad Stokes, University of Idaho, Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016.

A list of some beneficial organisms is provided below. For more details and photographs of beneficial organisms in insect management, see:

- CESAR website, <http://www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/>
- The GRDC *Insect ID: The Ute Guide* (<https://grdc.com.au/resources-and-publications/apps/insect-id-the-ute-guide>) and *Field peas: The Ute Guide* (<https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>)
- *Beneficial insects: the back pocket guide* (south and west), www.grdc.com.au/BPG-BeneficialInsects-SW

100 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

Beetles

- Carabid beetle (*Notonomus gravis*) <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Carabid-Beetles>
- Transverse ladybird and common ladybird <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Predatory-Ladybird-Beetles-Transverse-Ladybird-Common-Spotted-Ladybird-Minute-TwoSpotted-Ladybird-And-Others>

Bugs

- Damsel bug (family: Nabidae) <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Damsel-Bug>
- Assassin bug <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Assassin-Bugs>
- Glossy shield bug <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Glossy-Shield-Bug>
- Spined predatory shield bug (*Oechalia schellenbergii*) <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Spined-Predatory-Shield-Bug>

Flies

- Hoverfly (family: Syrphidae)
- Tachinid fly <https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Tachinid-Calliphorid-and-Sarcophagid-Flies>

Lacewings

- Green lacewing (family: Chrysopidae) <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Green-Lacewings>
- Brown lacewing (family: Hemerobiidae) <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Brown-Lacewings>

Mites

- Pasture snout mite (*Bdellodes lapidaria*) <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Snout-Mites-Pasture-Snout-Mite-And-Spiny-Snout-Mite>
- French Anystis mite <https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/French-Anystis-Mite>
- *Crop mites: the back pocket guide* <https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/bpg-cropmites>

Caterpillar wasps

- Orange caterpillar parasite wasp <https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Orange-Caterpillar-Parasite>
- Two-toned caterpillar wasp
- Banded caterpillar wasp <https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/North/Banded-Caterpillar-Parasite>
- *Telenomus* wasp and *Trichogramma* wasp <https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Caterpillar-Egg-Parasites>
- Orchid dupe <https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Orchid-Dupe>
- Braconid wasp (*Microplitis demolitor*) <https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/North/Microplitis-demolitor>

Aphid wasps

- *Aphidius ervi* and *Trioxys complanatus* wasps <https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Aphid-Parasites>

Spiders

- Wolf spider (family: *Lycosidae*)
- Jumping spider (family: *Salticidae*)

Insect diseases – viral & fungal

- *Bacillus thuringiensis* (Bt)
- Nuclear polyhedrosis virus (NPV)

8.17 Commonly used registered pesticides

Table 4: Registered insecticides commonly used in pulse crops in Australia.¹⁰¹

Active ingredient Example trade name	Red legged earth mite (RLEM)	Blue oat mite (BOM)	Lucerne flea	Bluegreen aphid	Native budworm	Brown pasture looper	Cutworm	Locust	Withholding period (days)	
									Harvest	Grazing
alpha-cypermethrin DOMINEX® DUO	NSW ACT Vic TAS SA WA	NSW ACT Vic TAS SA WA			NSW, ACT, Vic, SA, WA		NSW ACT Vic TAS SA WA	P	28	35
chlorpyrifos LORSBAN® 500 EC	NSW	NSW								2
cypermethrin SCUD®					NSW Vic TAS SA WA			P	28	35
deltamethrin DECIS® OPTIONS				All states			All states		7	
dimethoate Various	All states		All states							14
endosulfan* Various	All states	NSW WA							Nil	49
esfenvalerate SUMI-ALPHA FLEX®	All states	All states			All states				14	2
gamma-cyhalothrin TROJAN®	NSW Vic Tas SA WA				Sth NSW, WA, Vic, SA, ACT			P	7	7
lambda-cyhalothrin KARATE® ZEON	NSW Vic Tas SA WA				NSW Vic SA WA			P	7	7
Maldison FYFANON® ULV	All states									
omethoate LE- MAT®	NSW Vic Tas SA WA	Qld NSW								1
metarhizium anisopliae GREEN GUARD®								All states		

■ Registered for use in the indicated states. * Endosulfan not permitted post-emergence in pulses. P = Permit only so check if still applicable and which crops are listed on the permit.

Source: Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016.

¹⁰¹ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016

8.17.1 Comments on insecticides

Registrations and use details may differ between states. Always read the label for specific details and information on registration status and insects controlled. Check the APVMA website (<http://apvma.gov.au/>) for labels.

Table 5: Comments on insecticides.

Insecticide & trade name	Remarks
alphacypermethrin DOMINEX®	Best results if sprayed at egg hatching of native budworm. Apply when damaging numbers first appear in the crop. Use higher rate if native budworm larvae >10 mm. Use higher rate if native budworm are >20 mm for Fastac®. Can be used post-emergence for redlegged earth mite control in field pea.
beta-cyfluthrin BULLDOCK®	Use higher rate if native budworm larvae are >10 mm. Bulldock® Duo can also be mixed with mineral oil and applied at ULV rates.
chlorpyrifos LORSBAN®	Active against a wide range of insect pests. Not systemic. Rainfast within 4 hours. Toxic to fish.
cypermethrin SCUD®, SONIC®	Use higher rate if native budworm larvae are >10 mm. Control of larvae >20 mm is unreliable at this rate.
deltamethrin DECIS® OPTIONS	Apply as soon as infestation occurs. Use lower rates only when infestation is low and most larvae are <5 mm long. Longer larvae not readily controlled. Use higher rate for pea weevil under high infestation and for chickpea, faba bean and lentil.
dimethoate Various	Apply to the emerged crop, not to bare ground. Has contact and systemic activity. Rain within 24 hours may reduce effectiveness. Can also be used as a seed treatment at 150 ml in 1 L water/100 kg seed, but not mixed with rhizobia.
endosulfan* Various	For redlegged earth mite use 0.5 L/ha for broad area spraying of bare earth after sowing. Use 1 L/ha for perimeter spray to prevent reinvasion. Do not use post-emergence on any crop.
esfenvalerate SUMI-ALPHA FLEX®	Use 130 ml/ha for native budworm larvae less than 10 mm, 200 ml/ha if 10–20 mm long and 330 ml/ha for >20 mm long.
gamma-cyhalothrin TROJAN®	For native budworm use higher rate if larvae are >10mm or the crop is dense. Rainfast within 30 minutes. S5 poison schedule.
lambda-cyhalothrin KARATE® ZEON	For control of native budworm apply at hatching or soon after when the larvae are small. Use the higher rate if larvae are >10 mm or if the crop is dense.
omethoate LE-MAT®	Spray crop 2–5 weeks after opening rains and before serious damage occurs. Rainfast in 1 hour. Application in spring (according to TIMERITE®) will reduce redlegged earth mite the following year.
metarhizium anisopliae GREEN GUARD®	Biological control agent. Apply in 75–225 L/ha of water for best results when locusts and grasshoppers are at the nymph stage. Do not apply in gusty conditions with winds >8 m/sec or rainfall imminent in next 6 hours. Surfactant and oil required.

* Endosulfan not permitted post-emergence in pulses.

Source: Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 7-2016.

Diseases

Key points

- Field pea yields can be significantly impacted by diseases.
- Field pea requires good disease management to produce a high quality product of a suitable standard for human consumption markets.
- The key diseases of field pea in the southern region are caused by fungal pathogens: *Ascochyta* blight (blackspot), followed by bacterial blight, powdery mildew and downy mildew. Pea seed-borne mosaic virus can also result in significant costs to the industry.

9.1 Impact and cost of diseases

A 2012 GRDC study reported that disease costs the Australian pulse industry an average of \$74 million per year or 14.8% of the gross value of pulse production. Losses would be far higher without the current range of controls, which include the use of resistant varieties, rotation, paddock management and the use of pesticides.

Most field pea (79% of the area sown) is grown in the southern region, with the remainder grown in the western region and, in recent years, the northern region.

Diseases in the Australian field pea industry cause an estimated current average annual loss of \$23.7 million, or \$78.35/ha. Nationally, these losses were dominated by: *Mycosphaerella* blackspot, *Koologunga* blackspot, blackspot complex and *Phoma* blackspot, which are all part of *Ascochyta* blight ('blackspot complex').

The 2012 study estimated the potential losses caused by the top five diseases when uncontrolled (Table 1).

Table 1: The potential losses by the top five diseases when uncontrolled.

Disease	\$/ha	\$million
<i>Mycosphaerella</i> black spot	60.16	18.2
<i>Koologunga</i> black spot	57.11	17.3
Black spot complex	54.20	16.4
<i>Phoma</i> black spot	24.63	7.5
Pea seed-borne mosaic virus	22.48	6.8

Source: GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, <https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia>

In Table 1, all diseases except for Pea seed-borne mosaic virus are collectively known as *Ascochyta* or 'blackspot complex' and are difficult to distinguish in the field. Approximately two-thirds of the national costs are attributed to the southern region.

Most field pea crops in the southern region are treated either with seed or foliar fungicides, costing about \$7 million a year or \$30/ha.¹

9.2 Integrated disease management (IDM) strategies

Disease management in pulses is critical and relies on an integrated management approach to variety choice, crop hygiene and strategic use of fungicides. The initial source of the disease (primary inoculum) 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 (secondary inoculum).

A plant disease may be devastating at certain times and yet, under other conditions, it may have little impact. The interaction of host, pathogen and environment are all critical in disease development and can be represented by the two disease triangles (Figure 1 and Figure 2).

¹ GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, <https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia>

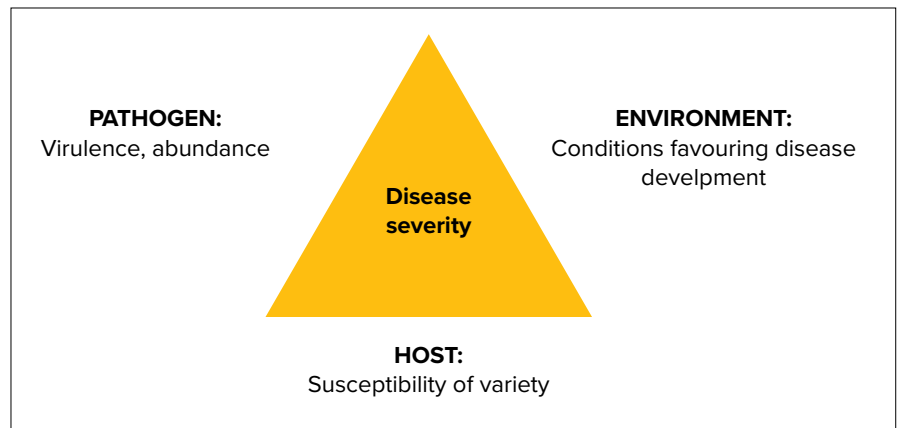


Figure 1: *Fungal disease triangle.*

Source: GN Agrios (1988) *Plant Pathology* (3rd edition). Academic Press, New York.

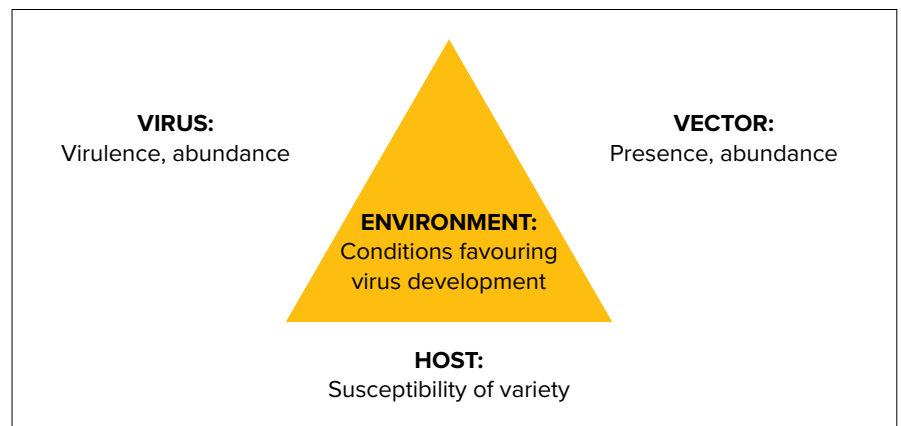


Figure 2: *Viral (and some bacterial) disease triangle.*

Source: RAC Jones, MJ Barbetti (2012) *Influence of climate change on plant disease infections and epidemics caused by viruses and bacteria*. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 7, 1-31.

Disease management should be a consideration when planning any rotation, particularly at the beginning of the season. This is especially important for field pea where the first action of defence against diseases begins with varietal selection. Naturally, other criteria, such as paddock selection, 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 disease impact. Fungicide disease-control strategies alone may not be economic in high-risk situations, particularly if susceptible varieties are grown.

The key aspects of managing diseases in pulses are detailed in [Section 9.3](#) to [Section 9.10](#). In summary:

- **Varietal resistance** – select a resistant variety
- **Distance** – separate by at least 500 m from stubble of the same pulse from the previous year, if possible. This reduces infection sources for some diseases.
- **Rotation** – aim for at least a 4-year rotation between planting the same pulse crop. A high frequency of crops like lentil, faba bean, vetch, field pea, chickpea, lupin or clover pasture puts pulses at greater risk of multi-host diseases such as Phoma blackspot, Sclerotinia and Botrytis grey mould. Canola can increase the risk of Sclerotinia.

- **Hygiene** – practice good hygiene by reducing last year’s pulse stubble, if erosion is not a risk, and removing self-sown pulses before the new crop emerges.
- **Clean seed** – sow seed from crops with no disease or a low level of disease, especially at podding. Avoid using seed where there was a known disease infection, particularly for susceptible varieties. Have seed tested for disease.
- **Fungicide seed dressing** – in high-risk situations seed dressings provide early suppression of diseases like Ascochyta blight (blackspot). Seed dressings containing imidacloprid, used to control aphids, may reduce the chance of virus infection.
- **Sowing date** – do not sow too early, to avoid excessive vegetative growth and early canopy closure. Early crop emergence may coincide with greater inoculum pressure from old crop residues nearby. Aim for the optimum sowing window for the pulse variety and your district. Use ‘Blackspot Manager’ to help determine the optimum sowing window.
- **Sowing rate** – aim for the optimum plant population (depending on region, sowing time, crop type, variety), as denser canopies can lead to increased disease severity. Adjust the seeding rate according to seed size and germination. See [Section 4.3 Sowing rate and plant density](#).
- **Sowing depth** – sowing deeper than normal any seed lot that is infected with disease will reduce the emergence of infected seedlings. The seeding rate should be adjusted upwards to account for lower emergence and establishment percentage.
- **Foliar fungicide applications** – susceptible varieties require a more intense fungicide program. Success depends on timing, weather conditions that follow and the susceptibility of the variety grown. Monitoring for early detection and correct disease identification is essential. Correct fungicide choice is also critical.
- **Mechanical damage** – physical damage from excessive traffic, wind erosion, frost, hail, post-emergent rolling or herbicide damage can increase the spread of foliar disease in pulses.
- **Control aphids** – integrated pest management (IPM) to reduce the incidence of aphids can reduce the spread of viruses. Spraying insecticide may assist, but is not always effective or economic. Usually virus spread has occurred by the time the aphids are detected.
- **Harvest** – harvest early to minimise disease infection on seed. Consider windrowing or desiccation as a tool to enable earlier harvesting.²

² Pulse Australia (2016). Southern Faba & Broad Bean – Best Management Practices Training Course, module 6-2016. Pulse Australia Limited

9.3 Select a resistant variety

Selecting a resistant variety is the most effective method of disease control. Other management practices are not always effective and can be expensive and highly dependent on seasonal conditions. Resistant varieties reduce the reliance on foliar fungicides.

The variety resistance ratings are defined as follows:

- Resistant (R) varieties – no economic yield loss is expected under average conditions. Control measures are unlikely to be profitable. Resistant varieties are not immune when conditions are conducive to disease.
- Moderately resistant (MR) varieties are expected to sustain low to moderate yield loss and control measures are likely to be cost effective.
- Moderately resistant to moderately susceptible (MR-MS) varieties are expected to sustain moderate to high losses and control measures are necessary to ensure a profitable crop.
- Moderately susceptible (MS) or worse varieties (susceptible (S) to very susceptible (VS)) will sustain very high to total yield loss and control measures are essential to produce a harvestable crop.³

No variety has resistance to all of the field pea diseases. Therefore, it is important to select the correct fungicide and application timing to best manage the target disease in the chosen variety. Control strategies vary according to the variety being grown.⁴

The disease ratings in Table 2 are from early 2016. Always check the updated disease ratings each year in the current Crop Variety Guides for each state or in the NVT Crop Disease Au app.

Table 2: Field pea disease ratings for 2017.

Variety	Blackspot (Ascochyta)	Bacterial blight (Field rating)	Downy mildew		Powdery mildew	PSbMV Pea seed-borne mosaic virus	BLRV Bean leaf roll virus (field rating)	Root-lesion nematodes (<i>Pratylenchus</i>)	
			Kaspa strain	Parafiels strain				<i>P. neglectus</i>	<i>P. thornei</i>
Yellow pea grain type									
PBA Hayman [Ⓛ]	S _p	MR _p	–	RMR	R	–	–	–	–
PBA Pearl [Ⓛ]	MS	MS	S	R	S	S	R	MRMS	MRMS
Sturt	MS	MS	S	MS	S	S	MS	MS _p	MR
Kaspa grain type									
Kaspa [Ⓛ]	MS	S	S	MR	S	S	S	MRMS	MRMS
OZP1101	MS	MRMS _p	MS	R	S	S	S	MRMS	MRMS
PBA Gonyah [Ⓛ]	MS	S	S	R	S	S	S	MR	MRMS
PBA Twilight [Ⓛ]	MS	S	S	R	S	S	S	MRMS _p	MRMS
PBA Wharton [Ⓛ]	MS	S	S	MS	R	R	R	MRMS _p	MR _p
Australian dun grain type									
Morgan [Ⓛ]	MS	MS	S	MR	S	S	S _p	RMR _p	MR _p
Parafield	MS	MS	S	S	S	S	S	MRMS	MR _p
PBA Coogee [Ⓛ]	S	MRMS _p	–	S _p	R	–	S _p	MRMS _p	MR _p
PBA Oura [Ⓛ]	MRMS _p	MRMS	MRMS	MR	S	S	MR	MRMS _p	MRMS _p
PBA Percy [Ⓛ]	MS	MR	S	S	S	S	S	MRMS	RMR _p

Disease ratings from Pulse Breeding Australia. Resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS. R = resistant, M = moderately, S = susceptible, VS = very susceptible p = provisional ratings – treat with caution
Source: Sigel *et al.* (2016) http://agriculture.vic.gov.au/_data/assets/pdf_file/0008/294893/VIC-Pulse-disease-guide-2017.pdf

³ L Sigel, J Brand, J Fanning (2017) Pulse Diseases Guide 2017. Agriculture Victoria, http://agriculture.vic.gov.au/_data/assets/pdf_file/0008/294893/VIC-Pulse-disease-guide-2017.pdf

⁴ Pulse Australia (2016) Faba bean: Integrated disease management. Pulse Australia website, <http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/idm-strategies>

9.4 Paddock selection

The selection of the most appropriate paddock for growing field pea requires consideration of a number of important factors, many of which are related to the modes of survival and transmission of pathogens such as *Didymella pinodes* (synonym *Mycosphaerella pinodes*), which causes Ascochyta blight (blackspot) on field pea, or *Peronospora viciae*, which causes downy mildew.

Rotational crops and weeds

If possible, allow at least 4 years between growing field pea crops in the same paddock and at least 500 m distance from the previous year's pea crop.

Sow field pea into standing stubble of previous cereal stubble to protect against rain-splash of soil-borne spores, to protect against erosion and reduce attractiveness of the crop to aphids that can spread viruses.

Some diseases have potential for cross-infection across more than one pulse crop (Table 3).

Table 3: Field pea diseases and potential for cross-infection from other pulses.

	Field pea	Lentil	Faba bean	Vetch	Chickpea	Lupin
Botrytis grey mould <i>Botrytis cinerea</i>	★	★★	★	★★	★★	★
Bacterial blight <i>Pseudomonas syringae</i> pv <i>syringae</i>	★★	★	★★			
<i>P. syringae</i> pv <i>pisi</i>	★★					
Blackspot <i>Mycosphaerella pinodes</i>	★★	★★				★
<i>Phoma koolunga</i>	★★	★	★	★	★	
<i>Phoma medicaginis</i> var <i>pinodella</i>	★★					
Downy mildew <i>Peronospora viciae</i>	★★	★	★	★	★	
Powdery mildew <i>Erysiphe pisi</i>	★★					
Root rots <i>Fusarium</i> sp.	★	★	★	★	★	★
<i>Pythium</i> sp.	★	★			★	★
<i>Rhizoctonia</i> sp.	★★	★★	★★	★★	★	★★
Septoria <i>Septoria pisi</i>	★★					
Sclerotinia spp.	★	★	★	★	★	★
Stem nematode <i>Ditylenchus dipsaci</i>	★★	★	★★	★	★	
Virus Non-seed-borne (e.g. BLRV)	★★	★	★★	★★	★★	
Seed-borne (e.g. PSbMV)	★★	★★	★★	★★	★★	

★ This disease occurs on this crop but has not caused major damage. ★★ This disease has caused major damage on this crop. Blank indicates plant is not a host. Pythium and Botrytis grey mould is worse (★★) in white peas than in duns (★)

Source: Grain Legume Handbook

The previous occurrence of soil-borne diseases like Sclerotinia stem rot, *Pratylenchus* nematodes or stem nematode can constitute a risk for subsequent field pea crops for up to 10 years. Sclerotinia can be hosted by canola, other pulses and many broadleaf weed species.

Some of the viruses affecting field pea also have wide host ranges. Weeds, particularly perennial legumes, host viruses and their aphid vectors e.g. Cucumber mosaic virus (CMV).

Herbicide interactions

Herbicide residues in soil and crop damage from herbicides are known to increase the risk of disease. This may be by directly damaging the plant, making it easier for the disease to enter, or by reducing the overall health of the plant, making it more vulnerable to disease.

To avoid damage ensure the maximum plant-back periods for herbicides are adhered to for triazine, clopyralid, imidazolinone and sulfonylurea herbicides, which are known to predispose plants to disease.

Currently there are no herbicide-tolerant ("XT") field pea varieties available for commercial production.

When diagnosing damage in the field it can be difficult to determine whether the cause of damage is disease or herbicide or a combination of both.⁵

9.5 Good crop hygiene

Pathogens such as Ascochyta blight (blackspot) can be transmitted via infested stubble, soil and seed (Table 4). Soil and stubble movement may occur by machinery, during windy and/or wet weather, and flooding. Therefore, it is essential that 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 individual paddocks. The logistics of actually doing this may be difficult when it comes time to harvest, however growers need to be aware that certain decisions that they or their contractor make may increase the risk of certain diseases in the future.

Table 4: Carryover of major field pea diseases. The relative importance as sources of infection is indicated by the number of stars, with three stars being the most important.

Disease	Stubble	Seed	Soil
Ascochyta blight (blackspot)	★ ★ ★	★ ★	★
Bacterial blight	★ ★ ★	★	★
Downy mildew	★ ★ ★	★ ★	★
Powdery mildew	★ ★ ★	★	★
Septoria blight	★ ★ ★	★ ★	★

Source: Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016 DRAFT.

Control of volunteer field pea during the summer–autumn season and in fallows is vital to reduce the carryover of inoculum of Ascochyta blight (blackspot) and bacterial blight pathogens. Some broadleaf weeds are alternative hosts for one or more of the viruses that affect field pea, and should be removed prior to planting and during crop growth.

Spray rigs should also be cleaned to reduce the risk of disease transmission, particularly if contractors are used. This is especially so with *Ascochyta rabeii* in chickpea, bacterial blight in field pea and anthracnose in lupin. [Section 9.13 Ascochyta blight \(AB\)](#) for further details on field pea.

Floodwaters may also transport disease agents. Floods during January 2011 would have moved field pea stubble infested with Ascochyta blight fungi, as well as soil and weeds harbouring the pathogen.⁶

5 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

6 Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016 Draft. Pulse Australia Limited

9.6 Use clean seed

Use only seed of high quality (purity, germination and vigour). Source seed from a paddock where diseases, particularly those that affect pods, were not detected. A crop known to have been heavily affected by *Ascochyta* blight (blackspot) or bacterial blight should not be used for seed.

Treatment of seed with a fungicide dressing is recommended to control seed-borne diseases like *Ascochyta* blight (blackspot) or where damping off, seedling root rots and other soil-borne fungal diseases have been known to cause problems (Table 5).

9.6.1 Seed dressings

Seed dressings registered for use with field pea are shown in Table 5.

Table 5: Seed dressings registered for field pea.

Active ingredient	Thiram	Thiram + thibendazole
Example trade name	Thiram	P-Pickel® T
<i>Ascochyta</i> blight (blackspot) <i>Didymella pinodes</i> (synonym <i>Mycosphaerella pinodes</i>), <i>Phoma medicaginis</i> var. <i>pinodella</i> , and <i>Ascochyta pisi</i> .	NR	R
Downy mildew	NR	NR
Damping off	-	R
Phytophthora root rot	-	-
Seedling root rots (<i>Pythium</i> spp. and <i>Fusarium</i> spp.)		R
Jurisdiction	All states	All states

R = Registered product label claim. NR = not registered for use in this crop. Refer to the current product label for complete 'Direction for Use' prior to application. Prior to the use of any crop protection product, ensure that it is currently registered or that a current permit exists for its use in field pea. Registered labels and current permits can be found on the APVMA website (www.apvma.gov.au).
Source: Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016. Pulse Australia Limited Table 6.2

Do not mix rhizobia inoculant with fungicide seed dressings. Apply the fungicide seed dressing first and then apply the inoculant as a second operation sometime later after the fungicide has dried and immediately prior to seeding.⁷

9.7 Sowing

9.7.1 Sowing date

Plant during the optimum sowing window for your region. The recommended sowing times are in Section 4.2 [Table 1 Optimum sowing times for southern Australia](#).

Avoid sowing too early as earlier planting often leads to excessive vegetative growth, which predisposes crops to *Ascochyta* blight (blackspot), bacterial blight and frost damage. Use 'Blackspot Manager' to determine the best time to sow.

9.7.2 Sowing rate and row spacing

Higher plant populations can increase foliar disease development by encouraging a dense canopy and a more humid environment.

Reduced humidity can be achieved by reducing the sowing rate, increasing the row spacing and by achieving good weed control.⁸

⁷ Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016 Draft. Pulse Australia Limited

⁸ F Stoddard, A Nicholas, D Rubiales, J Thomas, AM Villegas-Fernandez (2010) Integrated pest management in faba bean. Field Crops Research, 115, 308–318, https://www.researchgate.net/publication/229612261_Integrated_pest_management_in_faba_bean

Optimum plant populations for most field pea varies with field pea type see Section 4.3 [Table 3 Suggested plant density and seeding rate for field pea varieties.](#)

For tall field pea varieties' seed (e.g. 13–23 g/100 seeds), optimum plant populations can vary from 30–60 plants/m².

For Kaspas[®] field pea (e.g. 22 g/100 seeds), optimum plant populations can vary from 40–60 plants/m².

For medium type with less vigour (e.g. 22 g/100 seeds), optimum plant populations can vary from 40–60 plants/m².

Seeding rates resulting in lower than recommended plant populations can reduce disease but can also reduce potential crop yield.

Row spacing can be varied for field pea, but wider rows are only used if sowing is into standing cereal stubble to minimise lodging at harvest. Medium–wide row spacings (25–36 cm) may allow more air movement between rows in to assist disease control.

To avoid potential 'hotspots' for disease, consider 'tramlining' and controlled-traffic. Physical damage to the crop from machinery travelling over the paddock can be a major cause of disease outbreaks.

Some growers believe that sowing in wide rows in a north–south direction improves podset and disease control.⁹

9.8 Free alert services for diseases

Growers can subscribe to newsletters that provide local pest updates. The services listed below are all free.

South Australian Research and Development Institute (SARDI):

- Crop Watch disease newsletter by email. Subscribe by emailing DK Communications (dvkam@iprimus.com.au).
- Follow the Crop Watch twitter account @CropWatchSA
- Like the @Cropwatch Facebook page

Agriculture Victoria:

- Crop Alert disease update by email. Subscribe by emailing crop.safe@ecodev.vic.gov.au
- General grains information is available on the twitter @VicGovGrains

Southern NSW and northern Victoria:

- NSW DPI and GRDC provide the Crop Disease Bulletin for advisers in southern NSW and northern Victoria. To subscribe contact Kurt Lindbeck (kurt.lindbeck@dpi.nsw.gov.au) or Andrew Milgate (andrew.milgate@dpi.nsw.gov.au).

Australia-wide:

- GrowNotes™ Alert on the latest weed, pest and disease issues in your area delivered via App, SMS, voice, email, social media or web portal (or a combination of preferred methods). Subscribe to this GRDC and Agriculture Victoria service at <https://grdc.com.au/resources-and-publications/grownotes/alerts>
- For disease issues across Australia follow ExtensionAUS on Twitter @AusCropDiseases or Facebook.

More information about free information services is available at <http://extensionhub.com.au>

⁹ GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

9.9 Using fungicides

The legal considerations for using fungicides are the same as for herbicides see [Section 7.4 Using herbicides](#). In particular, watch the withholding periods (period before grazing stubbles, cutting/bailing straw/hay).

9.9.1 Registered products

Managing foliar disease in field pea is all about reducing the risk of infection. Most fungicides are preventative and need to be sprayed before disease is evident. Fungicides protect against new infection, but do not cure existing infection. Getting the timing right is critical.¹⁰

Unprotected crops can lose over 50% in grain yield. Grain quality can also be affected if seed is discoloured by disease.

Foliar fungicides are important for the management of Ascochyta blight (blackspot) in all varieties.

Monitoring for early detection and correct disease identification is essential. Ensure any disease is correctly identified to make sure the correct fungicide is selected. Controlling disease with fungicides depends on:

- the timeliness of spraying;
- the weather conditions that follow; and
- the susceptibility of the variety grown.

Fungicides last around 2–3 weeks. Any new growth after fungicide is applied is not protected. In periods of rapid growth and intense rain (50 mm over several days) the protection period will reduce to around 10 days.

The need for and timing of repeat fungicide sprays depends on:

- the amount of unprotected growth;
- rainfall since spraying; and
- the likelihood of a further extended rainy period.¹¹

Plan ahead to ensure that fungicides can be applied as soon as a decision is made. Do not compromise a fungicide spray to wait until it can be combined with a herbicide application. Ideally, spray 1–2 days before significant rain is forecast. Don't delay if rain has already started. A light rain of less than 12 mm can increase the efficacy of mancozeb.

Good leaf coverage with lots of fine droplets will maximise the benefit. Use high water rates. For ground application use 100 L water/ha unless a different minimum rate is specified on the label.

The registered fungicides for Ascochyta blight (blackspot) in field pea are mancozeb, metiram, chlorothalonil and copper oxychloride. Some of these fungicides are registered for processing peas and may not be registered in all states. Check pesticide permits and registrations for any changes in use patterns before using fungicides.

Selecting the right fungicide for the specific disease being targeted is important. Check the efficacy of each fungicide against each disease. Some products are broad-spectrum and are effective against more than one disease, for example products containing mancozeb and chlorothalonil. Mancozeb, chlorothalonil, metiram and copper are protectants and have no curative action on existing infections. Newly grown, untreated foliage will not be protected.

¹⁰ NSW DPI 2002 Foliar diseases of faba beans: management in southern NSW. Pulse point 16, NSW Department of Primary Industries, http://archive.dpi.nsw.gov.au/_data/assets/pdf_file/0017/157400/pulse-point-16.pdf

¹¹ Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016 Draft. Pulse Australia Limited

i MORE INFORMATION

For details on foliar fungicides and the diseases controlled, please see the Winter Crop Sowing Guide at: <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide>

Label regulations limit carbendazim to a maximum of 2 consecutive sprays at 14-day intervals. Carbendazim is a systemic fungicide with single-site specificity so the probability of resistance developing increases with regular use. It is best to alternate carbendazim with either chlorothalonil or mancozeb. Observe the withholding period for grain prior to harvest for carbendazim (4 weeks).¹²

9.9.2 Current minor use permits (MUP)

Some products may be available under permit, with conditions attached, until enough data is generated for full registration. In other cases, a temporary permit may be granted when there is a particular seasonal issue.

Pulse Australia holds several minor use permits (MUP) on behalf of the pulse industry and is actively involved in the pursuit of new permits and label registrations to meet industry needs.

Check for MUP at Pulse Australia (<http://pulseaus.com.au/growing-pulses/crop-protection-products>) or APVMA (<https://portal.apvma.gov.au/permits>) websites.

9.9.3 The critical periods for fungicide use

Monitor crops at least once a week during all critical periods. Be prepared to spray when rain is forecast. Visible lesions will only appear several days after wet conditions.

Fungicide application during critical periods is a standard practice in high-rainfall regions, irrigation districts, in a wet year or in high-disease-risk situations. A crop is at high risk if susceptible varieties are grown, crop rotation is short, if sown adjacent to field pea stubble, infected seed is sown or where all preventative management strategies cannot be followed.

Timelines and fungicide strategies based on the variety and disease being targeted are summarised in [Figure 3](#) and at <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide>. The strategy used for each disease is based on the resistance or susceptibility status of the variety. Use variety disease ratings [Section 3.3.1 Table 3 Disease resistance characteristics of field pea varieties](#), to do this. Choose a fungicide or a fungicide mixture to handle the targeted diseases.

¹² P Matthews, D McCaffery, L Jenkins (2017) Winter crop variety sowing guide 2017, NSW DPI Management Guide. NSW Department of Primary Industries, <https://www.dpi.nsw.gov.au/about-us/media-centre/releases/2017/2017-winter-crop-variety-sowing-guide-now-available>

SECTION 9 FIELD PEA

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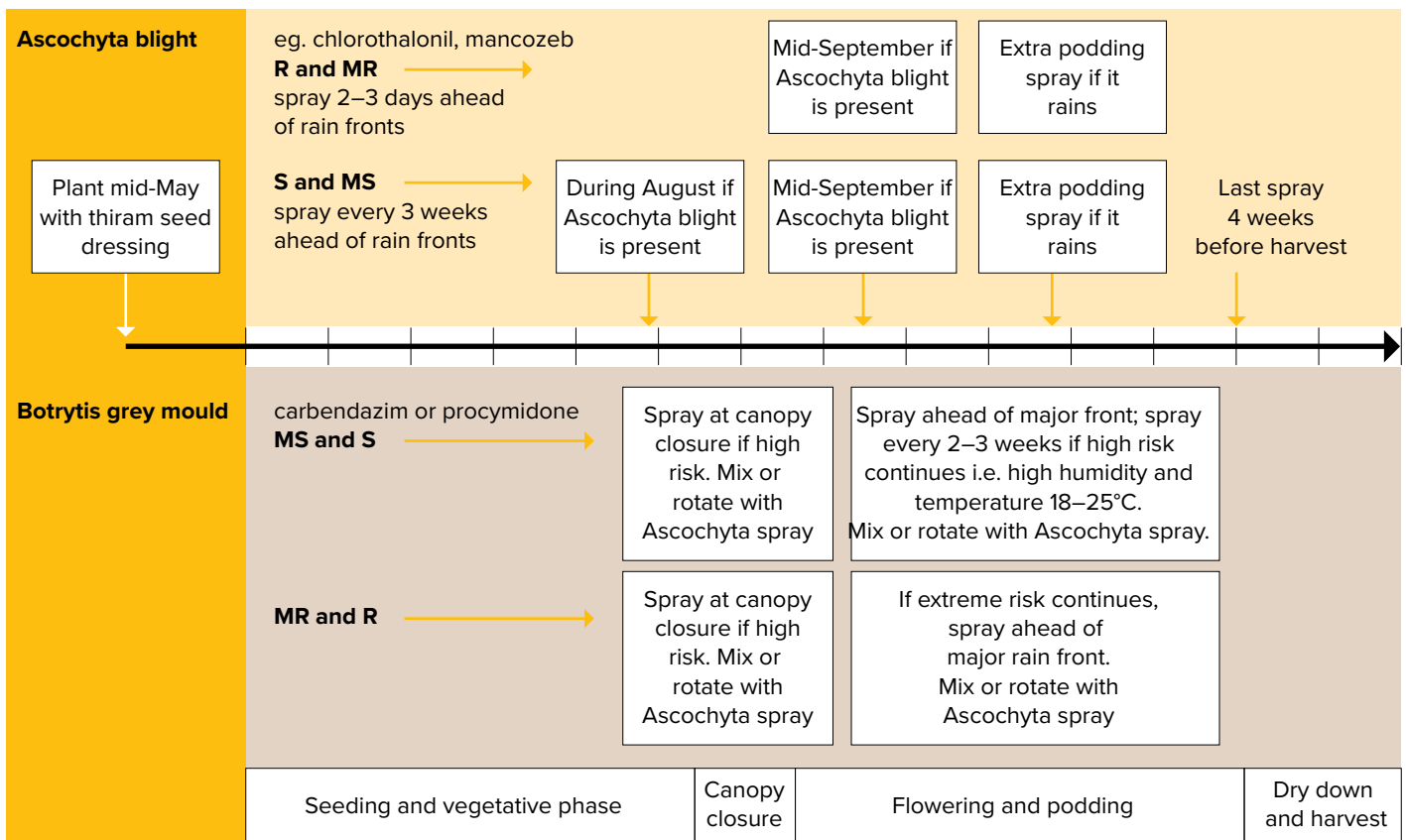


Figure 3: Fungicide timing of field pea disease control with specific variety choices.*

* Foliar fungicide application times based on variety resistance: Resistant (R) or Moderately Resistant (MR) versus Susceptible (S) or Moderate Susceptible (MS).

Source: Jenny Davidson, SARDI

Registered fungicides to use as seed dressings are listed in [Table 5](#). Registered fungicides to use as foliar fungicides are listed at <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide>.

Refer to the current product labels for complete 'Direction for Use' prior to application.

Prior to the use of any crop protection product, ensure that it is currently registered or that a current permit exists for its use in field pea.

Registered labels and current permits can be found on the APVMA website (<https://portal.apvma.gov.au/permits>).¹³

¹³ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 6-2016. Pulse Australia Limited

9.10 Risk assessment

Risk assessment is about assessing the known risks (e.g. paddock history), deciding what can be changed and weighing these up against the unknowns (e.g. seasonal conditions). While the overall aim is to reduce the level of risk, each grower will have a different level of tolerance to risk.

There are three steps in risk assessment:

1. Identify factors that determine risk (see [Figure 1](#) & [Figure 2](#))

Pathogen: Exotic v. endemic; biotypes, pathogenicity, survival and transmission, amenable to chemical management.

Host: Host range; varietal reactions, vulnerability, does susceptibility change with growth stage?

Environment: Weather dependency, interactions with nutrition, herbicides, other diseases, agronomic factors, e.g. planting depth, row spacing, no-tillage, soil conditions.

Risk management: Access to components of management plan; ease of implementing plan; how many options; cost of implementation.

2. Assess level of factors

Pathogen: Level of inoculum, infected seed, aggressiveness of isolate, alternative (weed) hosts prevalent in paddock or nearby, distance from infected stubbles, paddock history.

Host: How resistant, nutritional status, frost susceptibility, herbicide susceptibility.

Environment: Time of sowing (early), length of season; likelihood of rain, drought, waterlogging, irrigation; availability of spray equipment and trafficability; paddock characteristics (soil type), residual herbicide history.

Risk management: Has it not yet been considered; a plan is being developed; or is a plan in place?¹⁴

An example of the key driving factors in managing blackspot is shown in [Figure 4](#).

¹⁴ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 6-2016. Pulse Australia Limited

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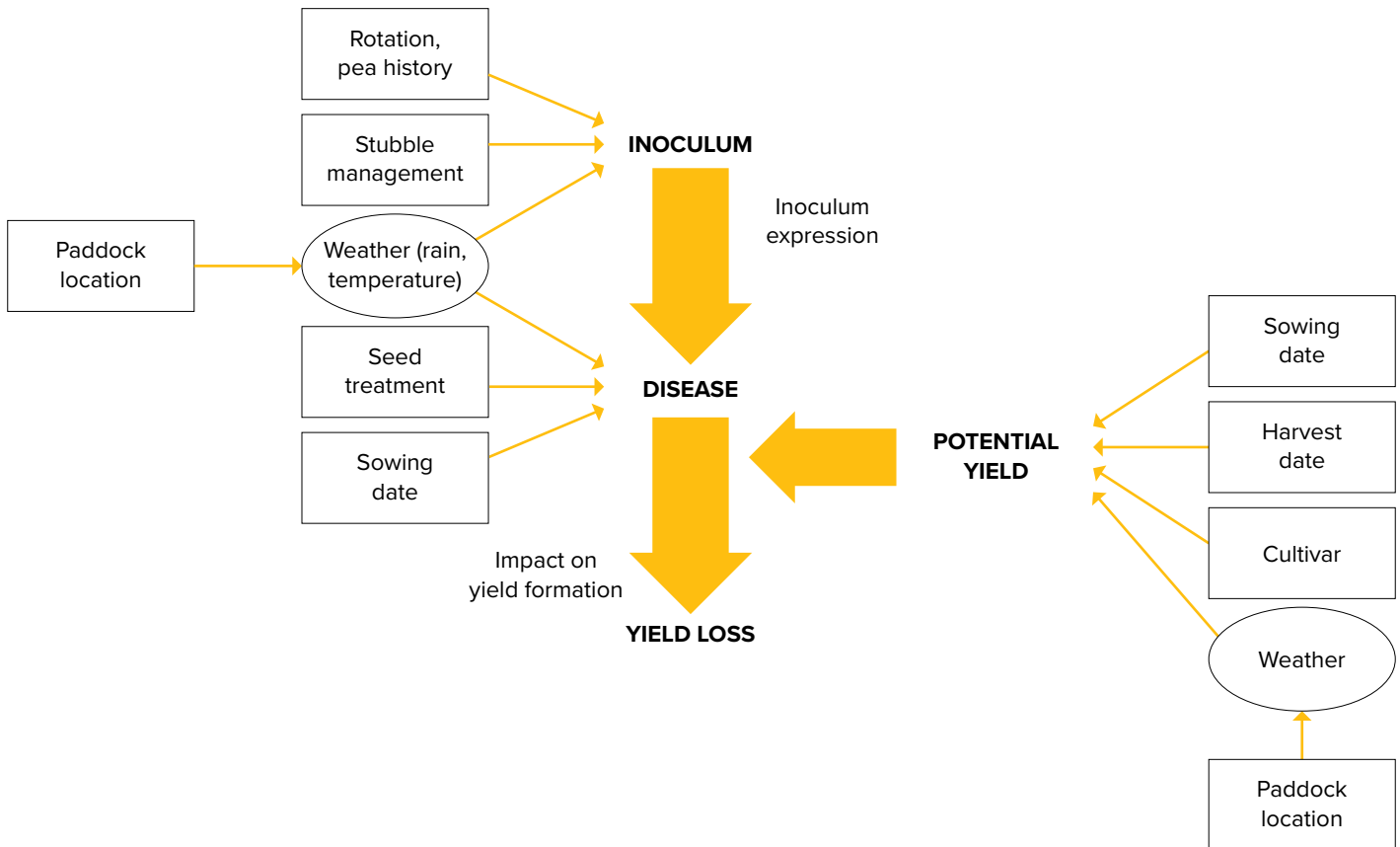


Figure 4: Key driving factors in blackspot, and the basis for managing the risk and maintaining yield potential. The same principles apply to the management of the other diseases.

Source: Australian Pulse Bulletin 2012, http://www.pulseaus.com.au/storage/app/media/crops/2012_APB-Fieldpea-disease-management-South-West.pdf

3. What risk level is acceptable?

High: Grower is prepared to accept substantial yield loss as potential returns are high and financial situation sound; crop failure will not impact on rotation or other components of the farming system.

Low: Grower needs cash flow and cannot afford to spend much or lose the crop; failure impacts seriously on farming system.¹⁵

15 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 6-2016. Pulse Australia Limited

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9.11 Symptom sorter

This symptom sorter (Table 6) featured in the app Field Pea: The Ute Guide. It can be used to help diagnose diseases from other crop damage causes.

Table 6: Field pea symptom sorter.

Crop affect	Distribution	Plant symptoms	Disorder
Poor emergence	Patches	Seed rotted Plants chewed	Damping off Mice Snails
	General	Plants distorted Plants stunted Ungerminated seed	Trifluralin damage Seed sown too deep Poor storage Insect damage
Wilting	Scattered plants	Reduced growth – yellow Yellow/red Premature death	Fusarium wilt Virus Root rots
	Patches	Stunted Premature death	Herbicide damage Fusarium wilt Waterlogging Virus Salinity
	General	Plants limp Leaves/stem distorted	Herbicide damage Stem nematode Virus Downy mildew Mites
	Patches	Yellow – death of young leaves Yellow/red	Iron deficiency Manganese deficiency Sulfonylurea damage Broadstrike® damage Damping off (pythium root rot) Virus Nodulation failure Herbicide damage (e.g. hormone)
Leaf and stem spotting/discolouration	Scattered plants	Brown Purplish black spots Yellow leaves	Bacterial blight Blackspot Virus
	General	Cream to white blotches Yellow/red Tip death	Diflufenican damage Septoria Triazine damage Iron and zinc deficiency Manganese deficiency
	Leaves	Yellow between veins	
Pods discoloured	General	Shrunken – purplish-brown	Blackspot
Fungal growth	Stems and leaves	Grey on underside of leaves White on upper side of leaves	Downy mildew Powdery mildew Botrytis grey mould
		May be with a soft slimy rot, may have larger sclerotes	Sclerotinia
Physical damage	Patches	Plants chewed	Mouse damage Snail damage Native budworm Lucerne seed web moth
		Pods chewed	
	General	Stem, leaves and pods damaged	Mouse damage Hail damage
		Stem bent and twisted	Frost

Source: Field peas: The Ute Guide, GRDC (2009), The Ute Guide, Southern region. GRDC Ground Cover Direct page 28 & 29

i MORE INFORMATION

NVT online: Disease app for android and iOS

<http://www.nvtonline.com.au/interactive-tools/apps/>

GRDC Field peas: The Ute Guide

<https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

9.12 Correctly identifying diseases

Correct disease identification is important as this will determine the choice of product.

Symptoms of Ascochyta and bacterial blight, downy mildew powdery mildew, Septoria leaf blotch, Pea seed-borne mosaic virus, Beet western yellows virus and other causes of damage to field pea may be confusing. Correct disease identification is necessary to avoid unnecessary spraying or incorrect fungicide use.

9.12.1 Diagnostic skills

Accurate diagnosis is essential to effectively manage disease. An incorrect diagnosis can be more costly than inaction.

Not all plant disorders are caused by plant pathogens; consider genetic, insect, animal, environmental and agronomic causes.

Some problems involve more than one cause, although usually there will be only one major cause.

Looking at the problem in the paddock is more likely to lead to a correct diagnosis than examining specimens in the office.

Take notes and photographs. As well as recording historical information (e.g. sowing date, variety, previous crop etc), describing the distribution and symptoms in writing forces us to see what we're looking at. Include this information when sending a sample away for diagnosis.

Follow these steps for an accurate diagnosis:

What is the distribution of the disorder across the district?

- Regional distribution of a problem can eliminate many causes and may identify likely ones.
- If only one crop or one grower in the district has the problem, the cause is unlikely to be environmental (but it could be lightning) or an air-borne disease.
- Isolated problems often reflect some agronomic problem e.g. wrong type or rate of herbicide, poor quality seed, inadequate nutrition, nodulation failure, deep seeding or a soil-borne pest or disease.

What is the distribution of the disorder across the paddock?

- Is the pattern linked with a farming operation (past and present)? e.g. cultivation, old fence line, sheep camp, sowing, varieties, spraying, harvesting?
- Does it follow drainage lines or is it confined to low or high parts of the paddock?
- Does it affect individual plants throughout the paddock; individual plants at the edge of the crop or in thin areas.
- Does it occur in patches?

Walk through the crop with your eyes shut sensing changes in soil compaction to establish links between hard zones and symptoms.

- Run your hands across the plants – do they feel stiff and leathery, cool or hot?

What's the weather been like?

- Could it be frost, heat stress, drought, waterlogging?

What's the insect activity been like?

- Aphids on the windscreen, moths in the crop.

Determine the progression of symptoms. Look at plants showing the range of symptoms from apparently healthy, to just starting to show the problem, to just about to die.

- Are plants easy to pull up?
- Do they break off at ground level?
- Look for evidence of feeding by insects, birds or rodents.

Dig up plants:

- Is soil clinging loosely to their roots (evidence of fungal hyphae)?
- Wash soil from roots in bucket and examine against a light-coloured background.
- Make progressive tangential slices into the root, collar and stem looking for vascular discolouration.

Finally, if you suspect a plant disease, remember the disease triangle ([Figure 1](#)). A crop can only have a serious disease problem if three conditions are met:

- susceptible host;
- prevalent causal agent; and
- favourable environment.

9.12.2 Sending samples for disease diagnosis

For accurate diagnosis it is imperative that specimens are carefully selected, well presented and submitted with adequate information.

Selection of specimens

Select plants that show the range of symptoms from slightly to severely affected. Include several healthy plants for comparison. Collect whole plants if practical, including the roots. For root diseases, include roots and some soil from the root zone (i.e. roots contained in a soil plug).

Preservation

Fresh plant specimens are preferred. If delays in transit are likely and plant material is likely to break down and/or become mouldy, dry specimens are recommended.

DO NOT FREEZE samples.

Fresh specimens are best stored in aerated conditions at high humidity and cool temperatures, preferably not on the back seat of a ute in the sun. Use an esky with fridge bricks to keep samples cool. Diagnosis of viruses requires very fresh specimens. Plants should be wrapped in dry paper and placed in a plastic bag. The paper should not be wet. If dead tissue is present on the sample, damp paper should be avoided as mould may develop.

Dried specimens are best when dried rapidly, but again, not in the back of the ute. Place plant parts between sheets of newspaper (with some pressure) and change paper daily for 1 week.

Packaging

Fresh specimens: specimens likely to decompose, e.g. pods, should be wrapped in paper and placed in a suitable container. Other plant parts can be placed in partially inflated plastic bags and tied-off (fairly loosely to allow aeration but not desiccation). Soil samples should be packed in a sealed plastic bag or airtight container.

Dry specimens: should be supported between two firm surfaces e.g. cardboard, before dispatch.

Note that diagnoses for suspect virus diseases can only be made with fresh specimens.

Labelling

Use waterproof ink. All containers should be clearly marked. If labels are placed inside bags use plastic as paper can become mushy.

Dispatch

Specimens should be sent ASAP after collection. Send early in the week to avoid delays over the weekend. Label the item 'Plant Specimens – Perishable' or 'Soil Samples'.

i MORE INFORMATION

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

SARDI webpage: PreDicta® B testing
http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

AgVic webpage: CropSafe
<http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/grain-and-crop-health/cropsafe-program>

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

DPIPWE webpage: Plant pathology
<http://dpiipwe.tas.gov.au/biosecurity/plant-biosecurity/plant-health-laboratories/plant-pathology-laboratory>

NSW DPI webpage:
<http://www.dpi.nsw.gov.au/content/aboutus/services/das/plant-pests-diseases/sample-preparation>

Extensionhub webpage: Disease testing services around Australia
<https://extensionhub.com.au/web/field-crop-diseases/-/disease-testing-services-around-australia>

Before sending check whether the relevant authority has a submission form.¹⁶

The information usually required includes:

- Name and address of grower and location of crop.
- Host and variety (if not obvious).
- Area of injury e.g. leaves, roots, pods.
- Nature of injury e.g. leaf scorch, root rot, leaf spot.
- Prevalence/distribution e.g. localised, entire field, scattered.
- Severity.
- Soil type, moisture and drainage.
- Previous cropping history.
- Other useful details such as chemical usage, fertiliser applications, irrigations, growing conditions, frost, weather conditions.

Relevant contacts

South Australia

SARDI Plant Diagnostic Centre

Ph: (08) 8303 9400

Seed and crop testing:

http://pir.sa.gov.au/research/services/crop_diagnostics/seed_and_crop_testing

Post to:

Locked Bag 100,
 Glen Osmond, SA, 5064

Courier to:

Plant Research Centre, Waite Institute
 Gate 2B, Hartley Grove,
 Urrbrae, SA 5064

South Australia

SARDI Molecular Diagnostics Group

Ph: (08) 8303 9400

PreDicta® B nematode testing:

http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

Post to:

C/- SARDI RDTS
 Locked Bag 100,
 Glen Osmond, SA, 5064

Courier to:

SARDI Molecular Diagnostics Group
 Plant Research Centre
 Gate 2B
 Hartley Grove
 Urrbrae SA 5064

¹⁶ Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 6-2016. Pulse Australia Limited

Victoria

DEDJTR Pulse Pathology,

Ph: (03) 5362 2111

Post to:

Private Bag, Natimuk Rd,
Horsham, VIC 3401

Courier to:

110 Natimuk Rd
Horsham, VIC 3401

Victorian samples may also be submitted via agronomists through the Cropsafe program. The program aims to provide the early detection of exotic diseases.

<http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/grain-and-crop-health/cropsafe-program>

Tasmania

Ph: 1300 368 550

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

Prices:

<http://dpiwve.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/plant-pathology-laboratory>

Western Australia

DPIRD Diagnostic Laboratory Services (DDLS) Seed Testing and Certification

DDLS conduct seed tests for CMV.

Department of Agriculture and Food

Reply Paid 83377

3 Baron Hay Court

South Perth, WA 6151

Ph: 08 9368 3721

Email: DDLS-STAC@agric.wa.gov.au

<https://www.agric.wa.gov.au/plant-biosecurity/ddls-seed-testing-and-certification-services>

New South Wales

Submission form:

<http://www.dpi.nsw.gov.au/content/aboutus/services/das/plant-pests-diseases/sample-preparation>

Plant Health Diagnostic Service – Wagga Wagga

Ph: (02) 6938 1608

Post to:

Wagga Wagga Agricultural Institute,
Private Bag, Pine Gully Road,
Wagga Wagga, NSW 2650

Plant Health Diagnostic Service - Tamworth

Ph: (02) 6763 1133

Post to:

Tamworth Agricultural Institute,
RMB 944, 4 Marsden Park Rd,
Calala, NSW 2340

9.13 Ascochyta blight (AB)

Ascochyta blight (synonym: blackspot) is one of the most important diseases affecting field pea. It is caused by four pathogens that occur as a complex in the field and cause a single disease where the symptoms caused by each pathogen are undistinguishable. They can all be found on a single diseased plant. However, the pathogens, *Didymella pinodes* (synonym: *Mycosphaerella pinodes*), *Phoma medicaginis* var. *pinodella*, *Phoma koolunga* and *Ascochyta pisi* are separable in laboratory and glasshouse studies. The disease is widespread in Victoria and South Australia. Field surveys have shown that *Didymella pinodes* predominates in Victoria.

9.13.1 Symptoms

The pathogen infects all above-ground parts of field pea plants, as well as the crown below ground level.¹⁷ Symptoms include purplish-black discolouration and streaking of the lower stem. Severe stem infections may also cause stem or foot-rot, which kills the plant.

Conspicuous spotting of the leaves and pods also occurs. The leaf spots may be either small, irregular, dark-brown and scattered over the leaf, or a few large, circular brown spots. Spots on the pods may coalesce to form large, sunken, purplish-black areas (Photos 1–4).

Infected seeds may be discoloured and appear purplish-brown. Discolouration is usually more pronounced on those areas of the seed coat next to diseased areas on the surface of the pod. Lightly infected seed may appear healthy.¹⁸



Photo 1: *Blackspot on leaves of pea.*

Photo: Grain legume handbook 2008, module 6, Plate 748

¹⁷ G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria. http://www.croppro.com.au/crop_disease_manual.php

¹⁸ H Richardson, F Henry (2013) Ascochyta Blight of Field Peas. AGNote AG0150, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ascochyta-blight-of-field-peas>

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Photo 2: *Blackspot on leaves and stems.*

Photo: Grain Legume Handbook (2008), module 6, Plate 7.49



Photo 3: *Blackspot on lower stems.*

Photo: Grain Legume Handbook (2008), module 6, Plate 7.50



Photo 4: *Blackspot on pods.*

Photo: Grain Legume Handbook (2008), module 6, Plate 7.51

9.13.2 Economic importance

Severity of the disease varies greatly from crop to crop and between seasons. In wet seasons when conditions are conducive, yield losses of up to 60% have been reported within individual crops, but in a dry season crop losses are less.

9.13.3 Disease cycle

The fungi that cause Ascochyta blight (blackspot) may either be seed-borne, soil-borne or survive in pea trash. The disease usually becomes established when sexual ascospores of the fungus (*D. pinodella*), produced in perithecia on old pea stubble, are carried into the new crop by rain and wind causing early infection (primary infection).

Secondary infection occurs when asexual conidia produced in pycnidia (fruiting bodies) infect pea plants. This can occur at any stage of plant growth. Pycnidia and perithecia develop on infected plants throughout the growing season and after harvest on pea stubble and infected volunteer plants. Ascospores are the main source of primary infection, whereas the secondary infection is caused by production of conidia (Figure 5).

Discharge of both types of spores needs rainfall or dew, therefore epidemics are more severe in wetter conditions. Spores produced on infected foliage are transferred onto adjacent healthy plants by wind and rain splash.

The disease can also become established by sowing of infected seed, which is a major concern and up to 90% of seed samples may be infected. The proportion of diseased seedlings arising from any infected seed lot is influenced by seasonal conditions such as high rainfall and soil factors. In a dry year, the planting of infected seed may not produce a diseased crop, but under wet conditions severe disease is likely.

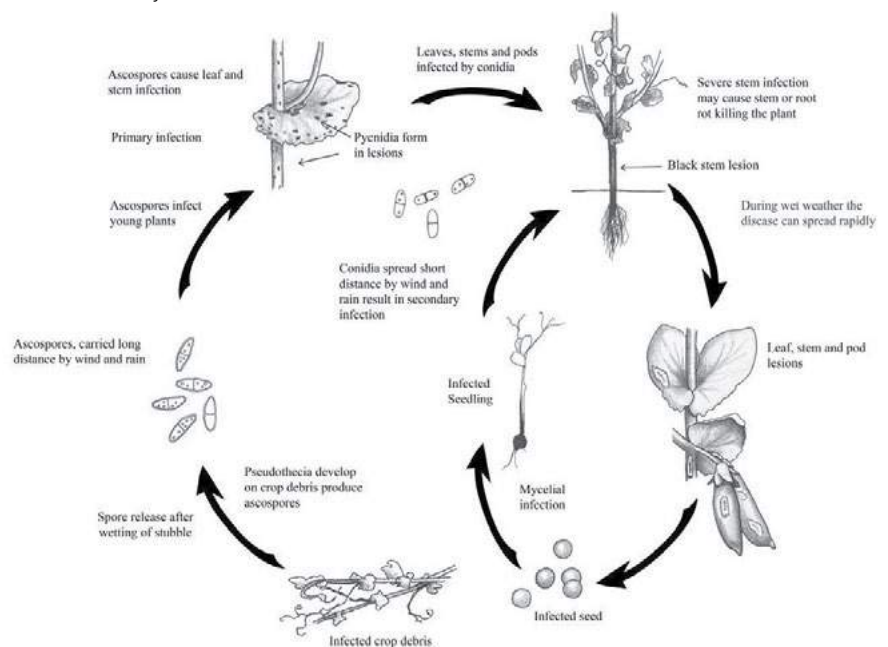


Figure 5: Disease cycle of *Ascochyta* blight of field pea.

Illustration: Kylie Fowler, DEDJTR Source: http://www.croppro.com.au/crop_disease_manual/ch07s02.php

9.13.4 Management options

Ascochyta blight is best managed using an integrated management package approach, involving crop management and hygiene. Control of black spot is the first priority in field pea and sets the basis for controlling the other diseases. Fungicide use is minor in the overall integrated programs.

Summary of recommended strategies to minimise disease in field pea:

- Paddock isolation: (>500 m) from pea stubble is the highest priority.
- Paddock history: aim for a minimum 4-year break between pea crops because soil-borne inoculum is significant.
- Seed source: use seed with minimal disease transmission. Test seed for disease and virus status.
- Fungicide seed dressing: can be effective in high-disease-risk situations.
- Sowing and rainfall: use the 'Blackspot Manager' computer model to assist with sowing date decisions. Do not sow within 2 weeks of the first rains of the season unless in low-rainfall/short-season areas and blackspot risk is low.
- Sowing date: sow within the optimum 'sowing window' for your district, using 'Blackspot Manager' to assist.
- Sowing rate: sow at the recommended plant population for the district, sowing time and variety.
- Variety selection: no variety is resistant to blackspot. Know the other disease susceptibilities of the variety sown.
- Hygiene: take all precautions to avoid disease spread. Spray or remove self-sown pea seedlings and ideally destroy pea stubbles before the new crop emerges.
- Foliar fungicide application: foliar fungicide can effectively control powdery mildew. A fungicide program for controlling blackspot and Septoria in peas is possible, but may not necessarily be economic.
- Mechanical damage: traffic, wind erosion, frost, hail or herbicide damage can spread bacterial blight.
- Harvest management: early harvest helps to minimise disease infection of seed and benefits grain quality.

Despite regional differences, predicting disease risk is possible based on proximity to pea stubbles, paddock history, soil test, rainfall information (timing and amount), stubble management and planned sowing date.

Decision-making tools to use are the 'Blackspot Manager' computer model (SA, WA and Victoria) and the PreDicta™ B soil test (not WA) along with the proximity of the nearest pea stubble (all areas). Plan to manage blackspot in peas first, followed by the other fungal diseases of local importance.¹⁹

Two of the best management options are isolating the new crop from sources of infection and not sowing too early. Ascochyta blight is best controlled by destroying infected pea trash and self-sown plants. The severity of disease may also be reduced by crop rotation, by the use of disease-free seed, resistant varieties, fungicidal seed dressing and foliar fungicides (in some situations).

Use clean seed

Seed should be tested for disease before sowing. Only use seed if <5% is infected. Using old or damaged seed can reduce seedling vigour and increase susceptibility to infection. Refer to Agriculture Victoria's 'Seed Health Testing in Pulse Crops' (AG1250) (<http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops>) or extensionaus.com.au for contacts on where to test seed.

¹⁹ Pulse Australia (2012) Field pea Disease Management Strategy, Southern & Western Region. Australian Pulse Bulletin. http://www.pulseaus.com.au/storage/app/media/crops/2012_APB-Fieldpea-disease-management-South-West.pdf

Destroy old crop residues

Destroying pea stubble by grazing and cultivation will reduce disease risk by minimising the number of spores available to infect new crops. However, care should be taken not to expose soil to wind erosion. Self-sown peas must also be controlled to prevent carryover of the disease.

Paddock selection

Avoid planting this season's crop near old field pea stubble. Previous pea crop residues can harbour the *Ascochyta* blight (blackspot) pathogens. Aim for a separation of at least 500 m from last year's pea paddock.

Crop rotation

The blight fungi can survive in soil and on old pea trash; it is only safe to re-crop an area with pea after all pea debris has decomposed. Pea should not be sown on land planted to pea the previous year nor on land adjacent to pea stubble. Where possible, pea should not be grown in the same paddock more than once in 3 years. If disease occurs, the rotation should be extended to one in 4 or 5 years.

Sowing dates

Follow the recommended sowing rates and sowing dates for your district. Avoid early sowing at high seeding rates as this increases exposure of pea seedlings to the *Ascochyta* (blackspot) pathogens and produces crops with a large canopy, increased lodging and high humidity, all of which increase the risk of developing disease.

Ascochyta spore forecasting model

'Blackspot Manager' is a forecasting model for *Ascochyta* blight (blackspot) of field pea. It can be used by agronomists and growers to help identify the best sowing dates that minimise the risk of *Ascochyta* blight without delaying sowing longer than necessary. The sowing dates are developed for different rainfall regions after first autumn rains. Blackspot Manager is produced by the Department of Primary Industries and Regional Development (DPIRD, formerly Department of Agriculture and Food, Western Australia (DPIRD)) and predictions are made for field pea crops in New South Wales, South Australia, Victoria and Western Australia.

Chemical control

Fungicidal seed dressings registered for use on *Ascochyta* blight of field pea, when applied correctly, will control seed-borne disease and protect young plants from early infection. It is recommended that all pea seed be treated with a fungicide. Where seed is to be inoculated apply the fungicide first and allow to dry. Apply the inoculum immediately prior to sowing. Fungicides and inoculant should never be mixed together. If the potential yield is over 2 t/ha, then use P-Pickel T® and seed dressing and apply mancozeb (2 kg/ha) at 9th node stage and again at early flowering.

Fungicide application for *Ascochyta* blight (blackspot) control has generally proven to be uneconomic for field pea that yield <2 t/ha. In some situations, applying mancozeb at 2 kg/ha, at strategic timings (9th node and again at early flowering prior to significant rain fronts) can lead to economic disease control in high-yielding pea crops. If field peas are sown according to recommendations of Blackspot Manager, ie after 50% of spores have been released, then blackspot disease is unlikely to reach severe levels. If the peas are sown before the peak spore release -- that is the spores are released in late May or June and peas re sown mid-May, then foliar fungicides are warranted for disease control. Trials in previous years have shown that potential yield needs to be at least 2t/ha for foliar fungicides to be economic in field peas even when blackspot is severe. While yields were high in 2011, blackspot severity was generally low, and application of fungicides was not economic in 2011. (see Field pea disease management strategy, http://www.pulseaus.com.au/storage/app/media/crops/2012_APB-Fieldpea-disease-management-South-West.pdf).

SARDI trial data 2016: re-thinking Ascochyta blight control strategy in field pea

Key findings:

In low-rainfall zones delayed sowing to manage Ascochyta blight risk often leads to yield loss.

Earlier sowing can be achieved with the use of foliar fungicides.

Research conducted in 2015 to test the efficacy of alternative fungicides alongside the current industry practice has improved Ascochyta blight disease control together with a yield benefit of up to 15% over the current industry practice.

See summary of trial below or full details: <http://www.farmtrials.com.au/trial/18345>

SARDI trial data 2016

The existing industry practice for Ascochyta blight control in field pea was developed by SARDI (McMurray *et al.*) and includes the use of a fungicide application strategy of P-Pickel T[®] seed dressing followed by two foliar applications of mancozeb (2 kg/ha at 9th node and early flowering). This strategy, developed in 2011, has been shown to suppress Ascochyta blight and is generally a viable economical option for crops yielding 1.5 t/ha or greater.

Research conducted in 2015 to test the efficacy of alternative fungicides alongside the current industry practice has indicated improved Ascochyta blight disease control together with a yield benefit of up to 15% over the current industry practice. This research also identified that the severity of disease onset was higher at an earlier growth stage in low-rainfall environments, such as Minnipa, SA. As such, the timing of the first foliar fungicide, at 8 weeks after sowing (WAS) was thought to be too late for effective control of Ascochyta blight in these environments. Further, in medium-rainfall environments, more favourable spring conditions often extend late season disease progression and therefore sprays towards the back-end of the growing season may be required.

The aim of the 2016 trials was to further assess these new experimental fungicides alongside the current strategy and also include variations in fungicide application timings to improve disease control efficacy.

Key findings

- The recommended industry practice of P-Pickel T[®] seed treatment and two foliar fungicides of mancozeb failed to significantly reduce disease infection levels or increase grain yield over untreated control treatments under high blackspot disease pressure in 2016.
- Early disease control applications (4 weeks after sowing) were important for reducing initial blackspot infection levels at Minnipa; conversely, later spring application were important at the higher-rainfall site of Hart.
- Over 2 consecutive years, a yield benefit of at least 15% has been obtained from application of new experimental fungicide actives over the current industry practice treatment.

Further research is required to understand the interaction in efficacy between fungicides and timing of disease infection, together with the drivers of Ascochyta blight control and progression in different field pea growing environments.²⁰

MORE INFORMATION

CropPro webpage: Ascochyta blight (blackspot) of field peas, http://www.croppro.com.au/crop_disease_manual/ch07s02.php

Blackspot Manager, <https://extensionhub.com.au/web/field-crop-diseases/-/blackspot-manager-for-field-peas>

Field pea disease management strategy for Southern and Western regions, http://www.pulseaus.com.au/storage/app/media/crops/2012_APB-Fieldpea-disease-management-South-West.pdf

²⁰ C Walela, L McMurray, J Davidson, L Davis (2016) Re-thinking the current ascochyta blight control strategy in field peas, Hart Trial Results 2016. http://www.hartfieldsite.org.au/media/2016%20Trial%20Results/Hart_Trial_Results_2016_Re-thinking_the_current_ascochyta_blight_control_strategy_in_field_peas.pdf

9.14 Bacterial blight of field pea

This disease, caused by the bacteria *Pseudomonas syringae* pv. *pisii* and *P. syringae* pv. *syringae*, is a serious disease of pea. Recently, the pathogen *P. syringae* pv. *syringae* has been considered the main cause of the disease in pea crops. Bacterial blight is widespread in field pea in southern New South Wales and Victoria, but its severity varies greatly from crop to crop and between seasons. The disease is seed-borne and is more prevalent after frost events; multiple frosts can cause epidemics resulting in significant yield loss.

9.14.1 Symptoms

The disease first becomes evident as small, dark-green, water-soaked lesions on leaves and stipules. The lesions may enlarge and coalesce, but are nearly always delimited by the veins and develop a characteristic fan shape. The lesions on the leaflets turn yellowish and later brown and papery; lesions on the pods are sunken and turn olive-brown (Photos 5 and 6).

Lesions may also develop on stems near ground level. These begin as water-soaked areas, which later turn olive-green to dark brown. Stem lesions may coalesce, causing the stem to shrivel and die. Stem infection may spread upwards to the stipules and leaflets.

Pre-emergence and post-emergence damping-off may occur, and even advanced plants may be killed. Heavily infected seed may be discoloured, but light infection has no visible effect on seed.

The symptoms of bacterial blight caused by *P. syringae* pv. *pisii* or *P. syringae* pv. *syringae* are indistinguishable from each other on the pea plant.²¹



Photo 5: Water-soaked lesions, caused by bacterial blight, spreading in a fan-shaped pattern into the leaf from the base.

Photo: P Baker, Rural Directions, Field peas: The Ute Guide Page 41



Photo 6: Olive-brown bacterial blight lesions on pea pods.

Photo: J Wilson, Elders

²¹ G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria. http://www.croppro.com.au/crop_disease_manual.php



Photo 7: Paddock affected by bacterial blight.

Photo: W. Hawthorne, formerly Pulse Australia

9.14.2 Economic importance

Bacterial blight is widespread in field pea in Victoria, but its severity varies greatly from crop to crop and between seasons. Severe epidemics can result in crop failure, however, losses are usually less than 20%.²²

9.14.3 Disease cycle of bacterial blight in field pea

Bacterial blight commonly becomes established within a field by sowing infected seed or from infected pea trash that is nearby. During wet weather, bacteria spread from infected to healthy plants by rain splash and in wind-borne water droplets (Figure 6).

Infection may occur at any stage of plant growth. The pathogens can remain on the surface of plants without causing symptoms. However, following rain, heavy dew, frost or other forms of damage to plant tissues, symptoms can develop. Damage to field pea enables entry of bacteria into the plant tissue. Early infections may lead to epidemics but later infection can also cause yield losses. Because the disease depends on wet conditions, bacterial blight is most severe in wet seasons. A combination of excessive rainfall and strong winds provides the most favourable conditions for spread of the disease within crops.

P. syringae pv. *pisi* is largely restricted to field peas but *P. syringae* pv. *syringae* has a wide host range including clover, common bean, faba bean, lentil, chickpea and vetch, which act as alternate hosts.

²² H Richardson (2012) Bacterial Blight of Field Peas. AGNote AG0148, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bacterial-blight-of-field-peas>

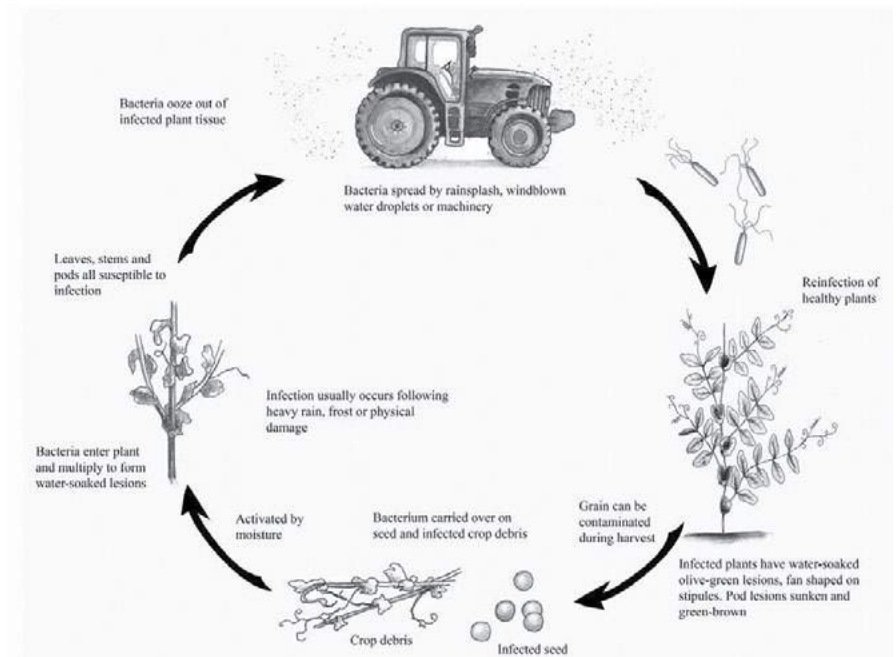


Figure 6: Disease cycle of bacterial blight in field pea.

Illustration: Kylie Fowler, DEDJTR Source: CropPro http://www.croppro.com.au/crop_disease_manual/ch07s03.php

9.14.4 Management options

Bacterial blight can be avoided by using an integrated approach to management that encompasses planting disease-free seed, crop rotation, variety selection and avoiding early sowing.

Use of disease-free seed

This is the main control measure recommended. The use of clean seed will minimise the possibility of disease, provided the land has not been cropped to pea for several years. Do not use seed from crops identified with bacterial blight during field inspections. A field inspection should occur at mid to late pod-fill. Bacteria remain viable on seed for at least 2 years. Seed testing for bacterial blight is available from:

DPIRD Diagnostic Laboratory Services (DLS) Seed Testing and Certification

Department of Primary Industries and Regional Development
 Reply Paid 83377
 3 Baron Hay Court
 South Perth, WA 6151

Ph: 08 9368 3721

Email: DDLS-STAC@agric.wa.gov.au

<https://www.agric.wa.gov.au/plant-biosecurity/ddls-seed-testing-and-certification-services>

AsureQuality

3-5 Lillee Crescent (PO Box 1335)
 Tullamarine
 Victoria 3043

Ph: 03 8318 9000

Fax: 03 8318 9001

<https://www.asurequality.com>

For information on virus testing, please see: [Section 9.20.6 Virus testing](#)

Rotations

To obtain a blight-free crop, pea should not be sown on land sown to pea in the previous year or adjacent to pea stubble. Where possible, pea should not be grown on the same land more than once in 3 years. If disease occurs the rotation should be extended to once in 4 years.

Stubble can be a significant source of inoculum. Destroy by burying, baling or burning infected stubble. The survival time of inoculum is significantly reduced by burying pea trash 10 cm below the soil surface.

Time of sowing

Early-sown crops are more vulnerable to bacterial blight infection than late-sown crops; never sow earlier than recommended for your district. In areas prone to bacterial blight avoid early sowing.

Crop damage

Bacterial blight is often associated with physical crop damage such as hail, frost, strong winds, sand blasting or machinery damage. Physical damage enables bacteria to enter plant tissue. Minimise the use of post-emergence herbicide sprays, if possible, as the severity of bacterial blight can increase if plant tissue is damaged. Avoid paddocks where sulfonylurea residues may be present and the more frost-prone paddocks.

Varieties

All varieties are susceptible to *P. syringae* pv. *pisii*, but the frequency of bacterial blight can be reduced by avoiding varieties susceptible to *P. syringae* pv. *syringae* (Table 8).

Table 7: Reaction of varieties to bacterial blight caused by *Pseudomonas syringae* pv. *Syringae*.

Variety	Reaction
Bundi	Susceptible
SW Celine	Susceptible
Dundale	Resistant
Dunwa	Resistant
Excell	Susceptible
Helena	Resistant
Kaspa [Ⓛ]	Susceptible
Maki	Susceptible
Moonlight	Very Susceptible
Morgan [Ⓛ]	Moderately Susceptible
PBA Gonyah [Ⓛ]	Susceptible
PBA Oura [Ⓛ]	Moderately Resistant
PBA Percy [Ⓛ]	Resistant
PBA Twilight [Ⓛ]	Susceptible
Parafield	Moderately Resistant – Moderately Susceptible
Snowpeak	Very Susceptible
Sturt	Moderately Resistant – Moderately Susceptible
Yarrum	Susceptible

Source: Richardson (2012) Bacterial Blight of Field Peas. AgNote AG0148, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bacterial-blight-of-field-peas>

i MORE INFORMATION

CropPro webpage: Bacterial Blight of Field Peas
http://www.croppro.com.au/crop_disease_manual/ch07s03.php

Farm hygiene

When bacterial blight is detected, steps should be taken to prevent the spread of disease. Where possible, harvest infected crops last to avoid contaminating healthy crops, and machinery used in an infected crop should be cleaned thoroughly and washed with disinfectant after use. Likewise, machine operators and farm workers should only move from crop to crop after taking precautions against the spread of bacteria. This is best achieved by wearing rubber boots and waterproof trousers that are washed with disinfectant immediately after leaving an infected field. Crops should never be inspected when they are wet as this increases the chance of spreading disease.

Chemical control

Fungicides and seed treatments are designed to be active against fungal diseases and are ineffective in the control of bacterial diseases. There are copper-based compounds, registered for use in field pea against bacterial blight, but evidence for their effectiveness in Australian field pea crops is limited and inconclusive.²³

9.15 Downy mildew of field pea

Downy mildew, caused by the pathogen *Peronospora viciae*, is a common disease of pea in Victoria, South Australia and Tasmania. Downy mildew is favoured by wet, cool seasons. Night temperatures below 10°C and morning dew promotes the disease. The disease also impairs wax formation on the leaves and makes plants susceptible to herbicide damage. Systemic infection can lead to the appearance of the disease late in the season if conditions are conducive, but yield losses due to downy mildew arise from the stunting of plants early in their growth, or from complete loss of seedlings. Substantial losses are likely to occur in cooler districts.²⁴

9.15.1 Symptoms

This disease is most common soon after seedling emergence, but it may affect plants at any stage of growth especially during periods of moist, cool weather.

Plants grown from infected seed are severely stunted and distorted, and have a sickly yellowish-green appearance. The undersides of the leaflets, in particular, are covered with a fluffy mouse-grey spore mass (Photo 8). Infected plants may turn yellow-while producing an abundant source of spores, which cause secondary infections.

Secondary infection results in the appearance of isolated greenish yellow to brown blotches on the upper surface of leaves (Photo 9), while on the underside of the leaf, masses of mouse-grey- coloured spores are produced.

The fungus usually affects the lowest leaves and then progresses up the plant, sometimes infecting flowers and pods. Infected pods are deformed and covered with yellow to brownish areas and superficial blistering.

23 G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria. http://www.croppro.com.au/crop_disease_manual.php
 24 G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria. http://www.croppro.com.au/crop_disease_manual.php



Photo 8: Downy mildew can be identified by the pale grey fungus underneath the leaves.

Photo: Grain Legume Handbook, chapter 7, Plate 7.52



Photo 9: Downy mildew on pea with greenish-yellow to brown blotches on the upper surface of leaves, and grey fungal growth on the underside.

Photo: Grain Legume Handbook (2008), chapter 7, Plate 7.53

9.15.2 Economic importance

Downy mildew causes most damage by stunting plants early in their growth or by killing seedlings in more extreme instances. Generally, plants will grow away from the disease as temperatures increase in late winter/early spring without significant yield loss.

The disease also impairs formation of wax on the leaves, which makes plants very susceptible to damage by herbicides. Substantial losses can occur in cooler districts.²⁵

9.15.3 Disease cycle

The fungus that causes downy mildew survives in the soil and on pea trash and can be seed-borne.

Infected seed can act as a primary source for systemic and local infections. The disease can develop quickly when conditions are cold (5–15°C) and humidity >90% for 4–5 days, often when seedlings are in the early vegetative stage. Individual

²⁵ T Bretag, H Richardson, F Henry (2013) Down Mildew of Field Peas. AGNote 0149, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/downy-mildew-of-field-peas>

seedlings become infected and act as foci of infection from which the disease spreads. Rain is the major means of spore dispersal and infection. Heavy dew will promote sporulation. Dry, warm weather is unfavourable for the disease. Systemic infection of plants can lead to the disease developing late in the season if conditions are favourable (Figure 7).

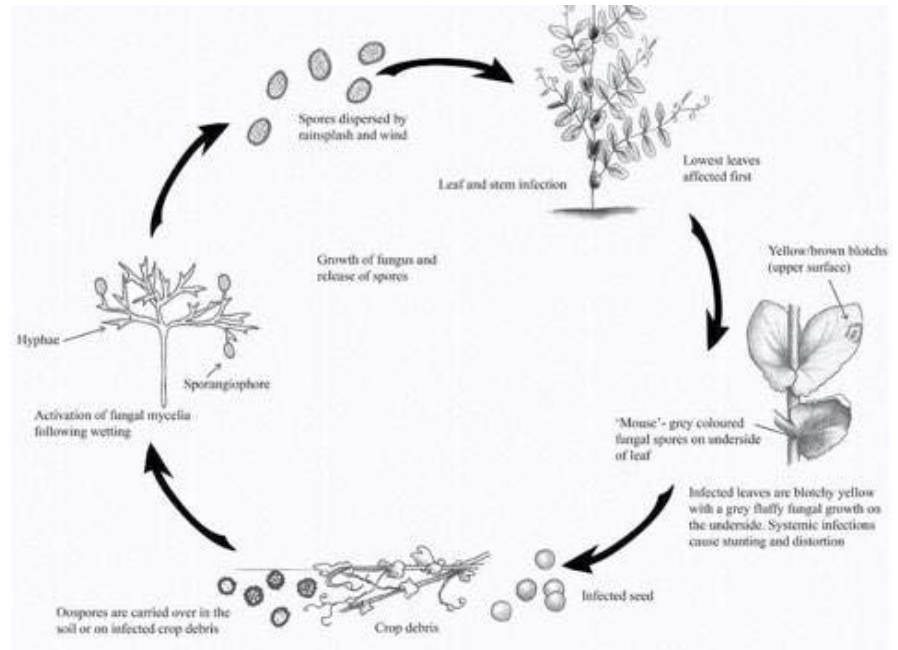


Figure 7: Disease cycle of downy mildew on field pea.

Illustration: Kylie Fowler, DEDJTR

9.15.4 Management options

Varietal selection

Growing a resistant variety is the most effective means of controlling downy mildew in districts prone to this disease. There are two strains of the downy mildew fungus. The Parafield strain, which is considered a non-virulent strain, infects all conventional-type tall field peas such as Parafield and Alma. Whereas the new Kaspas[®] strain is more virulent and can infect both conventional-type, older field pea varieties as well as newer semi-leafless varieties such as Kaspas[®] and PBA Oura[®].

There are no commercial varieties with resistance to both strains of the fungus.²⁶ The resistance of current field pea varieties to both strains of downy mildew is shown in Table 8.

²⁶ G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria, http://www.croppro.com.au/crop_disease_manual.php

Table 8: Reaction of field pea varieties to the strains of downy mildew caused by *Peronospora viciae*.

Variety	Reaction to Parafield strain	Reaction to Kaspas [Ⓛ] strain
Bundi	Resistant	Moderately Susceptible
SW Celine	Susceptible	Susceptible
Excell	Moderately Resistant	Susceptible
Kaspas [Ⓛ]	Moderately Resistant	Susceptible
Maki	Susceptible	Susceptible
Morgan [Ⓛ]	Resistant	Susceptible
PBA Gunyah [Ⓛ]	Resistant	Susceptible
PBA Oura [Ⓛ]	Moderately Resistant	Moderately Susceptible
PBA Percy [Ⓛ]	Susceptible	Susceptible
PBA Twilight [Ⓛ]	Resistant	Susceptible
Parafield	Susceptible	Susceptible
Sturt	Moderately Susceptible	Susceptible
Yarrum	Susceptible	Susceptible

Source: T Bretag, H Richardson, F Henry (2013) Down Mildew of Field Peas. AGNote 0149, Agriculture Victoria. <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/downy-mildew-of-field-peas>

Chemical control

Seed dressing with metalaxyl or oxadixyl (Group 4 systemic phenylamide fungicides) can be effective. Seed treatments reduce the number of seedlings with primary infection, thereby reducing the amount of air-borne spores that cause secondary infection in the surrounding crop. Seed treatments are recommended for districts where downy mildew occurs in most years. Not all fungicide seed dressings have activity against downy mildew. For more information on seed treatments, see Pulse Australia's Pulse Seed Treatments and Foliar Fungicides. http://pulseaus.com.au/storage/app/media/crops/2011_APB-Pulse-seed-treatments-foliar-fungicides.pdf

Crop rotation

Extended crop rotations and destruction of infected pea trash will minimise the risk of serious disease. Extended crop rotations allow spore numbers in the soil to decline before sowing again to field pea. A break of at least 3 years between field pea crops is recommended. Avoid sowing pea crops adjacent to last season's stubble.²⁷

9.16 Powdery mildew of field peas

Powdery mildew, caused by the pathogen *Erysiphe pisi*, can be a serious disease of pea in South Australia and Victoria. Severe infections can significantly reduce yield in susceptible varieties. Powdery mildew is most prevalent late in the season when warm days and cool nights result in dew formation.

Note: Downy mildew is caused by *Peronospora viciae*, a different fungus from that which causes powdery mildew.

9.16.1 Symptoms

Infected plants are covered with a white powdery film. Severely infected foliage turns blue-white in colour; tissue below these infected areas may turn purple (Photos 10 and 11). Symptoms first appear on the upper surfaces of the oldest leaves. Leaves, stems and pods may all become infected, resulting in withering of the whole plant.

²⁷ G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria. http://www.croppro.com.au/crop_disease_manual.php

MORE INFORMATION

CropPro webpage: Downy Mildew of Field Peas
http://www.croppro.com.au/crop_disease_manual/ch07s04.php

Severe pod infection can cause a grey-brown discolouration of the seeds. These seeds have an objectionable flavour that lowers the quality of the grain.²⁸



Photo 10: Typical white powdery mildew growth on an infected plant.

Photo: Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016. Pulse Australia Limited, Figure 7.12



Photo 11: Powdery mildew infects all parts of the plant including pods.

Photo: Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016. Pulse Australia Limited, Figure 7.12

9.16.2 Economic importance

Severe infections can reduce yield by 10–20%. Powdery mildew is most prevalent late in the season.

Crops sown late are more likely to be affected by powdery mildew than early-sown crops. Severe pod infection can lead to poor seed quality.²⁹

²⁸ G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria, http://www.croppro.com.au/crop_disease_manual.php

²⁹ T Bretag, H Richardson, F Henry (2012) Powdery Mildew of Field Peas. AGNote 0147, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/powdery-mildew-of-field-peas>

9.16.3 Disease cycle

The fungus over-winters on infected pea trash and produces spores, which are blown by wind into new crops (Figure 8). Under favourable conditions the disease may completely colonise a plant in 5–6 days and once a few plants become infected it rapidly spreads to adjacent areas.

Warm (15–25°C), humid (>70%) conditions for 4–5 days late in the growing season during flowering and pod-fill are favourable for disease development. Rainfall is not favourable for the disease, as it will actually wash spores off plants. Dewy nights are sufficient for disease development.

The disease may also be seed-borne, but this source of infection appears less important.

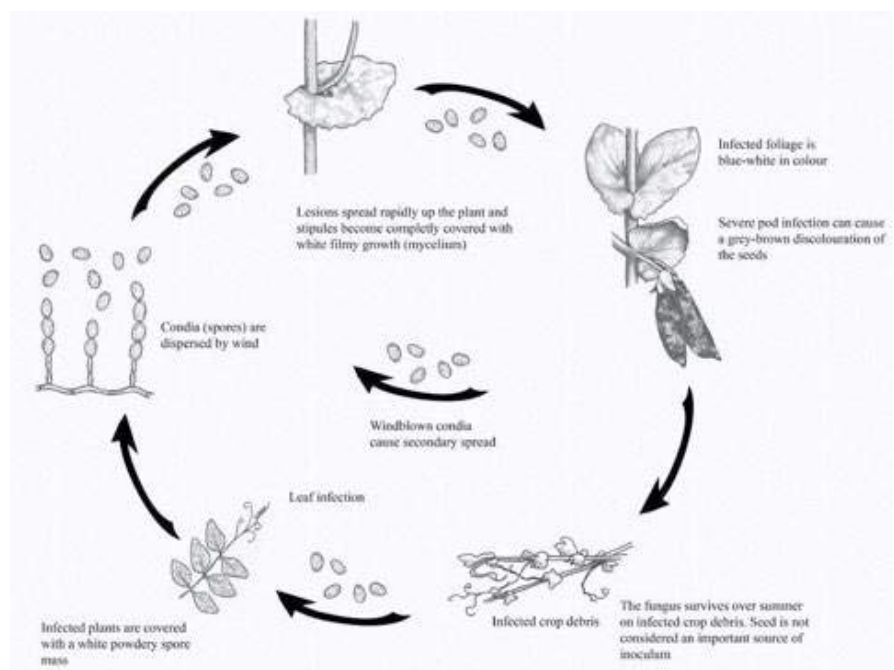


Figure 8: Disease cycle of powdery mildew of field peas.

Illustration: Kylie Fowler, DEDJTR

9.16.4 Management

Varietal selection

Growing a resistant variety is the most effective means of controlling powdery mildew. Maki and Yarrum are the resistant varieties currently available. For further information on disease ratings refer to the Victorian Pulse Disease Guide.

Crop rotation for powdery mildew control

Leave a 4-year break between growing field pea crops in the same paddock. Control volunteer field pea, which can harbour disease. Avoid sowing field pea crops adjacent to last season's stubble. Incorporate or burn infected pea stubble soon after harvest where practicable.

Seed treatment of powdery mildew

Seed treatments can be beneficial and are recommended for districts where powdery mildew frequently occurs. For more information on seed treatments, see Pulse Australia's Pulse Seed Treatments and Foliar Fungicides (http://pulseaus.com.au/storage/app/media/crops/2011_APB-Pulse-seed-treatments-foliar-fungicides.pdf).

i MORE INFORMATION

CropPro webpage: Powdery Mildew of Field Peas
http://www.croppro.com.au/crop_disease_manual/ch07s05.php

Powdery mildew foliar fungicides

Monitor crops from flowering onwards for signs of powdery mildew. If the disease is present the application of a foliar spray may be warranted. Fungicides need to be applied prior to disease development to be most effective. Fungicides for powdery mildew have limited systemic activity and will not protect the new growth following spraying. Good plant coverage with the fungicides is essential. Depending on disease pressure, foliage is protected for about 14 days.

Before using any chemicals check that they are currently registered for use. Refer to Pulse Australia’s Pulse Seed Treatments and Foliar Fungicides for more information on foliar fungicides.³⁰

9.17 Septoria blight of field pea

Septoria blight is caused by the fungus *Septoria pisi*. Septoria blight is a minor disease and appears to have little effect on the yield of most pea varieties. The disease has been particularly noted in NSW but occurs sporadically in Victoria and South Australia. The disease is often seen on old foliage, pods and stems late in the growing season.

9.17.1 Symptoms

Septoria blight of field pea is found mainly on the lower, senescing parts of the plant and the pods. The disease is characterised by yellow blotches on plant tissue, which become necrotic and covered in numerous brown spots. Lesions vary in size, are roughly circular and have no distinct margin. First they appear yellow, later becoming straw-coloured. Several such blotches may join to cover the entire leaf. As the blotches dry out many pinpoint-sized black pycnidia (fungus fruiting bodies) may be seen scattered widely on infected plant parts, including pods, (Photo 12). Diseased tissues may dry off prematurely.³¹



Photo 12: Typical leaf and pod lesions caused by *Septoria* infection. These blotches are brown and angular, containing very small brown to black spots.

Photo: Mary Burrows, Montana State University, www.Bugwood.org, Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016. Pulse Australia Limited, Figure 7.12

30 G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria, http://www.croppro.com.au/crop_disease_manual.php

31 G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria, http://www.croppro.com.au/crop_disease_manual.php

9.17.2 Economic importance

This disease occurs sporadically and seldom causes significant yield losses. However, losses of up to 40% have been reported in some susceptible pea varieties.³²

9.17.3 Disease cycle

The fungus over-winters on infected pea trash and seed. Spores of the fungus are carried by wind from infected trash into the new crop (Figure 9). Infection is found on the lower foliage where the humidity is high following rain or heavy dews. Disease development favours prolonged high humidity (at least 24 hours) and moderately warm temperatures of 21–27°C. Splattering of water assists in spreading the disease within a field. While seed-borne transmission can occur it is less important.

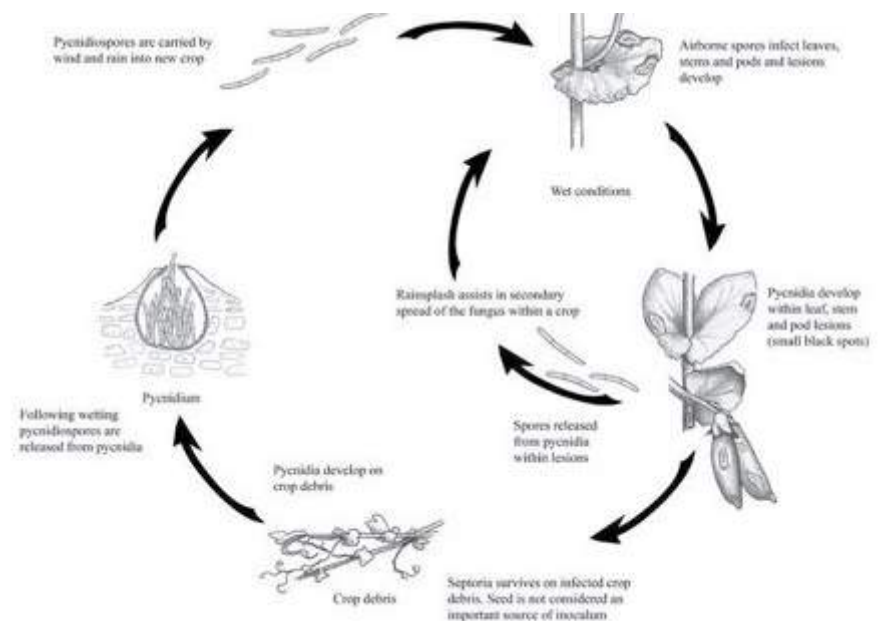


Figure 9: Disease cycle of *Septoria* of field pea.

Illustration: Kylie Fowler, DEDJTR

9.17.4 Management

Septoria can be managed by using an integrated approach that encompasses crop rotation, stubble management and fungicides. The *Septoria* blotch fungus survives in soil and on old pea trash. It is only safe to re-crop an area with pea after all pea debris has decomposed. Destroying pea stubble by grazing, burning and cultivation will help in reducing the pea debris more quickly.³³

i MORE INFORMATION

CropPro webpage: *Septoria* Blight of Field Peas
http://www.croppro.com.au/crop_disease_manual/ch07s06.php

To identify symptoms and management of field pea diseases:

GRDC App Field Peas: The Ute Guide, southern, for android and iOS, found at App Store

³² T Bretag, H Richardson, F Henry (2013) *Septoria* Blotch of Field Pea. AGNote AG1164, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/septoria-blotch-of-field-pea>

³³ G Hollaway, F Henry, M Mclean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Identification and management of field crop diseases in Victoria, http://www.croppro.com.au/crop_disease_manual.php

9.18 Stem nematode

Stem nematode (*Ditylenchus dipsaci*) is a soil-borne pest of pulses, oat and some pasture crops. The oat, lucerne and clover races of this nematode occur in South Australia and Victoria. The oat race infects oat, faba bean, field pea and wild oat, and has also been recorded on canola, lentil and chickpea seedlings. It can also be highly damaging to some horticultural, ornamental and nursery plants.³⁴

9.18.1 Symptoms

Heavy infections cause poor germination and patches of stunted malformed plants. Peas will often turn yellow-green. In many instances the symptoms – leaves curling and showing water-soaked areas – are confused with herbicide damage. Sometimes the stem will die back but this occurs more frequently in bean than in pea crops.³⁵



Photo 13: Stem nematode in field pea causes plants to become severely stunted and distorted.

Photo: Grain Legume Handbook (2008), chapter 7, Plate 7.62

9.18.2 Economic importance

Stem nematode is a soil-borne pest of oat, pulse and some pasture crops. In South Australia and Victoria there are three different races of the nematode: the oat, lucerne and clover races. The oat race infects the cultivated and wild oat, faba bean and field pea and has been recorded on lentil, chickpea and canola seedlings.

Access to some international and domestic markets requires seed to be tested and found free of stem nematode.³⁶

A heavy infestation of this nematode can cause large yield losses, but this has occurred only rarely.

9.18.3 Disease cycle

Stem nematode is spread by infested hay, straw, weeds and other plant material, and as a contaminant of seed. It is transferred in soil by machinery, humans and stock. Stem nematode is highly resistant to desiccation, and can survive in a dehydrated state for many years.

³⁴ Pulse Australia (2016) Southern/western field pea best management practices training course, module 6-2016. Pulse Australia Limited

³⁵ J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

³⁶ Plant Health Australia (2013) Stem nematode fact sheet. Plant Health Australia, <http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf>

i MORE INFORMATION

Plant Health Australia fact sheet: Stem nematode
<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf>

APPS fact sheet: *Ditylenchus dipsaci*
<http://www.appsnet.org/publications/potm/pdf/Mar11.pdf>

It infects above-ground parts of plants and can multiply many times during the growing season. Disease build-up is worse in wetter situations and at temperatures less than 15°C.³⁷

It is more common in high-rainfall areas on clay soil.³⁸

9.18.4 Management options

There are no chemical options for managing nematodes. Hygiene is very important. Do not introduce the nematode onto the farm or into clean paddocks. Test seed for the presence of stem nematode with a SARDI seed test. Do not bring oaten hay or straw from infested areas onto the property.

Rotate with non-host crops such as wheat and barley to reduce nematode numbers. Soil-borne disease risk can be assessed through the SARDI PreDicta® B soil test.

9.19 Root-lesion nematodes (RLN) (*Pratylenchus neglectus* and *P. thornei*)

Field pea is grown as a rotational crop to reduce the population of root-lesion nematodes (RLNs) in the soil.

9.19.1 Symptoms

In the field, symptoms are difficult to detect but RLNs cause stunted growth, uneven patches or waviness across the paddock.

RLNs invade the root tissue, resulting in light browning of the roots or localised deep brown lesions in the root cortex, not the stele. However, these lesions can be difficult to see on roots. The damage to the roots and the appearance of the lesions can be made worse by fungi and bacteria also entering the wounded roots.³⁹

Diagnosis can be difficult and can only be confirmed with a SARDI PreDicta® B test to identify the particular RLN species. PreDicta® B (B = broadacre) is a DNA-based soil-testing service that identifies soil-borne pathogens, including RLN, that pose a significant risk to broadacre crops prior to seeding.

9.19.2 Economic importance

Most field pea cultivars are resistant to *P. thornei* and *P. neglectus*, with minimal yield loss. However, some of the newer cultivars of field pea are moderately susceptible to *P. thornei*. Rotations that include resistant crops will reduce the RLN population in the soil.

RLNs can cause large grain yield losses in susceptible crops such as wheat and chickpea. At least 20% of cropping paddocks in south-eastern Australia have populations of RLNs high enough to reduce yield. The extent of yield loss is directly related to the population density at sowing.

Worldwide, the genus *Pratylenchus* is the second most important group of plant-parasitic nematodes, with more than 90 species of RLN known worldwide. The two main species of RLN in the southern region are *P. neglectus* and *P. thornei*.

P. teres and *P. penetrans* are found in the western region.⁴⁰

More than one RLN species can be found in the roots of an individual crop, although one species usually dominates. Identification is important as different crops have

37 Pulse Australia (2016). Southern/western field pea best management practices training course, module 6-2016 Draft. Pulse Australia Limited
 38 Plant Health Australia (2013) Stem nematode fact sheet. Plant Health Australia, <http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf>
 39 J Thompson, K Owen, T Clewett, J Sheedy, R Reen (2009) Root-lesion nematodes: Management of root-lesion nematodes in the northern grain region, https://www.daf.qld.gov.au/_data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf
 40 G Hollaway (2013) Cereal Root Diseases. Agnote AG0562, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases>

different resistance or susceptibility depending on the *Pratylenchus* type. All species of *Pratylenchus* have a wide host range.⁴¹

9.19.3 Life cycle

Nematodes are small, worm-like organisms less than 1 mm in length that are able to move freely through moist soils and young root tissues. As the females move through plants they feed on the plant roots, causing lesions and depositing eggs.

There may be 3–5 generations of nematodes within a growing season. Nematodes are likely to multiply under a range of host crops, such as wheat and chickpeas. Barley is only moderately susceptible. Many grass weeds and legumes can also host nematodes.

The nematode survives over the summer months in dry soil and root residues to become active again when the winter rains start.

Nematodes will not move great distances unless they are spread by surface water, soil on farm machinery or wind-blown soil in summer.⁴²

9.19.4 Management options

There are no chemical options for managing nematodes. Rotation with resistant crops such as lentil, faba bean, field pea or lupin is the most important management tool for RLN.

Resistant crops reduce the population of nematodes in the soil. Tolerant crops do not reduce the population, but are less vulnerable to damage from nematodes.⁴³

Resistant crop species can reduce nematode populations by up to 50% per year. A 2-year, or longer, break from susceptible crops may be necessary to minimise yield loss if nematode numbers are high.⁴⁴ Resistant varieties of susceptible crop species should be grown in the following years.

With the exception of chickpea, pulses tend to have good resistance to *P. neglectus* and *P. thornei*, so can reduce nematode populations in cropping rotations (Table 10).⁴⁵

Resistant crops may differ in their capacity to host *P. neglectus* or *P. thornei* so tailor rotations to manage the predominant species.⁴⁶ Crops such as field pea and lentil provide some control for *P. thornei*, while faba bean, field pea and lentil provide control for *P. neglectus*.

Controlling volunteer crops and host weeds is also important. Weeds that can host nematodes include wild oat, barley grass, brome grass, wild radish and *Brassica tournefortii*.

Nematode numbers increase where susceptible crops like chickpea and wheat are grown in rotation.

Reducing the nematode population can lead to higher yield in subsequent cereal crops. Yield loss in south-eastern Australia from RLN is lower than in northern Australia.⁴⁷

41 GRDC (2010) Plant parasitic nematodes Fact Sheet. GRDC, Southern and Western Regions, October 2010, <http://www.grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW>

42 Pulse Australia (2016) Southern Faba & Broad Bean – Best Management Practices Training Course, module 6-2016. Pulse Australia Limited

43 GRDC (2010) Plant parasitic nematodes Fact Sheet. GRDC, Southern and Western Regions, October 2010, <http://www.grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW>

44 G Hollaway (2013) Cereal Root Diseases. Agnote AG0562, Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases>

45 GRDC (2010) Plant parasitic nematodes Fact Sheet. GRDC, Southern and Western Regions, October 2010, <http://www.grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW>

46 V Vanstone G Hollaway, G Stirling (2008) Managing nematode pests in the southern and western regions of the Australian cereal industry: continuing progress in a challenging environment. *Australasian Plant Pathology*, 37, 220-234

47 G Hollaway, J Fanning, F Henry and A McKay (2015) Cereal root disease management in Victoria. GRDC Update Papers, 24 February 2015, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Cereal-root-disease-management-in-Victoria>

i MORE INFORMATION

Root-lesion nematodes Tips and Tactics

www.grdc.com.au/TT-RootLesionNematodes

GRDC Fact Sheet: Plant parasitic nematodes

<http://www.grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW>

Soil Quality Fact Sheet: Root lesion nematode

<http://soilquality.org.au/factsheets/root-lesion-nematode>

SARDI website: PreDicta® B testing
http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

VIDEO

Root-lesion nematodes
<https://youtu.be/Ntf08QGXPi0>



VIDEO

How to diagnose Root Lesion Nematode
<https://youtu.be/ttFltE-B4qA>



The simplest way to identify a nematode problem is with a SARDI PreDicta® B soil test (http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b) prior to sowing.

Table 9: Resistance and tolerance of pulses to the major *Pratylenchus* species.

Crop	<i>Pratylenchus neglectus</i>		<i>Pratylenchus thornei</i>	
	Resistance	Tolerance	Resistance	Tolerance
Faba bean	R	–	MR	MI
Chickpea	S - MR*	MI - T*	VS - R*	MI - T*
Field pea	R	–	R	T
Lentil	R	T	R	MT
Vetch				
- Blanchefleur	MR	T	S	I - MI
- Languedoc	MR	T	MS	I - MI
- Morava [†]	MR	T	MS	I - MI

* Chickpea varieties have a range of resistances and tolerances to *Pratylenchus* species.

Source: Pulse Australia (2016)

9.20 Viruses

Field pea crops can be affected by a number of virus diseases (Table 10). Some are seed-borne, but all require aphids to move between plants. Most require a ‘green bridge’ to survive between seasons.

Major viruses that are known to infect field pea in Australia include:

- Cucumber mosaic virus (CMV)
- Alfalfa mosaic virus (AMV)
- Bean yellow mosaic virus (BYMV)
- Pea seed-borne mosaic virus (PSbMV)
- Bean leaf roll virus (BLRV)
- Subterranean clover stunt virus (SCSV)
- Turnip yellows virus (TuYV) (synonym: Beet western yellows virus (BWYV)).

Less common viruses that occur in Australia are:

- Soybean dwarf virus (SBDV) (synonym: Subterranean clover red leaf virus (SCRLV))
- Clover yellow vein virus (CIYVV)
- Tomato spotted wilt virus (TSWV)
- Broad bean wilt virus (BBWV).

9.20.1 How viruses spread

Viruses need aphid vectors to spread from infected to healthy plants. The exception is Tomato spotted wilt virus (TSWV), which is transmitted by specific thrip species. Some viruses such as Pea seed-borne mosaic virus (PSbMV) are introduced by sowing infected seed.

The most important factors that predispose pulse crops to severe virus infection are:

- Infected seed or close proximity to a substantial virus reservoir (e.g. lucerne, summer weeds).
- A wetter than average summer–autumn with green plant material that allows uncontrolled multiplication of aphids during the time when numbers are usually

low. When aphids are present early in the season epidemics are more likely to occur and the level of damage will be higher.⁴⁸

While field pea seed infected with PSbMV may infect seedlings at a rate of 100%, the rate of transmission for faba bean is thought to be much lower (<1%).⁴⁹ Viruses can be classified by the manner in which they are transmitted by insect vectors: persistent or non-persistent.

Persistent transmission

These viruses are ingested by the insect and are passed to healthy plants through saliva. It can take more than a day for these insects to become infectious, but the insect will remain infectious for the rest of its life.

Not all aphid species are vectors of this kind of virus in pulses so the identification of aphid species is very important. The main vectors of persistent viruses are pea, cowpea, cabbage and green peach aphids. Viruses spread by these aphids include TuMV (synonym: BWYV), BLRV and SCSV. Infection will start with random plants and increase as the vectors colonise the crop. Aphids generally only become visible in the crop once they have colonised.

Insecticides that kill aphids can work in suppressing the spread of this type of virus as transmission rates increase dramatically when the aphids fly.

Non-persistent transmission

Aphids transfer non-persistent viruses on their mouth parts directly by carrying the virus from an infected plant to a healthy one. The aphid can only infect one or two more plants at a time. Many aphid species are vectors of this type of virus including ones that do not colonise legumes but just land and probe while searching for their preferred hosts (e.g. oat and turnip aphids). Non-persistent viruses include PSbMV, AMV, CMV and BYMV.

Insecticides are less effective at suppressing this type of virus as they do not act fast enough. They may make the situation worse as the insecticide can agitate aphids and increase virus spread.⁵⁰

48 B Coultts, R Jones, P Umina, J Davidson, G Baker and M Aftab (2015) Beet western yellows virus (synonym: Turnip yellows virus) and green peach aphid in canola. GRDC Updates Paper, 10 February 2015

49 J Davidson, R Kimber, L McMurray, M Lines, J Paull, A Ware and K Hobson (2014) Diseases in pulse crops during 2013. GRDC Update Papers, 25 February 2014, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Diseases-in-pulse-crops-during-2013>

50 Pulse Australia (2016) Southern/western field pea best management practices training course, module 6-2016 Draft. Pulse Australia Limited

Table 10: Virus categories and general symptoms.

Virus	Aphid transmission	Seed transmission*	Visual symptom type	Visual symptoms	Virus type (genus)
AMV	Non-persistent	Yes	Shoot tip	Necrotic or chlorotic local lesions, sometimes mosaics that do not necessarily persist.	alfamovirus
BBWV	Non-persistent	No	Mosaic, shoot tip	Vein clearing, mottling and necrosis of shoot apex, plant wilts, mottled, malformed and stunted.	fabavirus
BLRV	Persistent	No	Top yellowing	Upward leaf-rolling accompanied by interveinal yellowing of older leaves and flowers abscised.	luteovirus
TuYV/BWYV	Persistent	No	Top yellowing	Interveinal yellowing of the older or intermediate leaves. Mild chlorotic spotting, yellowing, thickening and brittleness of older leaves.	luteovirus
BYMV	Non-persistent	Yes	Mosaic	Transient vein chlorosis followed by obvious green or yellow mosaic. Usually no leaf distortion.	potyvirus
CMV	Non-persistent	Yes	Shoot tip	Mosaics, stunting and possibly some chlorosis.	cucumovirus
CIYVV	Non-persistent	No	Shoot tip, mosaic	Mosaics, mottles or streaks, vein yellowing or netting.	potyvirus
PSbMV	Non-persistent	Yes	Mosaic	Systemic dark and light-green zonal leaf mottle, slight to moderate downward rolling of leaf margins. Distortions of leaf shape associated with mottle patterns. Seed markings.	potyvirus
SCRLV	Persistent	No	Top yellowing	Mild yellowing, stunting and reddening.	luteovirus
SCSV	Persistent	No	Top yellowing	Top yellows, tip yellows or leaf roll. Leaf size reduced, petioles and internodes shortened.	nanavirus
TSWV	Persistent	No	Shoot tip, mosaic	Necrotic and chlorotic local lesions, mosaic, mottling, leaf shape malformation, vein yellowing, ringspots, line patterns, yellow netting and flower colour-breaking.	tosspovirus

* Seed transmission in field pea is minimal for most viruses except PSbMV, but of no epidemiological significance. However, it is important for quarantine to keep foreign virus strains out of Australia
Source: Pulse Australia (2016).

In 2014, a year where TuYV (synonym: BWYV) was widespread in canola crops across SA, Victoria and NSW, the South Australian Research and Development Institute (SARDI) found relatively low virus infection rates in field pea in SA and it was only detected at a high infection rate in one crop in SA late in the season ([Table 11](#)).

Table 11: Results of virus testing in South Australia in 2014.

Crop type	Number of crops or trials tested	Test period	Number of crops with positive virus tests (average % infection rate in brackets)					
			TuMV (syn. BWYV)	PSbMV	CMV	AMV	BLRV	BYMV
Field pea	9	Jul–Aug	8 (20.1%)	7 (6.1%)	1 (2%)	0	0	0
	6	Sep–Oct	4 (3%)	4 (20.5%)	0	0	0	0

Source: J Davidson, R Kimber, L McMurray, M Lines, J Paul, A Ware and K Hobson (2014) Diseases in pulse crops during 2013. GRDC Update Papers, 25 February 2014, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Diseases-in-pulse-crops-during-2013>

9.20.2 Symptoms

It can be difficult to distinguish plant disease symptoms caused by viruses in pea plants, as viral foliage symptoms are often similar to those caused by nutritional deficiencies, herbicide damage or waterlogging.⁵¹

Paddock symptoms

Seed-borne virus infection causes stunted plants that are scattered throughout the crop and act as foci for virus spread by aphids.

When the virus source is external to the crop, plants often become infected first in greatest numbers close to the paddocks edges or around thin or bare areas, particularly on the paddock’s windward side.

Pea seed-borne mosaic virus (PSbMV)

PSbMV is the only seed-borne virus of importance in field pea in Australia. It is non-persistently aphid-borne. Plant symptoms are usually very mild and difficult to detect:

- plants may be infected without showing symptoms;
- margins of young leaves roll downwards, there is mild chlorosis and mosaics, mild vein clearing may develop (Photo 14);
- terminal leaves are often reduced in size and tendrils excessively curled;
- infection at later growth stages may result in top leaves turning pale; and
- infected plants may also produce distorted flowers, which give rise to small distorted pods and fewer seeds. The seed coats may split as the seeds mature, and dark brown rings and tan spots develop.

51 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC Ground Cover Direct



Photo 14: Mild chlorosis, mosaic vein clearings, excessive curled tendrils on field pea infected with PSbMV.

Photo: Rohan Prince, DPIRD (formerly WADA)



Photo 15: Brown rings, tan spots and cracking of seed indicate PSbMV.

Photo: Trevor Bretag, DEDJTR

Alfalfa mosaic virus (AMV), Bean yellow mosaic virus (BYMV) and Cucumber mosaic virus (CMV)

These viruses are generally of minor economic importance. They are non-persistently aphid-borne and develop low rates of seed transmission in peas. General symptoms can include mosaic mottling and yellowing.

Alfalfa mosaic virus (AMV)

- Chlorosis and necrosis of new shoots. Necrotic spots or streaking of older leaves.
- Pods may be malformed and fail to develop seed.

Bean yellow mosaic virus (BYMV)

- Variable symptoms, but plants sometimes become infected while symptomless.
- When foliage symptoms develop, these consist of vein clearing and mottles and mosaics especially on young leaves.
- Necrosis sometimes develops in stems and veins.

Cucumber mosaic virus (CMV)

- Foliage symptoms are mild and difficult to observe.
- Possible leaf chlorosis and slight stunting (Photo 16).⁵²



Photo 16: CMV-infected pea plant (right) and healthy plant (left).

Photo: Crop Pro, Field pea viruses, http://www.croppro.com.au/crop_disease_manual/ch10s04.php

Turnip yellows virus (TuYV) (synonym: Beet western yellows virus (BWYV))

TuMV (synonym: BWYV) is persistently aphid-borne; no seed transmission. Symptoms include stunting and yellowing of plants (Photo 17).



Photo 17: TuMV (synonym: BWYV) infected field pea plant (right) and healthy plant (left).

Photo: Crop Pro, Field pea viruses, http://www.croppro.com.au/crop_disease_manual/ch10s04.php

⁵² B Coutts (2015) Diagnosing virus damage in field peas. Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/mycrop/diagnosing-virus-damage-field-peas>

Bean leaf roll virus (BLRV)

BLRV is persistently aphid-borne; no seed transmission. Symptoms include stunting and yellowing of plants. BLRV is the most important virus in northern field pea areas (Photos 18 and 19).



Photo 18: The three plants on the right are stunted and yellow from Bean leaf roll virus infection.

Photo: Grain Legume Handbook (2008), Grain Legume Handbook or Field Peas: The Ute Guide page 38



Photo 19: Premature death of field pea lines infected with Bean leaf roll virus.

Photo: M Schwinghamer, NSW DPI, Field Peas: The Ute Guide page 38

9.20.3 Economic importance

Viruses are not considered a major problem of field pea in the southern region, but should not be ignored (Table 13). Infection can reduce yield and seed quality.⁵³

Table 12: Incidence and field pea crop area affected by virus.

Virus	Incidence (%)	Area of crop (%)
Alfalfa mosaic virus	5.6	0.3
Bean leaf roll virus	17.1	8.8
Bean yellow mosaic virus	8.8	8.3
Beet western yellows virus	12.5	9.7
Cucumber mosaic virus	8.8	8.8
Pea seed-borne mosaic virus	49.4	34.2

Incidence as a proportion of years when the disease occurs and area as a percentage of crop area affected when the disease develops. Source: Murray and Brennan (2012)

Many field pea crops surveyed in Australia had Pea seed-borne mosaic virus (PSbMV) present, which is a seed-transmitted virus that can occasionally express as a major problem.

Other viruses like Bean leaf roll virus (BLRV) and Turnip yellows virus (TuYV) (synonym: Beet western yellows virus (BWYV)) have also been detected, but are not seed-transmitted.

In unique cases where field pea crops have experienced heavy losses from viral infection, it has been in association with prolonged, high levels of aphids that arrived early.⁵⁴

9.20.4 Disease cycle

Aphids bring the viruses into field pea crops from surrounding plants, mostly legumes (like lucerne or clovers). Some viruses, like TuMv (syn. BWYV), AMV, CMV, BYMV and TSWV, have a host range that includes non-legume species. Hence other plant species (e.g. sowthistle, turnip weed) can act as a virus source at the start of the season.

CMV and AMV are non-persistently transmitted by a range of aphid species including lucerne blue green aphid (*Acyrtosiphon kondoi*), cowpea aphid (*Aphis craccivora*), foxglove aphid (*Aulacorthum solani*), ornate aphid (*Myzus ornatus*) and green peach aphid (*Myzus persicae*). The luteoviruses are persistently aphid-transmitted, but are more vector specific. Correct identification of the aphid is important for effective management.

TSWV is spread by thrips.

Probing and feeding needs to be prolonged for persistently transmitted viruses (0.1–4.0 hours for luteoviruses), but only needs to be brief for non-persistently transmitted viruses. Eventually aphids colonise the field pea plant and become very visible in the crop.

Crop loss depends on the growth stage at infection and the number of plants infected. Early and widespread infections lead to the greatest losses.⁵⁵

Aphid activity is influenced by seasonal conditions and will require early monitoring in nearby crops and pastures. See [Section 8.6 Aphids and viruses](#) for more information on monitoring and managing aphids.

53 K Perry, P Mangano, P Umina, A Freeman, R Jones, W Hawthorne, J Davidson (2010) Aphids and viruses in pulse crops Fact Sheet. GRDC, Western and Southern regions, July 2010. <http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses>

54 W Hawthorne, J Davidson, L McMurray, E Armstrong, B McLeod, H Richardson (2012) Field Pea Disease Management Strategy, Southern & Western Region. Australian Pulse Bulletin, No. 6. http://www.pulseaus.com.au/storage/app/media/crops/2012_APB-Fieldpea-disease-management-South-West.pdf

55 K Perry, P Mangano, P Umina, A Freeman, R Jones, W Hawthorne, J Davidson (2010) Aphids and viruses in pulse crops Fact Sheet. GRDC, Western and Southern regions, July 2010. <http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses>

i MORE INFORMATION

GRDC Fact Sheet: Aphids and viruses in pulse crops

<http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses>

Pulse Australia webpage: Managing viruses in pulses

<http://pulseaus.com.au/growing-pulses/publications/manage-viruses>

Agriculture Victoria webpage:

Managing viruses in pulse crops

<http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/managing-viruses-in-pulse-crops>

9.20.5 Control

There are no proven methods for controlling viruses. Breeding resistant varieties is the most economical and sustainable way to control viruses.

Virus management in pulses aims at prevention through integrated pest management (IPM) that involves controlling the virus source, aphid populations and minimising virus transmission into and within the pulse crop.

While a large population of aphids is required to inflict feeding damage, virus transmission can occur before aphids are seen to be present. Pre-emptive management is required.

Management options at the planning stage are:

- Suppress the virus source within the crop by purchasing virus-tested seed. Only retain seed from crops with no visible symptoms.
- Grade out smaller grain, which is more likely to be infected. PSbMV, CMV, BYMV and AMV survive through seed transmission. A threshold of 0.1% seed infection is recommended for sowing in high-risk areas, and <0.5% for low-risk areas.
- Distance crops from lucerne, weeds or other species that act as a reservoir for viruses, diseases and aphids.
- Control volunteer weeds and self-sown pulses that are a ‘green bridge’ host for viruses and a refuge for aphids and their multiplication during summer and autumn.
- Rotate pulse crops with cereals to reduce virus and vector sources (aphids or other insects) and where possible avoid close proximity to perennial pastures (e.g. lucerne) or other crops that host viruses and aphid vectors.⁵⁶

Management options at sowing and in-crop:

- Suppress the virus source within the crop. Sow seed with <0.1% seed infection.
- Use a seed treatment like Gaucho 350SD® (imidacloprid) or Cruiser Opti® (thiamethoxam), which are registered for early aphid protection to control persistently transmitted viruses.
- Retain cereal stubble as aphids are less likely to land in stubble.
- Sow at recommended times to avoid autumn aphid flights.
- Sow at recommended plant densities to achieve early closure of the crop canopy. Closed canopies deter aphids.
- Note that high seeding rates and narrow row spacing to provide early canopy closure assists in aphid control, but conflicts with management of fungal diseases.
- Manage crops to minimise seedling stress through disease, herbicide damage and poor nutrition. Stressed crops are more attractive to aphids.
- Insecticides after emergence may be effective for persistently transmitted viruses. However, they may not be effective for non-persistently transmitted viruses as the insecticide can agitate aphids and increase virus spread.
- Monitor field pea and nearby crops and pastures for aphids. Be prepared to use insecticide when there may be localised flights.
- Consider the effect of insecticide on beneficial insects.

Growers should only consider applying insecticide to control aphids and prevent the spread of viruses 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.⁵⁷

56 K Perry, P Mangano, P Umina, A Freeman, R Jones, W Hawthorne, J Davidson (2010) Aphids and viruses in pulse crops Fact Sheet. GRDC, Western and Southern regions, July 2010, <http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses>

57 W Hawthorne, J Davidson, L McMurray, E Armstrong, B McLeod, H Richardson (2012) Field Pea Disease Management Strategy, Southern & Western Region. Australian Pulse Bulletin, No. 6, http://www.pulseaus.com.au/storage/app/media/crops/2012_APB-Fieldpea-disease-management-South-West.pdf

i MORE INFORMATION

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

DPIRD webpage:
<https://www.agric.wa.gov.au/plant-biosecurity/ddls-seed-testing-and-certification-services>

TASAG webpage:
<http://dpiwve.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories>

Agrifood Technology webpage:
<http://www.agrifood.com.au/index.php/services/food-safety>

For more information, please see:
Section 3.5.2 Seed testing for disease

9.20.6 Virus testing

Diagnostic testing is available for plant viruses. Only some tests can be performed with relative ease in the field. Current testing options may not detect the less common viruses.

Detection of virus in 1 or 2 plants is not proof that the virus is causing a problem. It is important to check for a range of viruses, as the one detected by a test may not be the virus actually causing symptoms.

Detection of a seed-borne virus does not mean there will be virus present in progeny seed. Seed samples from the crop require testing to determine if seed infection has occurred.

Serological testing for viruses is available through DDLS Seed Testing and Certification (formerly AGWEST Plant Laboratories), TASAG ELISA and pathogen testing service or Agrifood Technology.

TASAG also sell Agdia Immunostrips test kits. A result can be obtained in minutes.

DPIRD Diagnostic Laboratory Services (DDLS) Seed Testing and Certification

DDLS conduct seed tests for CMV.

Department of Agriculture and Food
Reply Paid 83377
3 Baron Hay Court
South Perth, WA 6151

Ph: 08 9368 3721
Email: DDLS-STAC@agric.wa.gov.au
<https://www.agric.wa.gov.au/plant-biosecurity/ddls-seed-testing-and-certification-services>

TASAG

TASAG offer in-house virus testing of plants or seed and test kits that can be used in the field (Agdia Immunostrips test kits, US website www.agdia.com).

Contact: Peter Cross

New Town Laboratories
13 St John's Ave
New Town, Tasmania, 7008

Ph: 03 6165 3252
Email: peter.cross@dpiwve.tas.gov.au
<http://dpiwve.tas.gov.au/biosecurity/plant-biosecurity/plant-health-laboratories/tasag-elisa-testing>

Agrifood Technology

Agrifood conduct testing for CMV and AMV.

Contact: Robert Rantino or Doreen Fernandez

260 Princes Highway,
Werribee, VIC 3030, Australia

Postal: PO Box 728,
Werribee, VIC 3030, Australia

Phone: 1800 801 312
<http://www.agrifood.com.au/index.php/services/food-safety>

9.21 Research of interest

J Davidson, C Wilmshurst, E Scott & M Salam (2013). Relationship between ascochyta blight on field pea (*Pisum sativum*) and spore release patterns of *Didymella pinodes* and other causal agents of ascochyta blight.

Pre-harvest treatments

Key points

- Desiccation is a practice applied to field pea crops that assists with the production of high-quality seed and planning around harvest.
- Desiccation is used to aid in uniform ripening of the crop and to kill green weeds.
- Desiccation enables a more timed harvest; generally an earlier harvest.
- Do not use glyphosate to desiccate field pea crops if the seed is to be retained for seeding production or for sprouting.
- Timing of desiccation is more critical than the rate of application of the desiccant.
- Crop-topping is a form of desiccation based on the weed stages of development to prevent weed seedset.
- Windrowing of field pea is possible, with some success using wider swathes into bulkier windrows.

i MORE INFORMATION

GRDC Fact Sheet: Pre-harvest herbicide use
www.grdc.com.au/GRDC-FS-PreHarvestHerbicide

Pulse Australia: Desiccation and croptopping in pulses
<http://pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping>

NSW DPI Desiccation and Harvest of field pea
http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/157099/pulse-point-05.pdf

Purpose

Pre-harvest treatments to assist with harvest and weed management include:

- Desiccation – herbicide is applied to a mature crop to remove moisture from the crop and any green weeds to enable an earlier harvest. Field pea is well suited to desiccation and it is a common practice.
- Crop-topping – herbicide is applied specifically to reduce weed seedset with minimal damage to the crop. Early-maturing varieties aid to this success.
- Windrowing – cutting the crop to assist with direct heading, uneven crop maturity or weed seed management.
- Weed wiping – herbicide is applied to weeds that project above the crop canopy.¹ It is successfully used in field pea to prevent seedset of ryegrass and other tall weeds that stand above the crop. Consider height of pea when choosing the variety.²

Desiccation and windrowing are primarily used to enable earlier harvest and to dry out green weeds. Timing is based on the maturity of the crop.

Crop-topping is primarily used to minimise weed seedset and is based on the maturity of the target weed. It is essential to ensure that the crop is mature enough so that the seed is not damaged.

Desiccation and crop-topping can reduce seed viability, depending on the timing and product used. They are not recommended for crops intended to be saved for seed.³

10.1 Desiccation

Desiccation is the chemical termination of plant growth at the stage when all growth functions have been completed. At this stage, seed size and yield have been set. In field pea, research has shown this occurs when seed moisture content drops to around 30% (Figure 1).

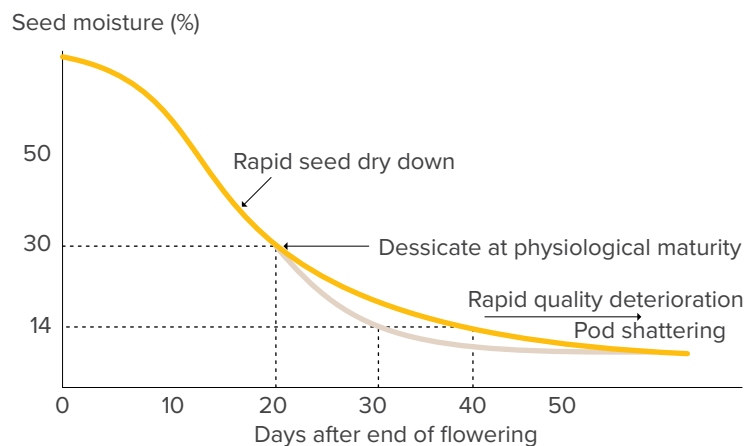


Figure 1: Dry-down pattern of field pea seeds with and without desiccation.

Source: E Armstrong, D Carpenter (1999) Desiccation & harvest of field peas. Pulse Point 5, Second Edition, NSW Agriculture, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/157099/pulse-point-05.pdf

Desiccation of field pea crops prior to harvest can improve timeliness of harvest, maintain grain quality, and reduce soil and trash contamination of the sample. In addition, crop maturity can be advanced by 7–14 days. Harvest problems caused by late weed growth or irregular ripening and yield losses from potential shattering, wet

1 Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited
 2 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>
 3 Pulse Australia (2016) Pulses: Desiccation and croptopping. Pulse Australia website, <http://pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping>

weather delays or hail damage can be minimised with desiccation. High seed quality is also maintained, with less damage from late insect attack or disease blemishes.

In seasons with hot dry finishes, the crop naturally matures quickly and evenly, and the benefits of desiccation can be greatly reduced. Producers need to assess their own circumstances to determine if desiccation will provide financial and managerial benefits.⁴

Desiccation also acts as the first of the summer fallow sprays and can help ease the workload in an already busy harvest period. This spray can also be used as a tool in herbicide-resistance management. Ryegrass plants are often not mature when field pea is ready to desiccate, and as such the application can act as a ‘spray-topping’ tool to reduce seedset of potentially resistant ryegrass.

10.1.1 Seed and pod development

Pod and seed maturation is very staggered up each podded branch and between branches. Immature seeds are in the top one-third to one-quarter of the canopy. Maturity time is generally more compressed and of shorter duration than flowering due to the effects of higher temperatures and varying degrees of moisture stress on the plant.

One of the challengers to growers is how to optimise the timing of the desiccant spray when there are various stages of seed maturity present on individual plants, as well as variation across the paddock.

This can be further compounded by soil type variation or irregular land surface, with alternating mounds and depressions/hollows (micro-relief) commonly referred to as ‘crab hole’ country. These soil mounds or depressions (‘crab holes’) can further add to the problem of uneven crop maturity.

Often, inspection of crops nearing desiccation reveals that while the lower pods have dried to below 15% seed moisture (seeds detached from pod), the upper 25% of pods on each fruiting branch are still at 30–40% moisture content and at varying stages of approaching physiological maturity.⁵

Estimating average seed moisture content (ASMC)

ASMC can be ascertained in a number of ways:

- Pick 10–20 stems at random and sub-sample sufficient seed to fill a moisture meter, which works well for harvest samples but is not very accurate with high moisture samples.
- Pick 10–20 stems at random and sample all the seed, weigh the wet sample and then desiccate/dry until constant weight.

$$\text{ASMC (\%)} = 100 \times (\text{wet weight} - \text{dry weight}) / \text{wet weight}.$$

Alternatively, the appearance (colour, opacity) or texture of the pods, the seed or whole plants (e.g. percent maturity) may be used to estimate the correct timing of these operations (Figure 2 and Figure 3).⁶

4 S Moore, G Cummings, L Jenkins, J Gentry (2010) Northern Region Field Pea Management Guide. Pulse Australia Ltd, http://porkrc.com.au/Field_Pea_Production_Guide.pdf

5 Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited

6 M Seymour (2016) A visual guide to key stages in the growth and maturity of field pea. <https://www.agric.wa.gov.au/field-peas/visual-guide-key-stages-growth-and-maturity-field-pea>

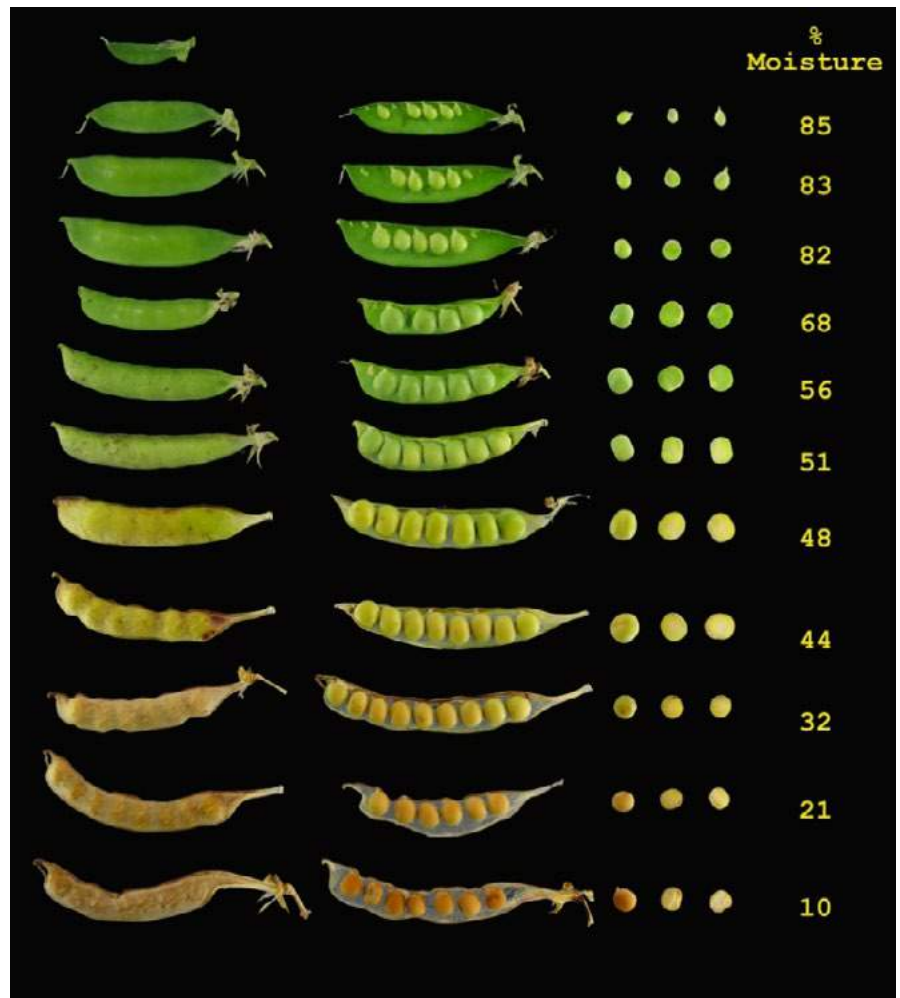


Figure 2: Seed colour can be used to estimate the seed moisture content (SMC) of field pea. Texture can also be used: >80% SMC, the seed is small, watery and easily squashed; at 40–80% SMC, the seed is easily split with fingernail pressure; at 25–40% SMC, the seed rapidly dries down and is firm but the seed dents with fingernail pressure and will split with increasing force.

Source: DPIRD, <https://www.agric.wa.gov.au/field-peas/visual-guide-key-stages-growth-and-maturity-field-pea>

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FEEDBACK

29th November	2nd December	7th December	12th December	15th December	20th December
10% Maturity 0% Brown pods	25% Maturity 20% Brown pods	75% Maturity 50% Brown pods	90% Maturity 75% Brown pods	95% Maturity 100% Brown Pods	100% Maturity 100% Brown pods
60% ASMC	50% ASMC	35% ASMC	27% ASMC	18% ASMC	7% ASMC

Figure 3: Appearance of crop, pods and seed at a range of seed moisture contents, Boyup Brook, WA 2005.

Source: DPIRD, <https://agric.wa.gov.au/n/369>

10.1.2 Timing of desiccation

The optimal stage to desiccate the crop is when the vast majority of seeds have reached full physiological maturity.

A good starting point to estimate the correct timing of desiccation is to record the end of flowering. Wait a further 20 days, then start closely monitoring the crop as maturity approaches.

1. Visibly assess pod colour and development changes. Desiccate when the lower three-quarters of pods along the stem are brown, the seeds are firm, rubbery and split rather than squash when squeezed, and the shells are thin and leathery. Field pea pods mature from the lowest flowering node upwards. Many plants at this stage may still have green tips.
2. Monitor seed moisture changes. Desiccate when seed moisture drops to around 30%. To collect seed for this, randomly pick 10–20 stems or more across the paddock (Figure 4).

Desiccating dun and white field pea

Cotyledons (splits) of these types gradually change in color from green to yellow during ripening. Desiccating these types too early can result in an unacceptable proportion of small green seeds in the harvest sample. Therefore, wait until at least 50% or more seeds have turned yellow before desiccating.

Desiccating blue peas

Cotyledons of this type remain green during the ripening process, but if left too long after ripening, tend to bleach into a mottled yellow/green color. This is termed 'blonding' and can lead to rejection. Therefore, it is safer and more desirable to desiccate these types even earlier than white types to preserve this rich green cotyledon color. Cooling during prolonged storage will also help maintain the intensity of this green colour.

Desiccants should be applied using ground equipment. If conducted at the correct crop stage and when the crop is damp with dew, little or no damage results.

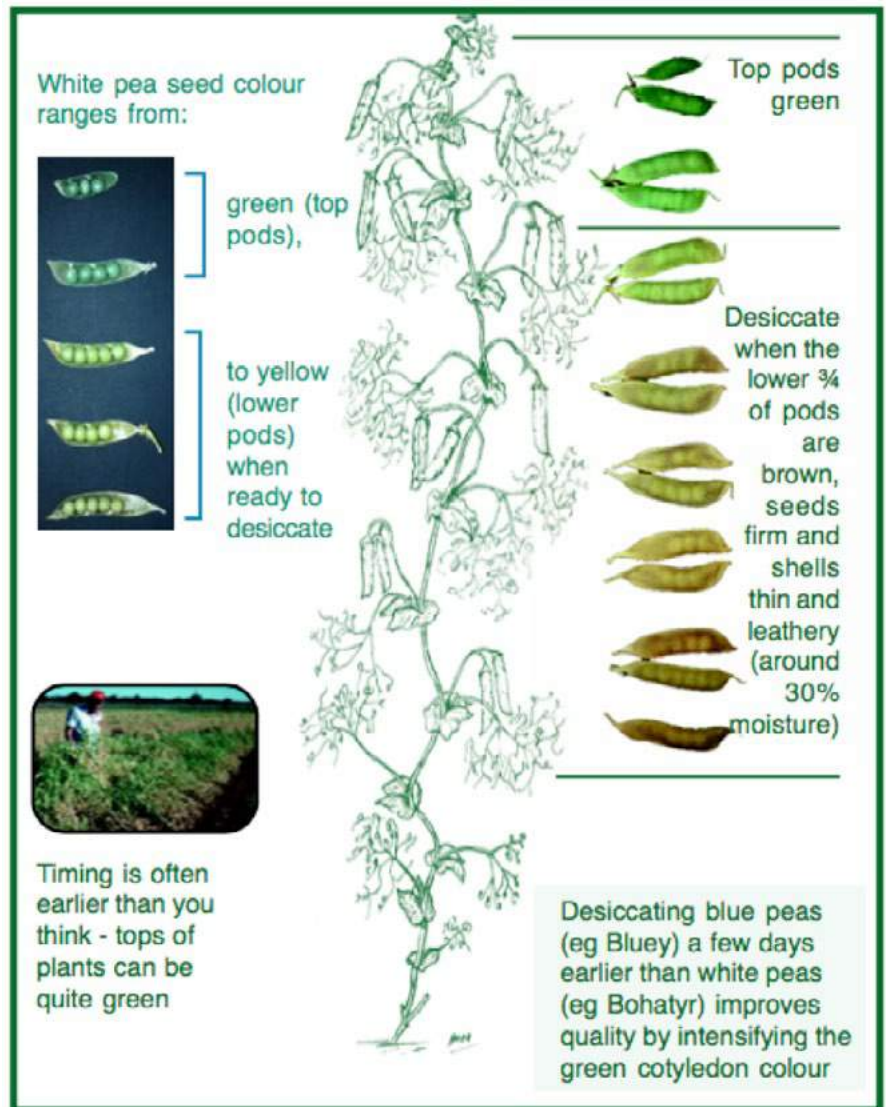


Figure 4: Guide to the timing of field pea desiccation.

Source: E Armstrong, D Carpenter (1999) Desiccation & harvest of field peas. Pulse Point 5, Second Edition, NSW Agriculture, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/157099/pulse-point-05.pdf

10.1.3 Products registered for the pre-harvest desiccation of field pea

Both glyphosate 540 g/L (e.g. Roundup PowerMAX®) and diquat 200 g/L (e.g. Reglone®) are registered for desiccation of field pea (Table 1). Do not use glyphosate to desiccate or crop-top field pea destined for seed or sprouting markets because it can affect the germination percentage of normal seedlings.

The reason for desiccation will determine product choice. For example some crops may require the removal of green material to reduce moisture content in the sample (e.g. glyphosate). In other crops a very quick desiccation will speed up maturity as a harvest aid (e.g. diquat).

Seed to be used for planting or sprouting should not be desiccated with glyphosate.⁷

Table 1: Registered products for desiccating field pea. Refer to current product label for full directions.

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 Ultra Max® (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.

* WARNING DO NOT use glyphosate to desiccate field pea that are to be used for seed or sprouting as germination is affected.
Source: Extract from Reglone® & Roundup Ultra Max® product labels

10.2 Crop-topping

Crop-topping is a form of desiccation; however, its timing is based on the weed stages of development (weed seedset) rather than the field peas' growth stage. This means that the field pea crop can be compromised if crop-topping is implemented too early. Product rates used to crop-top differ from those used to desiccate the crop.

Timing of crop-topping in field pea works very well in early-maturing varieties, e.g. PBA Gonyah[†], PBA Twilight[†] and PBA Wharton[†]. Timing of crop-topping can however be marginal in some years in other field pea varieties that are later maturing, e.g. Morgan[†]. Crop-topping is generally not always possible in those later varieties because they can be too late in maturing relative to the ryegrass in a lengthy growing season.

Crop-topping of field pea too early can result in discolored seed coat or cotyledons (kernel) and either rejection at delivery or severe downgrading. Even in other pulses, growers have to be aware of grain quality defects if crop-topping occurs earlier than the optimal crop desiccation or windrowing stage.⁸

⁷ S Moore, G Cummings, L Jenkins, J Gentry (2010) Northern Region Field Pea Management Guide. Pulse Australia Ltd, https://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

⁸ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

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Crop topping trials in SA in 2008 and 2009 (Lines and McMurray) and in Victoria in 2012 (Brand and vanderMark) demonstrate that variety, time of sowing and dry spring conditions can have an impact on whether crop topping is a useful technique to target the weed of concern and whether yields are reduced by applying this technique.

Other techniques such as brown manuring maybe a suitable option where weed control, particularly herbicide resistance is an issue, and in boosting soil nitrogen reserves.

See GRDC Fact sheet on Manuring pulse crops
<https://grdc.com.au/resources-and-publications/all-publications/factsheets/2013/09/manuring-of-pulse-crops>



Photo 1: Desiccating green weeds in field pea.

Photo: GRDC (2010), Late season herbicide use Fact Sheet found at this link http://www.goodfoodworld.com/wp-content/uploads/2015/02/GRDC_LateSeasonHerbicideUse_FS.pdf

10.2.1 Field trial

Southern Farming Systems and Victorian Department of Primary Industries trial data 2012: faba bean and field pea varieties and management Westmere, Victoria

Key message: Early sowing, concurrent with previous research, was highest yielding in 2012. There appear to be several promising new varieties available for southern Victoria, offering a range of grain types and forage options, associated with excellent yield potential. **Crop-topping results highlight the importance of growers and advisers being aware of both weed and crop growth stages, otherwise significant grain yield loss could occur.**

Seasonal conditions at Westmere were excellent for pulse production, with adequate rainfall and few high or low temperature events that impacted on yield. Grain yields ranged from 2.3 t/ha for PBA Hayman[®] sown 4 July to 5.0 t/ha for Kaspas[®] sown 9 May.

See summary of trial below or full details: <http://www.farmtrials.com.au/trial/16030>

Westmere trial data 2012

Aim

The field trial at Westmere 2012 aimed to investigate the adaptability of a range of field pea varieties to varying sowing dates, crop-topping and disease control.

Treatments

Varieties: Kaspas[®], PBA Oura[®], PBA Hayman[®], Morgan[®], PBA Pearl[®], OZP0805, OZP1103, OZP1101.

Sowing dates: 9 May (early), 6 June (mid), 4 July (late).

Crop-topping: mid – applied at ryegrass milky dough.

Disease control: fortnightly – chlorothalonil 500 @ 2 L/ha applied fortnightly starting 6 weeks after emergence; early – mancozeb @ 2 kg applied at 9 Node + early flower

Other details

Stubble: cultivated

Row spacing: 20 cm

Fertiliser: MAP @ 60 kg/ha at sowing

Plant density: 35 plants/m²

A summary for each of the agronomic treatments is outlined below.

- **Disease management** – there was no impact of disease management in field peas for 2012.
- **Sowing dates** – as there was no impact of disease management, data for sowing dates has been averaged across all disease management treatments (but excludes the crop-topping treatment (Table 2)). Generally, the early (9 May) and mid (6 June) sowing dates had similar yields, while the later sowing date

(4 July) was 30% lower yielding (Table 1). However, there were some varietal differences to this trend. PBA Hayman[®] showed a slight yield increase at the mid sowing date and no yield loss at the last sowing date. OZP1103 generally showed lower yield loss with delayed sowing compared with all varieties except PBA Hayman[®]. Conversely, PBA Oura[®] appeared to show the greatest yield loss between the early, mid and late sowing times. Comparing the overall yield of varieties, Kaska[®] and OZP0805 were highest and PBA Hayman[®] lowest (Table 2).

- **Crop-topping** – yield loss from crop-topping in 2012 ranged from 5–65% (Table 3). Generally, the yield reductions were least at the latest sowing date and highest at the early sowing date. PBA Hayman[®] showed the greatest yield loss with the crop-topping treatment at all sowing dates, while there was little difference between other varieties at the early and mid-sowing dates. At the latest sowing date, OZP1101 and OZP1103 appeared to show the least yield loss (Table 3).

Table 2: Effect of sowing date on grain yield (t/ha) of field pea varieties grown at Westmere, Victoria, in 2012.

Variety	9 May	6 June	4 July	Mean (t/ha)
OZP0805	4.89	4.73	3.54	4.39
Kaska [®]	4.98	4.72	3.38	4.36
OZP1103	4.55	4.54	3.73	4.27
OZP1101	4.80	4.76	3.03	4.20
PBA Pearl [®]	4.54	4.25	2.84	3.88
Morgan [®]	4.50	4.06	2.94	3.84
PBA Oura [®]	4.69	4.06	2.74	3.83
PBA Hayman [®]	2.44	2.91	2.28	2.54
Mean (t/ha)	4.42	4.25	3.06	3.91

Source: www.farmtrials.com.au/trial/16030

Table 3: Grain yield reduction (%) from crop-topping treatment applied to new field pea varieties sown at three dates at Westmere, Victoria, in 2012.

Variety	9 May	6 June	4 July	Mean (%)
OZP0805	26	42	16	28
Kaska [®]	25	32	21	26
OZP1103	34	45	6	28
OZP1101	32	36	5	24
PBA Pearl [®]	31	37	25	31
Morgan [®]	31	47	22	33
PBA Oura [®]	30	38	12	27
PBA Hayman [®]	65	63	46	58
Mean (%)	34	42	19	32

Source: www.farmtrials.com.au/trial/16030

Key findings and comments

- **Varieties** – Kaspas[®] and its potential replacement OZP0805 (PBA Wharton[®]), performed extremely well at Westmere in 2012, with yields in the top three lines across all sowing dates. The new white pea PBA Pearl[®] also showed promise and offers different marketing opportunities. Also of note is OZP1103, which showed both excellent yields and biomass (data not shown) as this variety has potential for dual-purpose cropping (i.e. both forage and grain). Further varietal details below.
- **Sowing dates** – as has been seen in previous research, early sowing produced the highest yields. Based on yields achieved of the earlier sown treatments (4.5 t/ha), peas could have achieved a gross profit of approximately \$1300/ha based on management costs of \$250/ha and grain price at \$340/t. Results from 2011 at Lake Bolac, Victoria, showed that sowing early increases grain yield. The three sowing dates used in 2011 were later than the ones used in 2012, the latest being 9 August. All varieties yielded particularly badly compared to the earlier sowing dates of 20 May and 16 June. Kaspas[®], PBA Ours[®] and PBA Hayman[®] were the varieties grown in both 2011 and 2012, and all produced similar yield in both trials. The earliest sowing date produced the greatest yields, followed by the mid sowing date, followed by the late sowing date for both Kaspas[®] and PBA Ours[®]. PBA Hayman[®] produced its highest yield at the mid sowing date, followed by the early, followed by the late in both years.
- **Crop-topping** – in 2012 at Westmere, crop-topping targeting ryegrass at the milky dough stage caused significant yield loss in all varieties grown. This could be expected as the crop was too green and seed not sufficiently developed for application of a desiccant. This highlights the importance of growers and advisers being aware of both weed and crop growth stages, otherwise significant grain yield loss could occur. Results from a similar trial in 2011 at Lake Bolac did not show any overall effect of crop-topping on grain yield. This again indicates that if the crop-top is applied at the correct timing, the risk of reducing grain yield is reduced.
- **Disease management** – these treatments were implemented to assess the effect disease is having on grain yields of field pea in a high-rainfall zone. Unlike 2011, there was no response to disease control as disease pressure was low. A fortnightly fungicide regime is unlikely to be economically viable, unless yields are above 2 t/ha and differences are in excess of 20% when using a fungicide. However, the early strategy, although not economically profitable, may be a risk management strategy to minimise the chance of yield loss from disease like black spot.⁹

⁹ J Brand & E vanderMark (2012) Faba Bean and Field Pea Varieties and Management – 2012 Results Westmere. https://www.farmtrials.com.au/trial/16030?search_num=4



Photo 2: Weeds in a mature field pea crop may need desiccation to enable easier harvest without green contamination in the grain sample.

Photo: Emma Leonard (2014), Pre-harvest herbicide use. GRDC Fact Sheet, www.grdc.com.au/GRDC-FS-PreHarvestHerbicide

i MORE INFORMATION

Pre-harvest herbicide use Fact Sheet
GRDC (2014)
<https://grdc.com.au/GRDC-FS-PreHarvestHerbicide>

10.2.2 Timing

The major differences between desiccation and crop-topping are:

- application timing is different and initiated by different criteria;
- herbicides for crop-topping and desiccation are not always the same ([Table 4](#));
- herbicide rates for desiccation are higher than that required for crop-topping ([Table 4](#));
- crop-topping will advance the harvest timing in some pulse crops; and
- both crop-topping and desiccation chemicals will cause reduced grain quality and yield if applied at the wrong maturity stage of the crop.

10.3 Windrowing

Windrowing of field pea is possible, but not common practice like it is for pulses faba bean. It is a practice primarily used to bring the harvest date forward, uniformly ripen the crop, protect the crop from shattering where harvest is to be delayed, or used as part of general management to reduce weed seedset.

Windrowing of field pea crops for uniform ripening and earlier harvest is generally considered impractical because field pea windrows often lack bulk, are difficult to pick up from the bare ground, and tend to be blown around in strong winds when left to dry-down. However, some growers have had success with semi-leafless peas like Kaspas[®] by placing wide swathes doubled into a bulkier windrow and using a ‘cotton wheel roller’ to compact the windrow (Photo 3 and Photo 4). Risk is reduced and harvesting efficiency improved because of the larger, compact windrow and wide swathe covered in the harvesting pass.



Photo 3: Swathing semi-leafless field pea.

Photo: I Pritchard (2014) Machinery used for swathing semi-leafless field peas, <https://www.agric.wa.gov.au/field-peas/swathing-semi-leafless-field-pea>



Photo 4: Rolling swathes of semi-leafless field pea.

Photo: I Pritchard (2014) Machinery used for swathing semi-leafless field peas, <https://www.agric.wa.gov.au/field-peas/swathing-semi-leafless-field-pea>

10.3.1 Windrow (swathing) or direct-heading field pea

Swathing

Swathing field pea reduces the risk of putting a stone through the header, which is more of a risk with direct-heading. Some growers would prefer to use the swather over the harvester, which costs more to operate per hectare. Swathing and harvesting can be carried out at around 9–10 km/h, whereas direct-heading is performed at slower speeds of around 6.5 km/h.

Timing is critical for proper swathing. Too early and field pea won't cut as well, while later timing increases the amount of shatter loss. Choosing the best timing can be difficult with variability of maturity throughout the field. Swathing at the right maturity time can help reduce the amount of time field pea lay in the swathe. In Australia and Canada growers aim for the field pea to be picked up in 7–10 days, depending on the weather.

Direct-heading

Some field pea growers prefer direct-heading (straight cutting) after desiccation (or crop-topping). Success can be attributed to having the right harvest equipment. Using a flex header with air reels can mean virtually no shatter on the knife, provided they can keep the speed of the combine harvester up. If the crop is shorter or thinner it can be difficult to keep the crop feeding well and the harvester moving at the desired speed. More losses occur in a thin, poor stand than a thick crop.

A key benefit of direct-heading field peas for many growers is time management. For some the time taken for field pea swathing can be too long and can overlap with when canola needs swathing/windrowing. Desiccating field peas can be completed in a fraction of the time of swathing, so allowing growers more time for management of other crops.

i MORE INFORMATION

For more information:
See [Section 11.4 Modifications and harvest aids](#)

AVPMA webpage: PubCRIS database
<https://services.apvma.gov.au/web/quest/pubcris>

While swathing/windrowing field pea preserves better colour, it is not necessarily enough of an advantage compared to the time saved using other methods.¹⁰

10.4 Chemical products registered for use in field pea

Pre-harvest chemical application to crops increases the risk of detectable herbicide residues in harvested grain, potentially leading to breaches of maximum residue limits (MRLs). MRLs vary according to herbicide, crop and market and these need to be understood. Detection of chemical residues above MRLs will jeopardise market access and the future of the Australian grains industry.

Follow product labels correctly and adhere to withholding periods for harvest and grazing or cutting for stock feed (GSF) (Table 4).

Glyphosate is **NOT REGISTERED** for seed crops and should not be used in pulses intended for seed production or sprouting

Table 4: Registered products for desiccation and crop-topping of field pea.

Herbicide	Example trade names	Operation	Crop	Rate	Withholding period
Diquat 200g/L	Regione®	Desiccation	Chickpea, faba bean, dry pea, lentil, lupin, mungbean	2 to 3 L/ha	Grazing/stockfeed (GSF): 1 day Harvest: 0 days (lupin/dry pea) 2 days (chickpea, lentil, faba bean)
Paraquat 250g/L	Gramoxone®	Crop-topping	Chickpea, faba bean, field pea, lentil, lupin, vetch	400 to 800 mL/ha	GSF: 1 day (7 days for horses) Stock must be removed from treated areas 3 days before slaughter Harvest: 7 days
Glyphosate 480g/L	Ripper 480®	Crop-topping	Faba bean, field pea	360 to 765 mL/ha	GSF: 7 days Harvest: 7 days
		Desiccation	Chickpea, faba bean, field pea, lentil, mungbean	765 mL to 2.025 L/ha	GSF: 7 days Harvest: 7 days
Glyphosate 500g/L	Touchdown Hi Tech®	Crop-topping	Faba bean, field pea	300 to 700 mL/ha	GSF: 7 days Harvest: 7 days
Glyphosate 540g/L	Roundup PowerMAX®	Crop-topping	Faba bean, field pea	320 to 680 mL/ha	GSF: 7 days Harvest: 7 days
		Desiccation	Chickpea, faba bean, field pea, lentil, mungbean	680 mL/ha to 1.8 L/ha	GSF: 7 days Harvest: 7 days
Saflufenacil	Sharpen®	Desiccation	Field pea, faba/broad bean, chickpea, lentil, lupin	34 g/ha plus recommended label rate of glyphosate or paraquat herbicide plus 1% Hasten® or high quality MSO	GSF: 7 days Harvest: 7 days

*GSF – withholding period for grazing or cutting for stock food. Observe the harvest withholding period and GSF for each crop. Always read the label supplied with the product before each use.

Source: Pulse Australia, Australian Pulse Bulletin, Desiccation and Crop-topping in pulses, <http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping>

Harvest

Key points

- Harvest early to minimise yield loss and also to avoid physical and weathering damage, which impacts on grain quality. Early harvest planning starts with sowing on time, pre-harvest treatments and being organised at harvest.
- Harvest at moisture levels up to 12–14% to avoid damage to grain.
- There are several modifications and harvest aids to assist harvesting of field pea. Modifications differ for conventional and semi-leafless varieties.
- Snails can be a problem for harvest of field pea in SA and Victoria. An integrated approach is required throughout the season with some post-harvest grain cleaning as a salvage option.
- Harvesting field pea can be hazardous for starting paddock and harvester fires.
- Spread pea stubble at harvest to minimise erosion risks

i MORE INFORMATION

GroundCover™ article: 'Profitable pulses – it's all about the harvest window',
<https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-118-Sep-Oct-2015/Profitable-pulses-its-all-about-the-harvest-window>

11.1 Impact of delayed harvest on profitability

The key to maximising profit from pulses is grain quality. Human food markets demand a quality sample without cracking, staining, de-hulled seeds or insect damage. Visual appearance is everything. Buyers do not want immature grains (shriveled or green kernel), bleached (if green peas), chipped, cracked or de-hulled seeds.¹

Therefore, early harvest of field pea is critical. Delays can result in significant yield loss and quality downgrading due to lodging, shattering, pod loss and diseases. Harvesting pea early improves both quality and harvest efficiency.

If managed correctly, pulses can be more profitable than cereals. Sow and harvest on time to maximise returns.

Some reason why growers may delay harvest of pulses include:

- When there is a clash with cereal harvest, field pea is often considered a 'secondary' crop compared with cereals.
- Perceived better chance of achieving premiums for high quality wheat or malting barley. In reality the premiums for harvesting pulses at the optimum time are often greater.
- The false perception that field pea tolerates weathering.
- Uneven ripening if not desiccated or windrowed, especially when grown on heavy clay or variable soil types.²
- Field pea can be slower or more difficult to harvest and there is a higher risk of harvester fires. Harvesting needs extra care, more frequent stopping to blow down residues from around hot spots on the header.

Despite these beliefs, delaying field pea harvest is not recommended. The impact of delays include:

- Greater harvesting difficulties due to:
 - » increased lodging;
 - » slower harvesting;
 - » growth of late weeds; and
 - » more dirt picked up by the header.
- Increased wear and tear on headers due to increased soil contamination.
- Harvest clashes with other crops is more likely.
- Yield is reduced due to pod shattering, seed drop and seed shrinkage.
- Seed quality is reduced due to:
 - » weather damage leading to seed blemishes and increased seed cracking and splitting, especially when handling is excessive;
 - » seed coat discolouration due to prolonged light exposure;
 - » bleaching in blue seed types;
 - » increased field mould infection;
 - » reduced seed viability; and
 - » more soil contamination of seed.
- Greater dust and health problems associated with post-harvest handling.
- Pea weevil escape into the paddock before silo fumigation.
- Greater risk of hail damage.
- More disease carryover on seed kept for sowing.³

1 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>
 2 T Weaver (2015) Profitable pulses – it's all about the harvest window. GRDC GroundCover™, Issue 118, September–October 2015 <https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-118-Sep-Oct-2015/Profitable-pulses-its-all-about-the-harvest-window>
 3 E Armstrong, D Carpenter (1999) Desiccation & harvest of field peas. Pulse Point 5, Second Edition, NSW Agriculture, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/157099/pulse-point-05.pdf

11.1.1 Yield losses

Yield losses increase significantly the longer harvest is delayed.

Some field pea varieties are very prone to pod splitting and pod drop with harvest delays, especially after weather events once the plant has dried down. Weathering of the grain can also occur in split pods. Kaspera-type varieties have a sugar pod, so do not shatter readily. However, the pod wall does deteriorate over time, leaving the grain more exposed to sun damage (Photo 1).



Photo 1: *Kaspera[®] field pea grain that has been sun and heat burnt through the sugar-pod wall. Normal (top) and different severities of burn (below).*

Photo: W. Hawthorne, formerly Pulse Australia

It is estimated that grain losses due to a 1–3-week delay in harvest range from \$150–\$250/ha, depending on seasonal conditions. Most of the losses are due to pod loss and shattering before harvest, as well as pod loss at the header front.

Yield losses of up to 50% have been recorded in the field after rains or strong winds.

11.1.2 Deterioration in grain quality

Grain quality deteriorates the longer the mature field pea is left exposed to weathering in the field.

The seed coat of field pea is very prone to wrinkling if it has been exposed to wetting and drying events due to rain or heavy dew during the summer harvest months. 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 operations.

Levels of cracked and damaged grain can be as high as 50% in extreme cases of field weathering and prolonged rainfall.

Field pea that do not meet the Number 1 Receival Standard of 3% maximum defective peas will need to be graded. This incurs a cost to the grower of:

- \$15–\$25/t grading costs; and
- downgrading of the seconds into the stockfeed market at a value of \$120–\$140/t.

MORE INFORMATION

For the current Australian Pulse Standards for field pea go to:
<http://www.pulseaus.com.au/marketing/receival-trading-standards>

Early harvested field pea seed is much more resilient against breakage during harvesting and subsequent handling, even at low moisture contents.

Most field pea are ultimately processed into a protein form, either a dahl or flour, by removing the seed coat (hull) and splitting the cotyledons. However, the visual appearance is still critical for marketing. Older seed, darkened with age splits more readily than new season grain. The milling process uses abrasive-type mills to gradually abrade the seed coat from the cotyledons, and is reliant 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 field pea after rain are also more difficult to thresh out at harvest, and often contain much higher levels of unthreshed pods and pod material.⁴

11.1.3 Missed marketing opportunities

An early harvest provides some degree of control over field pea grain quality, as well as how and when the crop is marketed. Late-harvested field pea can often result in a grower becoming a price-taker in a falling market or encountering delays in delivery.

Delayed harvest can often mean missing out on premiums paid for early harvested crops of good quality. This is often the case, except for seasons where major production problems have been encountered resulting in a shortfall of grain in the market.

⁴ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

11.2 Plan for early harvest

There are a range of management components that contribute to an early matured crop. It requires careful planning from the beginning of the season. There are three broad areas that contribute to a successful early harvest: sowing, in-crop management and harvest management.

Sowing

- Sow at the earliest opportunity but within the preferred planting window for your area. This may involve dry sowing by a particular calendar date.
- Moisture-seeking equipment and/or press-wheels can significantly enhance seeding opportunities under marginal soil moisture conditions.
- Use adapted varieties that meet your target for early harvesting.
- Using precision planters or machines with automatic depth control will often achieve more uniform plant establishment and crop development, and consequently more even crop maturity. This is particularly so when sowing into marginal soil moisture and drying conditions.



Photo 2: *Field pea sown early (left) mature before those sown later (right).*

Photo: W. Hawthorne, formerly Pulse Australia

In-crop management

- Control of diseases, if possible, before and during flowering.
- Control of native budworm during flowering to maximise early pod-set.
- Avoid using herbicides that delay crop maturity such as flumetsulam (e.g. Broadstrike®).

Harvest management

- Consider weed wiping (where able to) to kill tall, late weeds (in a short crop) that might otherwise delay harvest
- Consider using a desiccant (crop-topping or desiccation) to dry late plants and any weeds.
- Windrowing is an option to enable earlier maturity and harvest date
- If using glyphosate (or equivalent registered product) 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.
- Blend, aerate and/or dry the sample to the required receival standard of 14% moisture.⁵
- More frequent blow-down of harvesters is needed to avoid fire risk. Fine residues accumulating around the engine bay and exhaust can cause increased risk of fires.

For more information on desiccation, crop-topping and windrowing see [Section 10 Pre-harvest treatments](#).

11.3 Harvester set-up

Field pea is easily threshed, so concave clearances should be opened and the drum speed reduced.

Field pea is prone to cracking, so gentle harvesting will give the best seed quality. Rotary harvesters are gentler on the crop and will generally cause less grain damage than conventional harvesters.

Field pea can be harvested with minor adjustments and modifications. Flexi-fronts are best because they can harvest close to the ground and flex with ground contours. Open-front or pick-up fronts are also suitable.

Field pea, like all pulse crops, should be harvested as soon as it matures as pods will fall if harvest is delayed, especially after rain.

A field pea crop varies in height from 30 to 110 cm, with pods held up in the canopy so direct heading without crop lifters is possible with open front machines. Field peas thresh easily but are prone to cracking, so adjust thresher speed (400–600 rpm) and concave (10–30 mm) to suit ([Table 1](#)).

Be aware of thresher impact speeds that vary with the drum diameter and adjust drum speed to suit 12 m/second impact speed required.

Harvesting grain at high moisture levels up to 14% should help minimise cracking.

Desiccating the crop will kill summer weeds and ensure even crop ripening. Desiccate or harvest early before green weeds become a problem. This will help to reduce clogging, staining and sample contamination with green vegetative material.

If there are summer weeds present, the drum speed may need to be increased to ensure that weeds do not block the machine. Alternate wires and blanking-off plates may have to be removed. Maximum wind settings and barley sieve settings should ensure a good sample. If there are summer weeds, the rake at the back of the sieves should be blanked-off to stop them entering the returns. Summer weeds may cause walkers and sieves to block completely, causing high grain losses.⁶

⁵ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

⁶ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

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FEEDBACK

Table 1: Harvester settings for pulses.

	Chickpea	Faba bean	Green lentil	Red lentil	Lupin	Field pea	Vetch
Reel speed	medium	slow	slow	slow	slow	medium	slow
Spiral clearance	high	high	low	low	high	standard	low
Thresher speed	400–600	400–600	350–450	350–450	400–600	400–600	400–600
Concave clearance	10–30 mm	15–35 mm	20–30 mm	10–20 mm	10–30 mm	10–30 mm	10–30 mm
Fan speed	high	high	high	high	high	high	medium
Top sieve	32	32–38 mm	32 mm	16 mm	32 mm	25 mm	25 mm
Bottom sieve	16 mm	16–19 mm	8–16 mm	3–10 mm	16 mm	16 mm	10–16 mm
Rotor speed*	700–900	700–900	350–450	350–450	700–900	700–900	slow

* Rotary machines only.

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

VIDEO

Watch video:
Harvest 2010 Kaspas[®] pea
<https://youtu.be/b8QDjg5FkBM>



Photo 3: Harvesting field pea.

Photo: T. Bray, formerly Pulse Australia

MORE INFORMATION

Modify harvesters for semi-leafless field pea crops,
<https://www.agric.wa.gov.au/field-peas/modifying-harvesters-semi-leafless-field-peas-crops>

GRDC App Field Peas: The Ute Guide for android and iOS found at App Store

11.4 Modifications and harvest aids

Modifications to harvesters can be made that improve the ease and efficiency of harvesting field pea. Modifications to machinery may void warranty or insurance; please check before proceeding.⁷

Harvester modifications need to be carefully assessed as the benefits may not justify the costs.

Some modifications that may be useful for pulse harvest include:

- Flexible cutter-bar fronts (flexi-fronts) are hinged in short sections allowing harvest close to the ground.
- Aussie-air directs a blast of air through the reel fingers for both light and heavy crops.
- Harvestaire replaces the reel with a manifold to direct a blast of air into the front and is more effective in light crops.

⁷ I Pritchard, M Seymour (2015) Modifying harvesters for semi-leafless field pea. Department of Agriculture, Western Australia, <https://www.agric.wa.gov.au/field-peas/modifying-harvesters-semi-leafless-field-peas-crops>

- Vibra-mat vibrates with the knife to prevent bunching on open front headers. It is cheap and most effective for light crops, but speed needs to be carefully managed.
- Crop lifters are a knife attachment designed to lift lodged crops. Height control is important as they can bring in more sticks and soil.
- Extension fingers are plastic fingers approximately 30 cm long that are fitted over existing fingers to prevent pods from falling in front of the knife.
- Extended fronts extend the distance between the knife and the auger to a maximum of 760 mm to minimise losses from bunching at the auger.
- Platform sweeps are used with extended fronts and are fingers that rake material towards the auger to minimise bunching. They can be used with conventional fronts.
- Draper fronts (e.g. MacDon and Honey Bee) have large clearances behind the knife and carry the crop to the elevator.⁸
- Fire Knock Out will drench the engine bay in fire retardant using a self-actuating switch.
- Fire Prevention Shield reduces the temperature of the components in the engine bay by drawing air from the cooling fan through a heat exchanger, charging it to higher pressure to clean residues from around the muffler. This effectively reduces residues and temperature to lower the risk of fire.

11.4.1 Modifications for conventional and semi-leafless peas

The harvesting of semi-leafless, erect peas may need header adjustments to be made compared with conventional pea types (Table 2).

Table 2: Suggested harvest settings or modifications for conventional and semi-leafless peas.

Factor	Trailing varieties (e.g. Parafield)	Semi-leafless (e.g. Kaspa ⁸)
Harvest timing	Cool conditions	Warm conditions
Crop lifters	Essential	Not needed in an upright crop
Finger tyne adjustment	Tilt back slightly – assists lifting	Set in vertical position to force material down and into draper fronts
Reel speed	1.1 times ground speed	1.0 – 1.3 times ground speed
Raised cross auger	Usually not required	Improves speed of harvest of pluckers
Raised cross auger with paddles on middle section	Usually not required	Essential for draper fronts
Lupin breakers	Usually not required	On cross auger for draper fronts and table auger for conventional fronts. Essential for table auger of plucker fronts if raised cross auger not fitted
Position of broad elevator feeder house auger	Set back	Moving the feeder house auger forward may reduce blockages
Stripper plate	–	To stop material building up behind cross augers
Wire fence across back of fronts	Useful addition	Assists in light crops – raised cross auger + paddles more reliable
Concave	Easy to thresh 10–25mm	Ensure wire gaps at least 7 mm and not blocked
Straw chopper	Useful addition	Essential due to ropey vine

Source: GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

⁸ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

For taller, semi-leafless types like Kaspas[®] or Moonlight, plucker and draper fronts will require modifications to create downward pressure onto the harvested pea material or to force it into the broad elevator. There are generally fewer problems with conventional and flex fronts. Also a slower harvesting speed will reduce intake problems. Newer semi-leafless varieties like PBA Wharton[®] and PBA Twilight[®] are not as tall as Kaspas[®], but can still cause harvest issues of poor feeding into the front elevator.

For semi-leafless, non-shattering pea types, harvest under warmer conditions than conventional peas. The concave setting may need to be closer than normal and threshing time longer. A straw chopper may be essential to chop up the more ropey pea vine produced. It may be possible to remove the crop lifters if the crop is upright.

Set the finger tyne reel to force the pea material down onto the front. Moving the broad elevator auger forward can improve the feeding of light pea material. Fitting a raised cross auger, ideally with paddles on the middle section, is essential on draper fronts. A backing plate or cross wires at the back of the table may help all set-ups. Lupin breakers are a useful addition to cross or table augers to increase their aggressiveness on all set-ups, but particularly on plucker fronts. Flexible fingers above the plucker are a useful addition. Crop dividing coulters will assist all set-ups.⁹



Photo 4: Light crop lifter used in field pea.

Photo: G Reithmuller, DPIRD, Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited



Photo 5: Plastic extension fitted to a draper front.

Photo: Gordon Cumming, formerly Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited



Photo 6: Harvestaire front combined with extension fingers and a blue Vibra-mate.

Photo: G Cummings, formerly Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited

⁹ J Lamb, A Podder (2008) Grain Legume Handbook (u. Update 8 March 2008), Grain Legume Handbook Committee, GRDC <https://grdc.com.au/grainlegumehandbook>

i MORE INFORMATION

GRDC Fact Sheet: Snail management
<https://grdc.com.au/GRDC-FS-SnailManagement>

GRDC Booklet: *Bash 'Em Burn 'Em Bai 'Em*
<https://grdc.com.au/GRDC-Snails-BashBurnBait>

11.5 Managing snails

Snails can build up more rapidly in field pea, faba bean and canola compared with other crops (Photo 7). They need to be managed throughout the season using integrated management (see [Section 8.7 Snails](#)).



Photo 7: Snail damage to a near-mature pea pod.

Photo: Mary Raynes, formerly Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited

A rule of thumb is that snail numbers above 5/m² in pulses will contaminate grain at harvest.¹⁰

Pulse grain receival standards for pea is no dead or alive snails for export and no more than one (whole or more than half) dead or alive snails per 200 g for 'farmer dressed'.

Snails can be a major problem at harvest. They can clog up and damage harvesting machinery causing delays while snail pulp is removed from sieves and other parts of the machinery. If allowed to dry crushed snail guts and dust can set like concrete.

Both white and conical snails can cause problems by climbing plants and entering headers with the grain.

There is no quick and easy way to control snails, but a combination of a number of strategies and modifications to harvesting equipment can help.

Before harvest:

- Baiting snails – complete all baiting by the end of August to avoid the risk of bait entering grain samples at harvest, particularly with peas.
- Harvest crops early – the later they are left, the more difficult they will be to harvest.
- Leave badly infected areas until cool or damp weather when snails are more likely to be down off the plants.

At harvest:

- Minimise the entry of dirt into the header by using a grate in the bottom of the front elevator.
- Use a smaller top sieve, or 10 mm punch hole or octagonal top sieve.
- Weld a lip onto the front of the top sieve to stop snails falling off.
- Add removable panels to the header to allow easy cleaning.
- Add a steel slat in the elevator to keep the elevator clean.
- Slow down the speed of the grain elevators.
- Harvest with the repeat door open, but monitor losses.¹¹

¹⁰ GRDC (2012) Snail management Fact Sheet. GRDC, Southern and Western Regions, September 2012, <https://grdc.com.au/GRDC-FS-SnailManagement>

¹¹ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

VIDEO

Burning Snails and Weed Seeds
<https://youtu.be/zqQKFFqndKQ>



Dislodger bars can remove snails but will result in some yield loss. Research has shown that a rigid bar fitted with dangling V-belts at 100 mm spacing can dislodge 60% of round snails in pulse crops with up to 5% in crop losses.¹²

After harvest:

- Burning stubbles in autumn is effective if a complete burn of the paddock is achieved.
- Control grass along fence lines where snails can remain undisturbed.
- Roll, slash, cable or trash harrow stubbles so snails cannot get above 5 cm off the ground. Beware of erosion.¹³

11.5.1 Post-harvest grain cleaning

Samples with high numbers of snails will require cleaning to enable delivery to national receival standards. These steps can remove high numbers of snails with very little grain loss:

- Scalping.
- Use a soft, snail-crushing roller on field pea of 14–15% moisture content and with a roller clearance of 1–2.5 mm.
- Screening with 5.15-mm-diameter round screen.

Gravity separation may be effective for grain coming out of storage as dead snails are lighter in weight.¹⁴

11.6 Lodged crops

Conventional, trailing pea varieties lodge before harvest. Semi-leafless types may also lodge to some degree if tall enough or subjected to weather events of wind or rain. Where the crop has lodged, it is usually best to harvest into the opposite direction, or at right angles to the direction the crop has fallen. Crop lifters can definitely help.

If sown on wider 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.¹⁵

11.7 Harvesting for seed

Field pea seed kept for seeding in the following season should be harvested from an area that is as free as possible from diseases, pests and weeds.

Germination rates are best maintained if the grain is harvested at 12–14% moisture and then stored in aerated silos or immediately graded and bagged. Crop-topping with herbicides prior to crop maturity may reduce grain quality and seed viability. Retaining seed from a crop that has had glyphosate applied is not recommended; likewise if crop-topping was too early.

Ensure headers, bins, augers and other equipment are free of cereal contamination as these contaminant grains are hard to remove during cleaning.

Sprouting of unharvested grain after rain downgrades quality and germination.¹⁶

12 GRDC (2012) Snail management Fact Sheet. GRDC, Southern and Western Regions, September 2012, <https://grdc.com.au/GRDC-FS-SnailManagement>

13 Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

14 GRDC (2012) Snail management Fact Sheet. GRDC, Southern and Western Regions, September 2012, <https://grdc.com.au/GRDC-FS-SnailManagement>

15 Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

16 GRDC (2009) Field Peas: The Ute Guide, Southern region. GRDC Ground Cover Direct <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

11.8 Assessing harvest loss

Grain can be lost at a number of places during harvest and each loss needs to be assessed so that corrective action can be taken. Figure 3 shows the three places where grain can be lost:

- before harvest due to pod shedding;
- at the harvester front due to the type of harvester front or set-up; and
- in the threshing system of the harvester, due to drum, concave and sieve settings.

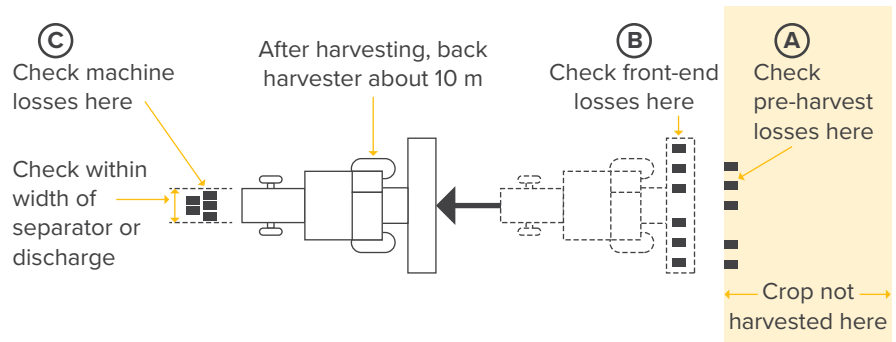


Figure 1: Sampling places for estimating grain losses at harvest.

Source: The Chickpea Book via Grain Legume Handbook (2008)

To determine grain losses, the following action should be undertaken:

1. Harvest a typical area without stopping the machine, then stop and allow the machine to clear itself of material.
2. Back the harvester about 10 m and shut down the machine.
3. Sample grain losses in each of the following three areas:
 - a. Pre-harvest (that is, in the standing crop in front of the harvester 'A').
 - b. Front (in the cut crop in front of the harvester 'B').
 - c. Behind (in the cut crop behind the harvester, including trash, 'C').
4. Sampling is best done using a quadrat with an area of 0.1 m².
 - a. Count the number of seeds on the ground within the 0.1 m² quadrat. Ideally take 10 quadrats for each of the three locations (A, B and C).
 - b. Average the number of seeds per 0.1 m² quadrat for each area. Multiply by 10 to get the number of seeds per square metre.¹⁷

Grain losses on the ground can then be calculated using the 100 seed weight from the seeding rates in [Section 4.3.1 Calculating seed rates](#) (also see [Section 3.3 Field pea varieties](#)).

Example: A typical 100 seed weight of Kaspas[®] field pea is 22 g/100 seeds.

If the seed on the ground is 32 m²

$$\begin{aligned} \text{Seed loss} &= \frac{\text{No. of seed/m}^2 \times 100 \text{ seed weight}}{10} \\ &= (32 \times 22)/10 \\ &= 70 \text{ kg/ha} \end{aligned}$$

¹⁷ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

i MORE INFORMATION

Ground Cover™ article: 'Careful harvester set-up puts more grain in the bin'

<https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-95-November-December-2011/Careful-harvester-setup-puts-more-grain-in-the-bin>

▶ VIDEO

Reducing the risk of harvester fires
<https://youtu.be/WqTfR2ifM1I>



i MORE INFORMATION

Booklet: Reducing harvester fire risk: The Back Pocket Guide
<https://grdc.com.au/GRDC-BPG-ReducingHarvesterFireRisk>

Pulse Australia: Avoiding harvester fires
<http://pulseaus.com.au/blog/post/avoiding-harvester-fires>

Ground Cover™ article: A few steps to preventing header fires
<https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-101/A-few-steps-to-preventing-header-fires>



Photo 8: Field pea grain lost at harvest.

Photo: W. Hawthorne, formerly Pulse Australia

11.9 Harvest fire risk

Harvesting pulse crops can be hazardous for starting paddock or header fires, perhaps more so than in some other crops. With hot, dry conditions in Australia's southern cropping region each summer, harvester fires are an extreme risk to life, crops and property. Farmers and contractors need to make sure that their harvesters are well maintained and cleaned to reduce fire risk, especially when harvesting lentil and chickpea, which have a higher fire risk than other crops. However, field pea, faba bean and lupin also have fine residues that powder easily and create a higher risk of ignition.

Flammable material can collect on the exhaust manifold and turbocharger in a harvester's engine bay, which is the most common cause of harvester fires. When these materials ignite, they can blow around the machine and into nearby crops, where they can cause spot fires.

Keeping your machines clean and well maintained is the best way to prevent harvester fires. Taking steps to prevent harvester fires should be a priority in all crops.

Harvester fires can be prevented by undertaking the following:

- Keep at least two fire extinguishers accessible on each of your harvesting machines.
- Perform regular blow-downs on the harvester. In extreme conditions this might be every half hour or every time after filling the harvester box.
- Keep equipment clean and well maintained.
- Ensure the manifold, turbocharger and exhaust free of flammable material.
- Do not overload electrical circuits.

Postpone paddock works during high fire-risk periods, which typically involve low humidity, high winds and vulnerable crop conditions.¹⁸

¹⁸ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

11.10 Leaving pea stubble post-harvest

Pea stubble can be a severe erosion risk, particularly if the crop was sown into bare cultivated soil. Header trails blow and the ground is often left bare in between header tailings (Photo 8). The newer, semi-leafless varieties (e.g. Kaspa[®]) leave a little more pea stubble rooted, but can still be an erosion risk if the header tailings are left in rows. Spreading pea straw out of the harvester does assist in erosion control (Photo 9). Sowing peas into a cereal stubble and harvesting above ground is clearly the best option to minimise erosion in pea stubbles.

Grazing of pea stubble creates a major erosion risk, especially on sandier soils.



Photo 9: Pea stubble can be an erosion risk, particularly if bare ground and left in header trails.

Photo: W. Hawthorne, formerly Pulse Australia



Photo 10: Pea stubble can be less of an erosion risk if spread at harvest.

Photo: W. Hawthorne, formerly Pulse Australia

i MORE INFORMATION

Field Pea receival standards are detailed at:

http://www.pulseaus.com.au/storage/app/media/markets/20160801_Pulse-Standards.pdf

11.11 Receival standards

The national receival standards for field pea are set by the pulse industry via Pulse Australia. They reflect the market requirements for a quality food product. Receival standards are set in order to achieve the export standards used by marketers and buyers internationally.

Pea types (dun, white, blue) are segregated with off-types becoming part of the defective count. The majority of deliveries continue to be into the Australian field pea number 2 grade receival which requires low insect damage and breakages (defectives 7% maximum) and minimal foreign material or impurities (3% maximum). Discolouration or staining of grain is not a specified rejection in number 2 grade. Failure to achieve this receival standard may mean price discounts at the discretion of the buyer or re-cleaning to make grade.

The Australian field pea number 1 grade receival may be applied by a few buyers who supply premium human consumption markets. This tighter receival grade requires minimal insect damage and breakages (defectives 3% maximum) and minimal discolouration or staining of grain (1% maximum). See pulse receival and export standards at http://www.pulseaus.com.au/storage/app/media/markets/20160801_Pulse-Standards.pdf

Table 3: Summary of National Field pea receival standards Maximum moisture content (%)

	Maximum moisture content (%)	Minimum Purity (%)	Maximum defective plus poor colour (%)	Screen size for defective (mm)	Poor colour maximum (5)	Foreign material maximum in total (%)
No 1 grade receival standard	14	97	3	3.75 slotted	1	3
No 2 grade receival standard	14	97	7	-	-	3

	Unmillable material maximum (%)	Snail maximum	Insect maximum	Nominated weed seed maximums
No 1 grade receival standard	0.5 (0.3% soil)	1 per 200g	15 per 200g	See receival standards appendix for amounts allowable
No 2 grade receival standard	0.5 (0.3% soil)	1 per 200g	15 per 200g	See receival standards appendix for amounts allowable

11.12 Grain delivery

Cash buying at harvest or warehousing options are not necessarily always available, close or desirable for field pea growers at harvest. Depending on the location, variety/type, market outlet or grower choice, grain may need to be stored on farm. Sales must therefore be made privately to processors, agents or direct to the end-user.

Like with most pulse grains, there are bulk handling storage locations that do handle field pea grain for warehouse storage or storage on behalf of buyers. There are also an increasing number of processors that receive field peas at harvest or after storage. Bulk storage most likely will not be for all types of field peas or their grades. Receival grades are usually based on the national standards receival grade 2 farmer dressed (CSP-10.2.1). See [Section 11.11 Receival standards](#).

White, green, marrowfat and even number 1 grade dun type field peas will most likely need specific arrangements with buyers or processors because bulk storage facilities for these types are usually unavailable or rare for these niche classes, unless traded as livestock feed. See a pulse trader list at <http://www.pulseaus.com.au/marketing/pulse-traders>.

Each year before harvest, bulk-handling facilities usually publish a list of locations, segregations and grades of products that they will receive. These segregations reflect the national receival standard for field peas as well as anticipated locations and volumes of production.

Glencore/Viterra in South Australia publish segregations they accept for field pea each year pre-harvest (see <http://www.viterra.com.au/index.php/classification/>). Look for 'grade segregations', which are usually for Dun types only, and based on variety type ('Kaspa[®]' types or other Dun types).

Look also for "receival standards" which are updated annually pre-harvest. See <http://www.viterra.com.au/index.php/receival-standards/>.

Field pea growers in Victoria and southern NSW likely will need to be in touch with the many private storage facilities and pulse processors direct (see <http://www.pulseaus.com.au/marketing/pulse-traders>).

Note that field pea grain sold as seed to other growers for grain, hay or green/brown manure uses can only occur if it is a variety not covered by Plant Breeder's Rights (PBR). If the variety is covered by PBR, as most new varieties are now, then arrangements must be made directly with the commercial partner for that particular variety.

Storage

Key points

- Field pea is prone to mechanical damage. Use efficient and a minimal number of handling stages.
- Harvest field pea at 13–14% moisture content to minimise damage during handling, but do not store at moisture contents above 12% without aeration cooling or aeration drying.
- Cone silos are ideal for storing field pea. For storage longer than 3 months ensure silo has aeration cooling and gas-tight sealing for fumigation.
- Store grain at low temperature and low moisture for maximum storage time.
- Good hygiene and low temperatures through aeration cooling are important for protection against pests.
- Fumigation options are limited for pulses. Successful fumigation requires a gas-tight, sealable silo.

12.1 Storing pulses

The successful storage of pulses requires a balance between ideal harvest conditions and ideal storage conditions. Harvesting at 14% moisture content captures grain quality and reduces mechanical damage to the seed, but it also requires careful management of seeds in aerated silos to avoid deterioration during storage.¹

Test quality and physiological age are two principal components of chickpea, field pea, lentil and faba bean seed quality. Both are affected by harvest and storage practices. Both also influence germination (although they are not the only factors), as well as other measures of seed quality that affect the ability of seeds to produce seedlings which can emerge and establish.²

Many of the quality characteristics of the grain from these crops are in the appearance, size and physical integrity of the seed. Mechanical seed damage, discolouration, disease, insect damage, split seeds or small seeds will lead to a downgrade in quality and market value. Buyers prefer large, consistently sized seed free of chemical residues for easy processing and marketing to consumers.

Unlike cereal grains, pulses cannot be treated with protectants to prevent insect infestations. Therefore, meticulous hygiene and aeration cooling to manage storage temperature and moisture are crucial to prevent insect damage and moulds from downgrading stored field pea. The Australian Pulse Standards stipulate standards for heat-damaged, bin-burnt, mouldy, caked or insect-infested field pea, and breaching of any of these can result in the discounting or rejection of product.³

Condition of the seed at harvest

Seed subject to field weathering before harvest will deteriorate a lot quicker in storage, even when stored at acceptable temperature and relative humidity.

Conditions of high relative humidity and high temperatures result in rapid deterioration in grain colour.

To maintain colour and minimise the darkening of seed, any grain stored >12% moisture content will require cooling and/or drying.

Growers should avoid even short to medium storage of weather-damaged grain.⁴

Gaining a better understanding of the insect pests themselves, and fighting them using the right combination of management choices and equipment, gives growers the upper hand. In a deregulated market there is a large range of domestic and export selling options. Growers strengthen their position when their storage facilities allow flexibility with grain handling and timing of sales.

As a bonus, many of the strategies used to minimise pest problems also significantly improve storage conditions for maintaining grain quality.⁵

1 P Burrill, P Botta, C Newman, B White, C Warrick (2014) Storing pulses. Fact Sheet. GRDC, updated July 2014, www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

2 RH Ellis, PK Agrawal, EE Roos (1988) Harvesting and storage factors that affect seed quality in pea, lentil, faba bean and chickpea. In *World Crops: Cool Season Food Legumes*. Springer Netherlands, Dordrecht. 303–329

3 Pulse Australia (2011) Australian Pulse Standards, 2011/2012 Season. Pulse Australia, <http://www.graintrade.org.au/sites/default/files/file/CommodityStandards/PulseStandards201112.pdf>

4 Pulse Australia (2013) Northern Chickpea—Best Management Practices Training Course Manual 2013. Pulse Australia

5 P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–14. GRDC Update Papers. GRDC, <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2013/07/grain-storage-future-pest-control-options-and-storage-systems-2013-2014>

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Watch GCTV Stored Grain: Storing Pulses
<https://youtu.be/CeWA-OdhhSk>



VIDEO

Watch Stored Grain: Managing Sealed and Unsealed Storage
<https://youtu.be/TIsOS-7DwxA>



MORE INFORMATION

Stored Grain information hub
<http://storedgrain.com.au/>

12.1.1 How to store product on-farm

Key points

- Combining good hygiene with well-managed aeration cooling and regular grain inspections provide the best foundation for successful grain storage.
- Findings of recent ecological research, which involved trapping flying storage pests across grain-growing regions, reinforced the value of cleaning up grain residues in storages and equipment.
- New, easy-to-use functions in automatic aeration controllers provide improved reliability of achieving good results from aeration cooling.
- Recirculation and ground-level applications have a role to play in effective, safe fumigation.⁶

Summary

Harvesting pulses at 13–14% moisture content preserves grain quality and reduces mechanical damage. However, pulses should not be stored at moisture contents above 12%. To successfully store pulses:

- Avoid mechanical damage to pulse seeds to maintain market quality and seed viability and to ensure they are less attractive to insect pests.
- Pulses above 12% moisture content can be held safely with aeration cooling for up to 3 months.
- Pulses above 12% moisture content will require aeration drying to maintain quality over 3 or more months.
- Prevent pests with careful hygiene and aeration cooling.
- Control pests with fumigation in gas-tight, sealable storage.⁷

Regular monitoring is required to ensure grain quality in storage is maintained. Check monthly, taking samples from the bottom and, if safe, from the top. Monitor:

- insect pests;
- grain temperature;
- grain moisture content; and
- grain quality and germination.⁸

12.2 Handling field pea

Field pea are prone to mechanical damage, particularly during rough handling. This especially applies to:

- overly dry grain (<10% moisture content); and
- crops that have been exposed to weather damage prior to harvest.

The use of tubulators or belt conveyors can reduce damage compared to conventional spiral augers.

Grain can be handled up to six times before delivery to receival points, so it is important that growers:

- Minimise the number of handling stages wherever possible.
- Use efficient handling techniques that minimise damage.

⁶ P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–14. GRDC Update Papers. GRDC, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Grain-Storage-Future-pest-control-options-and-storage-systems-2013-2014>

⁷ P Burrill, P Botta, C Newman, B White, C Warrick (2014) Storing pulses. GRDC Fact Sheet. Updated July 2014, <https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses>

⁸ GRDC (2013) Grain storage pest control guide. Grain storage fact sheet, Northern and Southern Regions. GRDC, June 2013, <http://www.grdc.com.au/GRDC-FS-GrainStoragePestControl>

If using augers:

- operate slow and full;
- use large diameter augers;
- the flight pitch should be greater than the auger diameter;
- length of the auger should be no longer than is necessary – the shorter the better;
- keep auger incline as low as practical;
- check flight casing clearance – optimal clearance is typically 50% of grain size to minimise grain becoming wedged between the auger spiral and the casing, causing cracking; and
- auger drives should be at the discharge end, and not on the intake.

12.3 Grain cleaning

Re-cleaning field pea after harvest is sometimes necessary. Cereals can be cleaned from most other pulses, but not field pea because of their similar size. Cleaning of cereals out of field pea must occur with herbicides in the paddock well before the cereals produce any grain.

Vetch and tare seeds are difficult to remove by cleaning from field pea grain. If the paddock has a potential vetch or tare problem a suitable-sized field pea variety should be chosen to assist with grading.

Screens or paddles can be damaged beyond repair if the grain jams in rotary screens. Fitting the screens with a spacer will provide additional clearance and so avoid the problem.

Milk thistle buds can be difficult to separate if they contaminate the sample because they are similar in size and weight to peas. However, if desiccated or given time to dry, the buds disintegrate when put through an auger and can be easily separated.

Dirt and most small weed seeds can be separated in rotary screens, however the dirt will increase component wear.⁹



Photo 1: Grain cleaning to remove vetch and tare seeds.

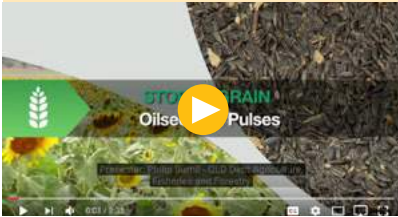
Photo: M Raynes, formerly Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited image 8.35

⁹ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

VIDEO

Watch GCTV Stored Grain: Oilseeds and Pulse Storage

<https://youtu.be/JvzfJ2Xo6Sq>



12.4 On-farm storage

Growers in the southern region are investing in on-farm storage for a range of reasons. In the eastern states, on-farm storage gives growers options into domestic and export markets, while in South Australia – where the majority of grain goes to bulk handlers – growers tend to set up storage to improve harvest management.

Growers might only plan to store grain on-farm for a short time, but markets can change, so investing in gas-tight, sealable structures means you can treat pests reliably and safely and leave your business open to a range of markets.

Growers should approach storage as they would purchasing machinery. Growers spend a lot of time researching a header purchase to make sure it is fit-for-purpose. Grain storage can also be a significant investment, and a permanent one, so it pays to have a plan that adds value to your enterprise into the future.

Agronomists tip: decide what you want to achieve with storage, critique any existing infrastructure and be prepared for future changes. A good storage plan can remove a lot of stress at harvest – growers need a system that works so they capture a better return in their system.¹⁰

The two most common of the serious threats to grain quality in Australia’s storages are insect pest infestations and grain moisture problems causing the growth of mould or fungus. Key initial strategies include:

- Maintain thorough hygiene in storages and equipment.
- Keep grain in storage cool and dry.

Attention paid to the three areas listed below will provide reliable grain quality:

- Good storage and equipment hygiene reduces early pest infestations and grain-contamination problems. Sieve and inspect grain in storages monthly.
- High-moisture grain in storage – have the right equipment and management strategies in place to deal promptly with any growth of mould or fungus. Monitor regularly.
- Cool grain temperature – use aeration to achieve cool, uniform temperature in storages in the first few weeks after harvest. Monitor to maintain these conditions.¹¹

In most cases, for on-farm storage to be economical it will need to deliver on more than one of these benefits ([Table 1](#)). Under very favourable circumstances grain-storage facilities can pay for themselves within a few years, but it is also possible for an investment in on-farm storage to be very unprofitable. The grain storage cost-benefit analysis template is very useful step in the decision-making process to test the viability of grain storage on your farm.¹²

¹⁰ GRDC. (2015) Grain storage. Extension tailored for regional challenges. Ground Cover™ issue 119, <http://www.grdc.com.au/rv/gcs118>

¹¹ P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–14. GRDC Update Papers, GRDC, <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Grain-Storage-Future-pest-control-options-and-storage-systems-2013-2014>

¹² GRDC. (2015) Grain storage strategies in the northern region. <https://grdc.com.au/archive/key-issues/grain-storage-strategies-in-the-northern-region>

Table 1: Advantages and disadvantages of grain storage options.

STORAGE TYPE	ADVANTAGES	DISADVANTAGES
Gas-tight sealable silo	<ul style="list-style-type: none"> Gas-tight sealable status allows phosphine and controlled atmosphere options to control insects Easily aerated with fans Fabricated on-site or off-site and transported Capacity from 15 tonnes up to 3000 tonnes Up to 25 year plus service life Simple in-loading and out-loading Easily administered hygiene (cone base particularly) Can be used multiple times in-season 	<ul style="list-style-type: none"> Requires foundation to be constructed Relatively high initial investment required Seals must be regularly maintained Access requires safety equipment and infrastructure Requires an annual test to check gas-tight sealing
Non-sealed silo	<ul style="list-style-type: none"> Easily aerated with fans 7–10% cheaper than sealed silos Capacity from 15 tonnes up to 3,000 tonnes Up to 25 year plus service life Can be used multiple times in-season 	<ul style="list-style-type: none"> Requires foundation to be constructed Silo cannot be used for fumigation — see phosphine label Insect control options limited to protectants in eastern states and dryacide in WA. Access requires safety equipment and infrastructure
Grain storage bags	<ul style="list-style-type: none"> Low initial cost Can be laid on a prepared pad in the paddock Provide harvest logistics support Can provide segregation options Are all ground operated Can accommodate high-yielding seasons 	<ul style="list-style-type: none"> Requires purchase or lease of loader and unloader Increased risk of damage beyond short-term storage (typically 3 months) Limited insect control options, fumigation only possible under specific protocols Requires regular inspection and maintenance which needs to be budgeted for Aeration of grain in bags currently limited to research trials only Must be fenced off Prone to attack by mice, birds, foxes etc. Limited wet weather access if stored in paddock Need to dispose of bag after use Single-use only
Grain storage sheds	<ul style="list-style-type: none"> Can be used for dual purposes 30 year plus service life Low cost per stored tonne 	<ul style="list-style-type: none"> Aeration systems require specific design Risk of contamination from dual purpose use Difficult to seal for fumigation Vermin control is difficult Limited insect control options without sealing Difficult to unload

Source: Kondinin Group, B White (2012) Planning for efficiency and quality, A Grains Industry Guide. GRDC, http://storedgrain.com.au/wp-content/uploads/2013/07/GRDC-GS-FACILITIES-Booklet-2013_Final.pdf

The following videos show some of the benefits of on-farm storage:

- Video On-farm storage in the SA Mallee, with Corey Blacksell, <https://youtu.be/IFKJYlp0hk>
- Video On-farm storage in SA, Linden Price, https://youtu.be/V9pSYmh_c00
- Video Over the Fence: On-farm storage pays in wet harvest, May 2011, <https://youtu.be/ejwX-WytTs>
- Video Over the Fence: storage delivers harvest flexibility and profit, <https://youtu.be/UWr7CTMxVMg>

12.4.1 Silos

Silos are ideal for storing pulses, particularly those with a cone base as there is less likely to be grain damage at out-loading (Photo 1). When storing for longer than 3 months only use storage that is suitable for aeration cooling and gas-tight for fumigation. Ideally an aeration controller should be used to optimise aeration efficiency and cooling of the grain.



Photo 2: On-farm storage silo.

Photo: GRDC

It is especially important with pulses to always fill and empty silos from the centre holes because they have a high bulk density. Loading or out-loading off-centre puts uneven weight on the structure and may cause it to collapse.

The approximate weight of grain stored in a cubic metre of silo is shown in Table 2. The actual figures can vary as much as 6–7% in wheat and barley and 15% in oats. In pulses the variation is likely to be less (3–4%) and will vary with the grain size, variety and season.

Table 2: Calculating silo capacities.

Grain	Cubic metres	Kilograms	3-bushel bags
Lentil	1	800	9.2
Chickpea	1	750	9.2
Faba bean	1	750	9.2
Broad bean	1	645	9.2
Field pea	1	750	9.2
Lupin	1	750	9.2
Vetch	1	750	9.2
Wheat	1	750	9.2
Barley	1	625	9.2
Oat	1	500	9.2

Source: Grain Legume Handbook (update 2008) <https://grdc.com.au/grainlegumehandbook>

VIDEO

Watch GCTV Stored Grain: Stay Safe Around Grain Storage,
<https://youtu.be/CM2mgmo3jWU>



MORE INFORMATION

GRDC Fact Sheet: Storing pulses,
<https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses>

Calculating silo capacity

Calculating the volume of a cylinder

$$\text{Volume} = \text{area of base (diameter squared} \times 0.7854) \times \text{height}$$

Calculating the volume of a cone

$$\text{Volume} = 1/3 (\text{area of base} \times \text{height})$$

12.4.2 Safety around grain storage

Watch GCTV Stored Grain: Stay Safe Around Grain Storage.

12.5 Grain quality in storage

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

Quality in storage can be reduced by:

- weather damage prior to harvest;
- moisture;
- heat; and
- pests, including insects, mould and fungi.

Growers should avoid even short to medium storage of weather-damaged grain. Seed that has weathered prior to harvest will deteriorate a lot quicker in storage, even if stored under ideal conditions.

Field pea will darken in storage, although not as dramatically as faba bean or desi chickpea. Rate of seed coat darkening (deterioration in grain colour) will be accelerated by:

- high seed moisture content.; high temperatures;
- high relative humidity;
- condition of the seed at harvest; and
- sunlight.¹³

¹³ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

12.6 Moisture content and temperature

Typical harvest temperatures of 25°C–35°C and grain at a moisture content greater than 13–14% can provide the ideal conditions for mould and insect growth (Figure 1 and Table 3). High-moisture grain will generate additional heat when in confined storage, such as a silo, further encouraging mould and insect growth. Without aeration grain can maintain its warm harvest temperature for a long time.¹⁴

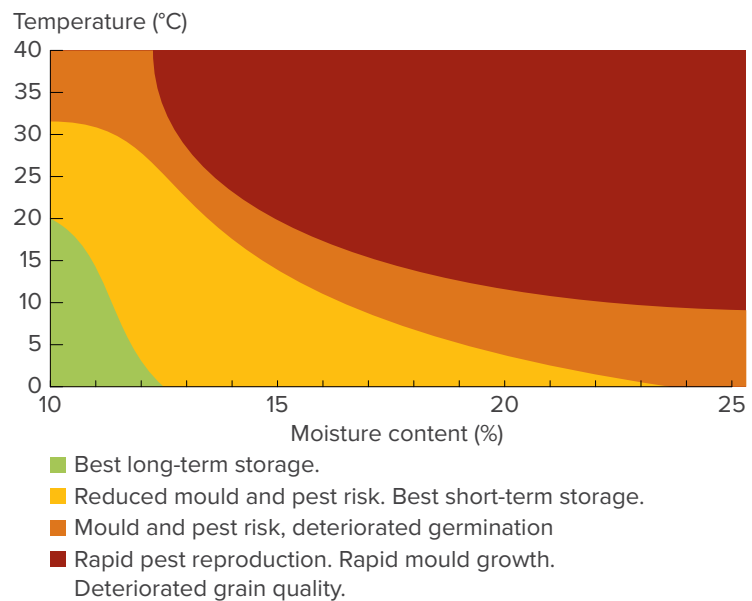


Figure 1: Effects of temperature and moisture on stored grain.

Source: CSIRO Ecosystems Sciences, Stored Grain Project (2013) Dealing with high-moisture grain, Grain storage fact sheet, GRDC, June 2013, <https://grdc.com.au/GRDC-FS-HighMoistureGrain>

Table 3: The effect of grain temperature and moisture on stored grain insect and mould development.

Temperature (°C)	Insect and mould development	Grain moisture content (%)
40-55	Seed damage occurs, reducing viability	
30-40	Mould and insects are prolific	>18
25-30	Mould and insects active	13–18
20-25	Mould development is limited	10–13
18-20	Young insects stop developing	9
<15	Most insects stop reproducing, mould stops developing	<8

Source: Kodinin Group, GRDC (2013) Grain storage pest control guide. Grain storage fact sheet, Northern and Southern Regions, GRDC, June 2013, <https://grdc.com.au/GRDC-FS-GrainStoragePestControl>

Moisture

Pulses harvested at 14% moisture or higher must be dried before going into storage to preserve seed germination and viability. As a general rule, every 1% rise in moisture content above 11% will reduce the storage life of pulse seed by one-third (see Table 3). Any pulse stored above 12% moisture content will require aeration cooling to maintain quality.

¹⁴ C Warrick and C Nicholls (2013) Aerating stored grain: Cooling or drying for quality control. A Grains Industry Guide. GRDC, <http://storedgrain.com.au/aerating-stored-grain/>

Temperatures

High temperatures in storage will cause deterioration in grain viability. Temperatures of stored pulse grain should not exceed an average of 25°C and preferably the average temperature should be below 20°C. In general, each 4°C rise in average stored temperature will halve the storage life of the grain. See Table 4 and Figure 2.

Table 4: Maximum recommended storage periods by temperature and moisture.

Grain moisture (%)	Grain temperature (°C)	
	20°C	30°C
14	3 months	n/a
13	9 months	3 months
12	> 9 months	9 months

Source: CSIRO Stored Grains Research Laboratory, Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited Table B.14

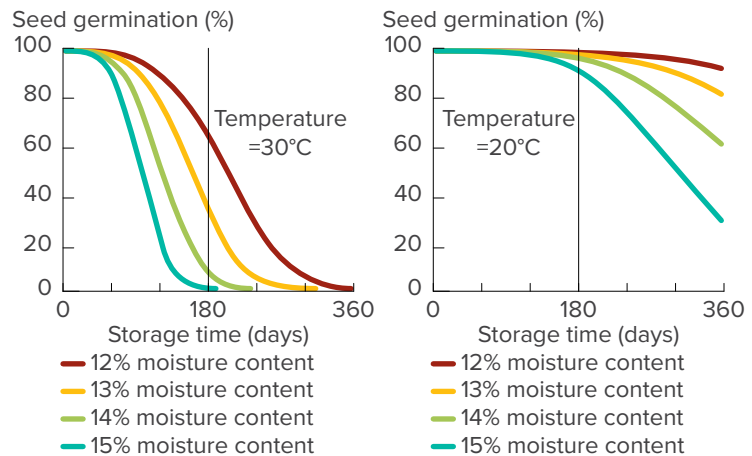


Figure 2: Generalised graph of storage temperature* and moisture effect on seed vigour.

* The left graph shows effects of moisture content on wheat germination when stored at 30°C. Right graph is when stored at 20°C.

Source: CSIRO Stored Grain Research Laboratory, Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited Figure 8.3 Used in Lentil Section 13 Fig 2

Fumigate using sealable, gas-tight silos immediately after filling to stop any insects present from creating moisture. Maintain the grain at low temperatures and moisture content for the maximum storage time.

12.7 Cooling and drying pulses

Grain aeration systems are generally designed to carry out either a drying or a cooling function, but not both.

Knowing whether grain needs to be dried or cooled can be discovered by following these simple rules:

- Grain that is dry enough to meet specifications for sale can be cooled, without drying, to slow insect development and maintain quality during storage.
- Grain of moderate moisture will require aeration drying to reduce the moisture content to maintain quality during storage.
- If aeration drying is not available immediately, moderately moist grain (up to 14% maximum) can be cooled for a short period to slow mould and insect development, then dried when the right equipment is available.
- After drying to the required moisture content, cool the grain to maintain quality.

- High-moisture grain (>14% for pulses) will require immediate moisture reduction before cooling for maintenance.¹⁵

Grain that is over the safe storage moisture content of 12.5% can be dealt with by:

- Blending with low-moisture grain, then aerating. Blending can be used for grain up to 13.5% moisture content. Blending is less suitable for pulses because the additional handling can damage the seed.
- Aeration cooling – grain up to 15% moisture content can be held short-term until drying equipment is available.
- Aeration drying – large volumes of air are pumped through the grain gradually reducing moisture. Additional heating can be used.
- Continuous flow drying – grain is transferred through the dryer, which pumps a high volume of heated air through the continual grain flow. This is a highly efficient way to dry large volumes of grain.
- Batch drying 10–20 tonnes of grain at a time with a high volume of pre-heated air, usually using a transportable trailer.¹⁶

One practical way of reducing temperatures is to paint the silo white as dark coloured silos will absorb more heat (Photo 3).

Grain in large silos (>75 t) will remain cooler as grain is a poor conductor of heat and day/night temperature fluctuations rarely reach 15 cm beyond the silo wall. Small silos (<20 t) and field bins will have larger temperature fluctuations and can cause deterioration in grain quality.¹⁷



Photo 3: Silos painted white to reduce temperature.

Photo: GRDC

¹⁵ C Warrick and C Nicholls (2013) Aerating stored grain: Cooling or drying for quality control. A Grains Industry Guide. GRDC, <http://storedgrain.com.au/aerating-stored-grain/>

¹⁶ Stored Grain Project (2013) Dealing with high-moisture grain, Grain storage Fact Sheet. GRDC, June 2013, <https://grdc.com.au/GRDC-FS-HighMoistureGrain>

¹⁷ Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016. Pulse Australia Limited

VIDEO

Watch GCTV2: Grain Storage Cooling Aeration,
<https://youtu.be/qb3WAXZO1fg>



12.7.1 Aeration cooling

Cooler temperatures of grain in storage have several advantages:

- seed viability (germination and vigour) is maintained longer;
- moist grain can be safely stored for a short time before blending or drying;
- moisture migration is reduced;
- insect breeding cycles are slowed (or ceased in some instances) and ‘hot spots’ are prevented;
- mould growth is reduced; and
- darkening of the seed coat is slower.

Aeration cooling is a vital tool when storing pulses. It allows for longer-term storage of low-moisture grain by creating cool, uniform conditions. These conditions maintain seed quality, protect seed viability, and reduce mould and insect development. Aeration cooling also allows grain to be harvested earlier, and at higher moisture levels, capturing grain quality and reducing mechanical seed damage.

Aerated silos are fitted with fans that push air through the grain, to cool the grain, and equalise the moisture and temperature throughout the silo (Photo 4). With an aeration system, a waterproof vent on the top of the silo allows the air to escape as it is forced from the base of the silo. This vent needs to be replaced with a sealed lid or a capped venting tube during fumigation.



Photo 4: Silo fitted with aeration fan for cooling.

Photo: Evan Collis Photography

It is important to know the capacity of an existing aeration system. Aeration cooling can be achieved with airflow rates of 2–3 L/second per tonne delivered from fans driven by 0.37 kilowatt (0.5 horsepower) electric motor for silos of around 100-tonne capacity.

Correctly controlled aeration should aim to reduce grain temperature to 20°C or lower. Controlling aeration cooling is a three-stage process: continual, rapid and then maintenance. Cooling achieved during storage depends on both the moisture content of the grain, and the humidity and temperature of the incoming air.

An understanding of the effects of relative humidity and temperature when aerating stored grain is important. Automatic aeration controllers that select optimum fan run times provide the most reliable results and are deemed best for convenience.¹⁸

MORE INFORMATION

GRDC Booklet: *Aerating stored grain: cooling or drying for quality control*,
www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

GRDC Fact Sheet: Performance testing aeration systems,
<https://grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems>

¹⁸ Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016, Pulse Australia Limited

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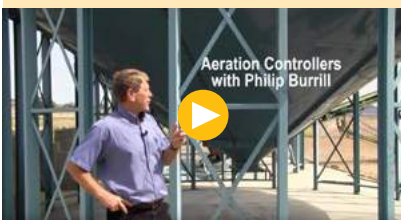
VIDEO

Watch GCTV5: Aeration Drying – getting it right,
<https://youtu.be/vzMHzyHCWuw>



VIDEO

Watch 10: Grain Storage with Philip Burrill – Using Aeration Controllers,
<https://youtu.be/vxoBO71rTDg>



MORE INFORMATION

GRDC Grain Storage Fact Sheet: Storing Pulses,
<https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses>

GRDC Grain Storage Fact Sheet: Grain Storage Pest Control Guide,
<https://grdc.com.au/GRDC-FS-GrainStoragePestControl>

GRDC Grain Storage Fact Sheet: Dealing with High-Moisture Grain,
<https://grdc.com.au/GRDC-FS-HighMoistureGrain>

GRDC *Aerating stored grain: Cooling or Drying for Quality Control, A Grains Industry Guide*,
http://storedgrain.com.au/wp-content/uploads/2016/10/GRDC-Aeration-Book-2016_R2.pdf

12.7.2 Aeration drying

If high moisture content (>14%) pulses are to be stored for longer than 3 months they require drying or blending to maintain seed quality. Aeration drying is the preferred method as it has a lower risk of cracking or damaging pulses than using hot-air dryers.

Careful selection of conditions using dry ambient air (using an automated controller) can remove moisture from the stored grain over a period of weeks.

Unlike aeration cooling, drying requires higher air flow rates of at least 15–25 L/sec/tonne of grain (Photo 5).¹⁹ Aeration drying is a slow process that also relies on high air-flow rates, well-designed ducting for even air flow, exhaust vents in the silo roof, and warm, dry weather conditions.²⁰



Photo 5: Aeration drying requires air-flow rates of 15–25 L/sec/tonne of grain.

Photo: GRDC

Supplementary heating can be used to aid the drying process by removing moisture more effectively than cold air and by reducing the relative humidity of the air.

Once drying is complete all grain needs to be cooled, regardless of whether supplementary heat was used.²¹ Storage pests stop breeding at temperatures below 15°C (Table 3). Aim for less than 23°C in summer and less than 15°C in winter.²²

12.7.3 Heated air drying

Continuous-flow or batch dryers provide reliable drying, although they can reduce quality if run at too high a temperature. Check the specifications or talk to the manufacturer about safe conditions for drying pulses.

¹⁹ Stored Grain Project (2014) Storing pulses. Grain storage Fact Sheet, GRDC, July 2014, <https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses>

²⁰ Stored Grain Project (2013) Dealing with high-moisture grain, Grain storage Fact Sheet. GRDC, June 2013, <https://grdc.com.au/GRDC-FS-HighMoistureGrain>

²¹ C Warrick and C Nicholls (2013) Aerating stored grain: Cooling or drying for quality control. A Grains Industry Guide. GRDC, <http://storedgrain.com.au/aerating-stored-grain/>

²² GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions, GRDC, June 2013, <https://grdc.com.au/GRDC-FS-GrainStoragePestControl>

12.8 Preventing moisture migration

Grain stored in sealable, gas-tight silos must be of sufficiently low moisture content to prevent moisture migration. Use an aerated, sealable, gas-tight silo with adequate ventilation fitted. Sealable, gas-tight/aerated silos should only be sealed for fumigation and then aerated once the fumigation is completed.

Do not load grain with excess moisture (>12%) into a sealable, gas-tight store where there is no escape of moisture. In a sealable, gas-tight silo moisture can migrate to condense in upper grain layers. This top area of the grain is at high risk from mould and insect colonisation.

Moisture sources include grain, insects, any green material, immature seeds, condensation and leaks.

Grain

Grain and seed are living and release moisture as they respire. This moisture moves upwards by convection currents created by the temperature difference between the grain in the centre of the silo and the walls, which can be either warmer or cooler.

Insects

Insects or mites in the grain respire and release moisture and heat into air spaces. If grain is stored at less than 14% moisture and is free of insects the increase in moisture content in the upper layers of the grain will be insignificant. If grain is stored above 14% moisture content there may be enough moisture in the upper grain layers to cause mould. Moisture builds up quicker and to higher levels from insect respiration than from grain respiration alone. There is no moisture migration in an aerated silo as the entire stack is normally cooled to an even temperature (20°C or less).

Condensation

Moisture carried into the silo headspace can condense on a cold roof and fall back as free water. This can cause a circle of mould or germinated grain against the silo wall. Moist grain can also contain greater numbers of insects.

Leaks

Water entering through structural damage will increase grain moisture content to a level where mould and insect growth can occur.

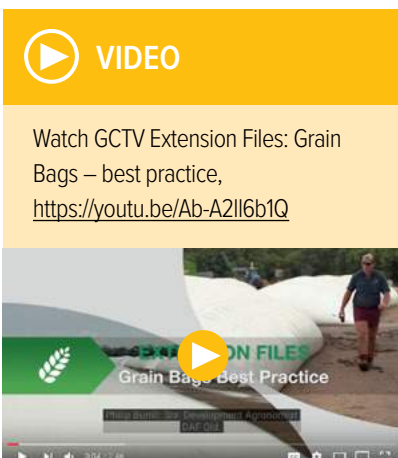
12.9 Grain bags for pulse storage

Harvest bags (also known as ‘silo bags’ or ‘sausage bags’) are a polymer-membrane-based storage system providing a cost-competitive option to grain growers ([Photo 6](#)). There are, however, industry concerns over grain spoilage, contamination, insect control and out-turned processing quality with their use for pulses.²³

Grain bag capacity varies with bag size, which ranges from from 40–90 metres long, and from 100 to 300 tonnes, depending on the type of grain and how much the bag is stretched during filling.

Grain bags are best used for short-term, high-volume grains storage to assist with harvest logistics. Their success as a storage option is dependent on site planning and preparation, best management practices and frequent monitoring for repairs and patching of holes.

Aeration cooling is not yet proven with grain bags and storing high-value legumes or canola is not recommended.²⁴



23 JA Darby, LP Caddick (2007) Review of grain harvest bag technology under Australian conditions. CSIRO Entomology, Technical Report No. 105, <https://publications.csiro.au/rpr/pub?list=BRO&pid=procite:d0d5771-fbb-4ffd-bfd4-de675a9a044e>

24 Stored Grain Project (2012) Successful storage in grain bags. Grain storage Fact Sheet, GRDC, March 2012, <https://grdc.com.au/Resources/Factsheets/2012/03/Grain-Storage-Fact-Sheet-Successful-storage-in-grain-bags>



Photo 6: Silo bag.

Photo: Rod Peterson © GRDC

In theory, grain in a correctly sealed bag will convert residual oxygen into carbon dioxide (hermetic conditions), which will asphyxiate insects and inhibit fungal growth. However, CSIRO research has shown that it is difficult to achieve these conditions, particularly with high grain temperatures and the relatively dry grain harvested in Australia. It is unlikely a bag will not have some holes, tears or punctures throughout the storage period, which will allow air to enter and compromise the hermetic environment.²⁵

Storing pulses in grain bags is a bigger risk than storing other crops. Pulse grain has been rejected because of objectionable taints and odours resulting from improper storage in grain bags.

The risks of storing pulses in grain bags are:

- Pulse grain may not retain its quality, colour or freedom from odour, especially if the seal is breached or moisture ingress occurs.
- Contamination and moisture can enter bags from tears or where vermin and other pests create holes in the bag.
- Excessive grain moisture can result in condensation within the bag, causing localised areas of mould and an offensive, distinctive mouldy odour throughout. Marketers have rejected pulse grain because of objectionable moulds, taints and odours acquired through storage in grain bags. Such taints and odours are not acceptable in pulse markets, particularly human consumption end uses. Odour virtually cannot be removed once present.
- Grain moisture content is critical. Pulses, particularly the larger-seeded ones like faba bean or kabuli chickpea, have bigger airspaces between grains than cereals, so moisture can move more freely through them.
- Removing taints and odours in affected grain is often not possible, even with further aeration.
- An overall offensive, distinctive 'plastic' odour can occur, and it requires considerable periods of aeration to remove. There is nil tolerance of odours in receival standards.

VIDEO

Watch GCTV Extension Files: Grain Bags – a grower's perspective, <https://youtu.be/cLRgjjdErOU>



²⁵ JA Darby, LP Caddick (2007) Review of grain harvest bag technology under Australian conditions. CSIRO Entomology, Technical Report No. 105, <https://publications.csiro.au/rpr/pub?list=BRO&pid=procite:d0d57771-fbb-4ffd-8fd4-de675a9a0448>

i MORE INFORMATION

Pulse Australia: Grain Bags
<http://pulseaus.com.au/growing-pulses/publications/grain-storage-bags>

GRDC Fact Sheet: Successful storage in grain bags
<https://grdc.com.au/Resources/Factsheets/2012/03/Grain-Storage-Fact-Sheet-Successful-storage-in-grain-bags>

- Storage at harvest temperatures of more than 30°C favours high insect reproduction rates so hygiene and monitoring are vital. Achieving a low oxygen environment (hermetic conditions) under Australian conditions is difficult and should not be relied upon as the only source of storage insect control.²⁶

12.10 Grain storage: get the economics right

As growers continue to expand their on-farm grain storage, the question of economic viability gains significance. There are many examples of growers investing in on-farm grain storage and paying for it in 1 or 2 years because they struck the market at the right time, but are these examples enough to justify greater expansion of on-farm grain storage?

The grain storage extension team conduct approximately 100 grower workshops every year, Australia-wide, and it is evident that no two growers use on-farm storage in exactly the same way. Like many economic comparisons in farming, the viability of grain storage is different for each grower. Depending on the business's operating style, the location, the resources and the most limiting factor to increase profit, grain storage may or may not be the next best investment. For this reason, everyone needs to do a simple cost-benefit analysis for their own operation.

Comparing on-farm grain storage

To make a sound financial decision, we need to compare the expected returns from grain storage with expected returns from other farm business investments, such as more land, a chaser bin, a wider boomspray, a second truck or paying off debt. The other comparison is to determine if we can store grain on-farm cheaper than paying a bulk handler to store it for us.

Calculating the costs and benefits of on-farm storage will enable a return-on-investment (ROI) figure, which can be compared with other investment choices and a total cost of storage to compare to the bulk handler's.

Cheapest form of storage

The key to a useful cost-benefit analysis is identifying which financial benefits to plan for and costing an appropriate storage to suit that plan. People often ask 'What's the cheapest form of storage?' The answer is the storage that suits the planned benefits. Short-term storage for harvest logistics or freight advantages can be suited to grain bags or bunkers. If flexibility is required for longer-term storage, gas-tight, sealable silos with aeration cooling allow quality control and insect control.

Benefits

To compare the benefits and costs in the same form, work everything out on a basis of dollars per tonne. On the benefit side, the majority of growers will require multiple financial gains for storing grain to make money out of it. These might include harvest logistics or timeliness, market premiums, freight savings or cleaning, blending, or drying grain to add value.

Costs

The costs of grain storage can be broken down into fixed and variable. The fixed costs are those that don't change from year to year and have to be covered over the life of the storage. Examples are depreciation and the opportunity or interest cost on the capital. The variable costs are all those that vary with the amount of grain stored and the length of time it's stored for. Interestingly, the costs of good hygiene, aeration cooling and monitoring are relatively low compared to the potential impact they can have on maintaining grain quality. One of the most significant variable costs, and one that is often overlooked, is the opportunity cost of the stored grain. That is, the cost of having grain in storage rather than having the money in the bank paying off an overdraft or a term loan.

26 Pulse Australia (2016) Grain bags for pulse storage. Pulse Australia website <http://pulseaus.com.au/growing-pulses/publications/grain-storage-bags>

The result

While it's difficult to put an exact dollar value on each of the potential benefits and costs, a calculated estimate will determine if it's worth a more thorough investigation. If we compare the investment of on-farm grain storage to other investments and the result is similar, then we can revisit the numbers and work on increasing their accuracy. If the return is not even in the ball park, we've potentially avoided a costly mistake. On the contrary, if after checking our numbers the return is favourable, we can proceed with the investment confidently.

Summary

Unlike a machinery purchase, grain storage is a long-term investment that cannot be easily changed or sold. Based on what the grain storage extension team are seeing around Australia, the growers who are taking a planned approach to on-farm grain storage and doing it well are being rewarded for it. Grain buyers are seeking out growers who have a well-designed storage system that can deliver insect-free, quality grain without delay.

Table 5 is a tool that can be used to figure out the likely economic result of on-farm grain storage for each individual business. Each column can be used to compare various storage options including type of storage, length of time held or paying a bulk handler.²⁷

Financial gains from storage		Example \$/t
Harvest logistics/timeliness	Grain price x reduction in value after damage % x probability of damage %	\$16
Marketing	Post-harvest grain price – harvest grain price	
Freight	Peak rate \$/t – post harvest rate \$/t	\$20
Cleaning to improve grade	Clean grain price – original grain price – cleaning costs – shrinkage	
Blending to lift average grade	Blended price – ((low grade price x %mix) + (high grade price x %mix))	
Total benefits	Sum of benefits	\$36.20
Capital cost	Infrastructure cost / storage capacity	\$155
Fixed costs		
Annualised depreciation cost	Capital cost \$/t / expected life storage e.g. 25 years	\$6.20
Opportunity cost on capital	Capital cost \$/t x opportunity or interest rate e.g. 8% / 2	\$6.20
Total fixed costs	Sum of fixed costs	\$12.40
Variable costs		
Storage hygiene	(Labour rate \$/hr x time to clean hrs / storage capacity) + structural treatment	\$0.23
Aeration cooling	Indicatively 23¢ for the first 8 days then 18¢ per month / t	\$0.91
Repairs and maintenance	Estimate e.g. capital cost \$/t x 1%	\$1.51
Inload/outload time and fuel	Labour rate \$/hr / 60 minutes / auger rate t/m x 3	\$0.88
Time to monitor and manage	Labour rate \$/hr x total time to manage hrs / storage capacity	\$0.24
Opportunity cost of stored grain	Grain price x opportunity interest rate e.g. 8% / 12 x No. months stored	\$7.20
Insect treatment cost	Treatment cost \$/t x no. of treatments	\$0.35
Cost of bags or bunker trap	Price of bag / bag capacity tonne	
Total variable costs	Sum of variable costs	\$11.32
Total cost of storage	Total fixed costs + total variable costs	\$23.72
Profit/loss on storage	Total benefits – total costs of storage	\$12.48
Return on investment	Profit or loss / capital cost x 100	8.1%

Source: GRDC <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/09/grain-storage-get-the-economics-right>

27 Warrick C. (2016). GRDC Update Papers: Grain storage—get the economics right. <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/09/grain-storage-get-the-economics-right>

i MORE INFORMATION

Booklet: *Stored grain pests identification: the Back Pocket Guide*, <https://grdc.com.au/GRDC-BPG-StoredGrainPests>

GRDC Fact Sheet: *Stored Grain Pests Identification*, <https://grdc.com.au/GRDC-FS-StoredGrainPestID>

▶ VIDEO

Watch GCTV2: Grain silo hygiene, <https://youtu.be/3VU7qJCoCwI>



12.11 Insect pests in storage

The most common pulse pests are the cowpea weevil (*Callosobruchus* spp.) and pea weevil (*Bruchus pisorum*). The cowpea weevil has a lifespan of 10–12 days, while the pea weevil only breeds one generation per year.²⁸

The tolerance for live pests sold off-farm is nil. Growers need an integrated approach to pest control. Prevention is better than a cure. Grain hygiene and aeration cooling can overcome 85% of pest problems. Insect-control options are limited for pulses, making hygiene, aeration and regular monitoring essential.

Most insect development ceases at temperatures below 20°C (Table 3). Freshly harvested grain usually has a temperature of around 30°C, which is an ideal breeding temperature for many storage pests. Aeration fitted to stores will rapidly reduce grain temperatures, reducing insect breeding and aiding grain quality.²⁹

Controlling pea weevil

Control programs for pea weevil are best carried out in the flowering crop. See Section 8.5 Pea weevil (*Bruchus pisorum*).

However, effective fumigation with phosphine will destroy all stages of insects, adults, eggs, larvae and pupae. Effective fumigation requires a sealable, gas-tight silo (see Section 12.13 Fumigation in sealed silos). Fumigation should be carried out as soon as the silo is filled to ensure the feeding stage (larvae) and the non-feeding (pupae and adult) are eliminated before further grain damage or weight loss occurs.

Early harvest and immediate fumigation will reduce the number of adults which could emerge from the peas to infest crops in the next growing season.³⁰

12.12 Farm and grain hygiene

Pest control is best managed with an integrated whole-of-season approach. Options for control are limited at storage so remove pests from storage site before harvest.

12.12.1 Grain silo hygiene

Where to clean

Clean silos and storages thoroughly. This includes cleaning up spillage and minimising places where insects can collect. Clean after harvest to prevent insect build-up during the year. Areas to clean include:

- empty silos and grain storages;
- augers and conveyers;
- harvesters;
- field and chaser bins;
- spilt grain around grain storages;
- leftover bags of grain (seed grain and stock grain); and
- equipment brought onto the farm from outside.

If an insect infestation is found, destroy all grain residues to prevent re-infestation.

Successful grain hygiene involves cleaning all areas where grain gets trapped in storages and equipment. Grain pests can survive in a tiny amount of grain, so any fresh parcel of grain passing through machinery, storage or equipment can easily become infested.

28 Stored Grain Project (2014) Storing pulses. Grain storage Fact Sheet, GRDC, July 2014, <https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses>

29 GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions, GRDC, June 2013, <https://grdc.com.au/GRDC-FS-GrainStoragePestControl>

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

When to clean

Straight after harvest is the best time to clean grain-handling equipment and storages, before they have time to become infested with pests. A trial carried out at the start of a harvest in Queensland revealed more than 1,000 lesser grain borers in the first 40 L of grain through a harvester, which had been considered reasonably clean at the end of the previous season. Discarding the first few bags of grain at the start of the harvest is a good idea.

Studies have revealed that insects are least mobile during the colder months of the year. Cleaning around silos from July–August can reduce insect numbers before they become mobile.

How to clean

The better the cleaning job, the less chance there is of pests being harboured. The best ways to get rid of all grain residues use a combination of:

- sweeping;
- vacuuming;
- compressed air;
- blow guns or vacuum guns;
- pressure washers; and
- fire-fighting hoses.

Using a broom or jets of compressed air gets rid of most grain residues, and a follow-up wash-down removes grain and dust left in crevices and hard-to-reach spots. Choose a warm, dry day to wash storages and equipment so they dry out quickly and do not get rusty. When inspecting empty storages, look for ways to make the structures easier to keep clean. Seal or fill any cracks and crevices to prevent grain lodging and insects harbouring. Bags of leftover grain lying around storages and in sheds create a perfect harbour and breeding ground for storage pests. After collecting spilt grain and residues, dispose of them well away from any grain-storage areas.



Photo 7: Hygiene needs to be a priority when storing grain on-farm.

Photo: GRDC

The process of cleaning on-farm storages and handling equipment should start with the physical removal, blowing and/or hosing out of all residues. Once the structure is clean and dry, consider the application of diatomaceous earth as a structural treatment.³¹

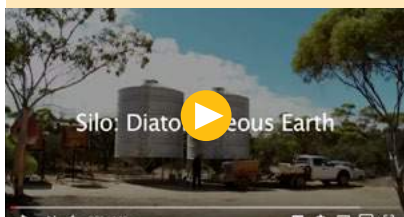
³¹ Stored Grain Project (2013) Hygiene and structural treatments for grain storage. Fact Sheet. Stored Grain Information Hub. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/factsheets/2013/06/grdc-fs-hygiestructuraltreatments>

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FEEDBACK

VIDEO

Watch GCTV7: Applying Diatomaceous Earth Demonstration, <https://youtu.be/L-lyCgstk0>



MORE INFORMATION

GRDC Fact Sheet: Hygiene and structural treatments for grain storages, www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

12.12.2 Structural treatments for field pea storage

Using chemicals for structural treatment is not recommended. They do not list the specific use before storing pulses on their labels and Maximum Residue Levels (MRLs) are either extremely low or nil. There is a high risk of exceeding the MRL.

Diatomaceous earth (DE) as a structural treatment can be used to treat storages after cleaning. It is an amorphous silica that is sold commercially as Dryacide®. It acts by absorbing the insects' cuticle or protective waxy exterior, causing death by desiccation. Before applying DE for use with pulses, wash and dry the storage and all equipment to be used in the application to remove any residues left from previous years. This will ensure the DE doesn't discolour the grain surface. If applied correctly, with complete coverage in a dry environment, DE can provide up to 12 months of protection for storages and equipment.

Application

Inert dust requires a moving airstream to direct it onto the surface being treated; alternatively, it can be mixed into a slurry with water and sprayed onto surface. Follow the label directions. Throwing dust into silos by hand will not achieve an even coverage, and so will not be effective. For very small grain silos and bins, a hand-operated duster, such as a bellows duster, is suitable. Larger silos and storages require a powered duster operated by compressed air or a fan. If compressed air is available, it is the most economical and suitable option for use on the farm; connect it to a Venturi duster (e.g. Blovac BV-22 gun).

The application rate is calculated at 2 g/m² of the surface area treated. Although DE is inert, breathing in excessive amounts of it is not ideal, so use a disposable dust mask and goggles during application (Table 6).

Table 6: Diatomaceous earth application guide.

Storage capacity (t)	Dust quantity (kg)
20	0.12
56	0.25
112	0.42
224	0.60
450	1.00
900	1.70
1,800	2.60

Source: Stored Grain Project (2013) Hygiene and structural treatments for grain storage. Fact Sheet. Stored Grain Information Hub. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/factsheets/2013/06/grdc-fs-hygienestructuraltreatments>

Silo application

Apply the DE dust from the top of the silo, otherwise open all outlets and apply via the ground access door. Moving the Blovac gun quickly, coat the roof, walls then base of the silo. Finish by closing all outlets, top and bottom, to capture the remaining suspended dust and keep moisture out of the silo.

If silos are fitted with aeration systems, distribute the DE dust into the ducting without getting it into the motor, where it could potentially cause damage.³²

Check with grain buyers before using any product that will come into contact with the stored grain.³³

³² Stored Grain Project (2013) Hygiene and structural treatments for grain storage. Fact Sheet. Stored Grain Information Hub. GRDC, www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

³³ Stored Grain Project (2014) Storing pulses. Grain storage Fact Sheet, GRDC, July 2014, <https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses>

12.13 Fumigation in sealed silos

Hygiene, cleaning storages, treating for insects and managing quality are all part of the comprehensive management and responsibility of growers producing grain for food. With 40% of Australian grain growers storing their product on-farm, understanding how to use fumigants safely is a necessity.³⁴

Aeration and phosphine fumigation are the main methods to control insects in pulses. Controlled atmosphere (inert gases such as carbon dioxide or nitrogen) may be an option. Other grain protectants are not registered for pulses.³⁵

Successful fumigation requires a gas-tight, sealable silo. To be effective against all live insect stages, as well as insects with resistance, fumigants must be held in the silo at a given concentration for a certain period of time. This is only possible in gas-tight, sealable silos (Photo 8).



Photo 8: Unsealed silos are both ineffective and dangerous for fumigants such as phosphine.

Photo: Grain Legume Handbook (2008), Harvesting, module 9, Plate 122, <https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook>

VIDEO

Watch GCTV2: Pressure Testing Sealed Silos, <https://youtu.be/BHKUNjnnhIE>



12.13.1 Pressure testing sealed silos

According to the new Australian Standard AS2628, a silo is only truly sealed if it passes a 5-minute, half-life pressure test. A pressure-relief valve gives a quick means of checking the seal of the silo. During testing, oil levels in the pressure-relief valve must take a minimum of 5 minutes to fall from 25 mm to a 12.5 mm difference. Pressure testing of silos should be carried out:

- when a new silo is erected on-farm;
- when silo is full of grain and before fumigation; and
- as part of the annual maintenance routine.³⁶

See [Section 12.15.1 Testing silos for seal](#).

³⁴ J Severs (2016) Grain storage is about food and safety. Ground Cover™, Issue 123, July-August 2016 <https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-123-JulyAugust-2016/Grain-storage-is-about-food-and-safety>

³⁵ GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions, GRDC, June 2013, <https://grdc.com.au/GRDC-FS-GrainStoragePestControl>

³⁶ C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, <http://storedgrain.com.au/fumigating-with-phosphine-and-ca/>



Photo 9: Pressure-relief valve on a sealable, gas-tight silo gives a quick means of checking the seal of the silo.

Photo: Grains Legume Handbook (2008), Harvesting, module 9, Plate 123, <https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook>

When not to fumigate

Not all silos can be sealed adequately to enable fumigation. An unsealed silo will not hold the fumigant for more than a few minutes, even using a high dosage rate. However, aeration can be added to all silos. Fitting aeration cooling will help immensely with insect control. Aeration coupled with excellent hygiene can overcome many potential insect problems in grain storage. Having at least one sealable, gas-tight silo as a ‘hospital’ bin enables the grower to correctly and effectively manage any insect infestations when detected.

It is illegal and highly dangerous to put phosphine into unsealed systems.

When to fumigate?

Storages should be cleaned prior to filling with new grain (refer to [Section 12.12.1 Grain silo hygiene](#)). However, if there is reason to believe there are stored grain insects in a silo, fumigation should be carried out as soon as possible. This will ensure that all insect stages are eliminated before any grain damage or weight loss occurs. Early harvesting and immediate fumigation will reduce the number of insects in stored pulses.³⁷

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

12.13.2 Using phosphine

Phosphine is the only fumigant currently registered for use in pulses. It is illegal and highly dangerous to put phosphine into unsealed systems.³⁸

Phosphine is the single most relied upon fumigant in the Australian grains industry. Continued misuse is leading to poor insect control and developing resistance (Figure 3). To kill grain pests at all stages of their life cycle (egg, larva, pupa, adult) the only option is to fumigate in a gas-tight, sealed silo. A GRDC survey in 2010 showed that only 36% of users applied phosphine correctly in a gas-tight, sealed silo.

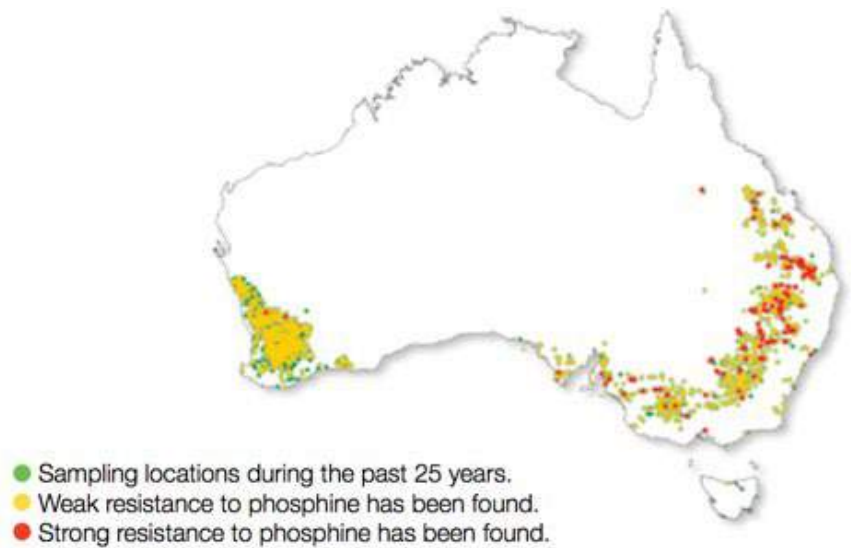


Figure 3: Phosphine resistance in Australia.

Source: DPIRD, Stored Grain Project (2014) Grain Fumigation - a Guide. Grain storage fact sheet, GRDC, January 2014, <https://grdc.com.au/GRDC-FS-GrainFumigationGuide>

Handling phosphine

Phosphine is a highly toxic substance (Schedule 7). To purchase and use phosphine a relevant chemical user registration must be held in the state (or territory) of operation.

Caution should always be used when dealing with phosphine gas as it is not only toxic but also highly explosive. Observe all ventilation and withholding periods for handling and grain use.

Gas respirators suitable for protection against phosphine must be worn. Always open containers of phosphine preparations in the open air. When opened, use the entire contents or dispose of excess chemical. Do not reseal leftover tablets as once they have been exposed to air they will begin to evolve into gas and may become explosive.

Face masks must fit properly for protection. This may be difficult for those with bearded faces, but is essential to avoid poisoning. Appropriate mask maintenance is also essential. For safety reasons, it is best not to work alone when applying phosphine tablets, or inside structures that have been fumigated.³⁹

As a minimum requirement, the label directs the use of cotton overalls buttoned to the neck and wrist, eye protection, elbow-length PVC gloves and a breathing respirator with combined dust and gas cartridge. Operators should work in an open, well-ventilated area with the wind coming from the side.

³⁸ Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

³⁹ Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016, Pulse Australia Limited

Workers must not be exposed more than 4 times per day to more than 1 ppm for longer than 15 minutes, with at least 1 hour between each exposure. And workers must not be exposed to more than 0.3 ppm for more than 8 hours per day or 40 hours per week.

The odour threshold is 2 ppm, so once a worker can smell the phosphine they have already exceeded the safe exposure limit. Workers should wear a personal phosphine monitor that will sound an alarm if more than 0.3 ppm is detected.⁴⁰

Warning signs must be clearly displayed when fumigation is in process (Figure 4). These should have details of when the fumigation commenced, the end date and information on ventilation. Entry into the silo is prohibited during both fumigation and ventilation. Signs should be placed at all storage access points during fumigation.⁴¹

Fumigation success

In order to kill grain pests at all stages of their life cycle (egg, larva, pupa, adult), including pests with strong resistance, phosphine gas levels for fumigation are:

- 300 parts per million (ppm) for 7 days when grain is above 25°C
- 200 ppm for 10 days when grain is between 15–25°C.

Do not use phosphine below 15°C as insects are hard to kill at low temperatures.

Fumigants take longer to distribute in storages with more than a few hundred tonnes capacity unless forced circulation is used.

Fumigation trials in silos with small leaks show that phosphine levels can be as low as 3 ppm close to the leaks, making it impossible to kill insects at all life stages. Poor fumigations may appear to have been successful when dead adults are observed; however, many of the eggs and pupae are likely to survive and will continue to infest the grain.

In addition, insects that survive are more likely to carry phosphine resistance genes, which has serious consequences for future insect control across the entire industry.⁴²

Phosphine application and dosage rates

REFER TO LABEL INSTRUCTIONS.

Phosphine is slightly heavier than air and spreads rapidly. As grain does not absorb phosphine well, phosphine circulates through the stack effectively.

There are two forms of phosphine available for use on-farm: bag chains and tablets.

Bag chains are the safest form, and ensure there is no residue spilt onto the grain.

Tablets are the more traditional form and can be purchased in tins of 100.

Phosphine **blankets** are also available; however, these are designed for bulk storages of 600t or more.

The same amount of phosphine must be applied regardless of the amount of grain in the silo. When using fumigants, the volume of space determines the required amount of fumigant, not the grain in the storage.

The rate of application is the same for all crops:

- using a standard bag chain = 1 bag chain per 75m³
- using tablets = 1.5 g/m³ (equivalent to 3 tablets per 2 m³).⁴³

40 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, <http://storedgrain.com.au/fumigating-with-phosphine-and-ca/>

41 Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016, Pulse Australia Limited

42 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, <http://storedgrain.com.au/fumigating-with-phosphine-and-ca/>

43 Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016, Pulse Australia Limited

Table 7: Recommended rates of phosphine tablets (sealable, gas-tight silo only).

Cubic metres	Bushels	Tonnes	Number of tablets
18	500	14	28
37	1,000	28	56
56	1,500	42	84
74	2,000	56	111
92	2,500	70	138

Source: Grain Legume Handbook (2008), <https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook>

Some silos may also be fitted with purpose-built facilities to apply phosphine from the ground. These must have a passive or active air circulation system. This is so the phosphine gas is carried out of the confined space as it evolves, otherwise an explosion can occur.⁴⁴

Always read and follow label directions when using phosphine. Arrange tablets evenly across trays to expose as much surface area as possible to air so that the gas can disperse freely. Trays should be hung in the head space or placed on the grain surface. Bag chains can be hung in the head space or rolled out flat on top of the grain. Bottom application systems require air-circulation systems to carry the gas out of the confined space as phosphine can reach explosive levels if left to evolve in a confined space.

After fumigation ventilate silos to remove harmful gas residues. Remove tablet residues and bag chains and leave silos open for no less than 5 days, or no less than 1 day with aeration fans operating. A further 2-day withholding period is required before delivering or using for human or animal consumption.

Aeration fans fitted on gas-tight, sealed silos provide a number of benefits including a shorter ventilation period following fumigation.

Always read the Safety Data Sheet (SDS) for more information and the required personal protective equipment (PPE).⁴⁵



Figure 4: A phosphine warning sign must be clearly displayed.

Source: Stored Grain, <http://storedgrain.com.au/phosphine-warning-sign/>

Timing

Minimum fumigation times following application of phosphine are:

- 7 days at grain temperatures above 25°C; and
- 10 days at grain temperatures 15–25°C.

The fumigation period varies from 7 to 20 days depending on temperature and product used. It is important to follow concentration and exposure instruction carefully, as overdosing may reduce the fumigants effectiveness.

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

45 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, <http://storedgrain.com.au/fumigating-with-phosphine-and-ca/>

i MORE INFORMATION

Booklet: *Fumigating with phosphine, other fumigants and controlled atmospheres*, <http://storedgrain.com.au/fumigating-with-phosphine-and-ca/>

GRDC Fact Sheet: Stay safe around grain storage, <https://grdc.com.au/Resources/Factsheets/2011/11/Stay-safe-around-grain-storage>

GroundCover™ article: Effective phosphine fumigation takes time, <https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-119-Nov-Dec-2015/Effective-phosphine-fumigation-takes-time>

Printable phosphine warning sign, <http://storedgrain.com.au/phosphine-warning-sign/>

Do not use phosphine when the grain temperature is below 15°C or when grain moisture is below 9%.

Ventilation after fumigation

If there is only natural air flow moving over the grain, a minimum period of 5 days' ventilation is required to allow the phosphine concentrations to drop to safe levels below 0.3 ppm time weighted average (twa).

The concentration of phosphine can be measured with a multigas detector pump, fitted with a Draeger testing tube for phosphine. This equipment can detect levels of phosphine as low as 0.01 ppm in the air.

The detector is available from Draeger Australia, 8 Acacia Place, Notting Hill, VIC 3168, telephone (03) 1800 647 484, https://www.draeger.com/en_aunz/Home

Disposal

Tablet residues and expended sachets should be swamped with dilute acid or soap water in open air until bubbling ceases and then buried at least 30 cm below the soil surface. The expended tablets should not be piled together as there is a risk they may catch fire.

First aid

If a person is exposed to phosphine gas, they should immediately be moved into the open air and given oxygen treatment if possible. Standard first aid emergency procedures (DRSABC) must be implemented. This may include some to all of the following:

- **Danger** – ensure area is safe
- **Response** – check for alertness
- **Send** for help – dial 000
- Clear **airway**
- Check for **breathing**
- Start **CPR**.

If a phosphine tablet is swallowed, vomiting should be induced as soon as possible. Milk, butter, oils (castor oil) or alcohol should not be consumed.

Accidents are always possible so an emergency plan should be prepared in advance. Ensure all personnel understand first aid treatment for phosphine poisoning. Standard first aid emergency procedures should be displayed as well as emergency phone numbers.⁴⁶

12.14 Alternative fumigants for pulses

If phosphine resistance is suspected other options for fumigation of pulses are limited. These options are more expensive than phosphine and still require a gas-tight, sealable silo.

Controlled atmosphere (CA) options change the balance of natural atmospheric gases to produce a toxic atmosphere. They have the advantage of being non-chemical control options. These are:

- Carbon dioxide (CO₂) – displacing air in storage with a high enough concentration of CO₂ to be toxic to pests. A minimum concentration of 35% CO₂ must be maintained for 15 days.
- Nitrogen – this method is currently under research and not recommended for on-farm use

Other fumigants such as ProFume® and Vapormate® are not registered for pulses.⁴⁷

⁴⁶ J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, <https://grdc.com.au/grainlegumehandbook>

⁴⁷ C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, <http://storedgrain.com.au/fumigating-with-phosphine-and-ca/>

12.15 Sealing silos

The Australian Standard (AS 2628-2010) allows growers to refer to an industry benchmark when purchasing a gas-tight, sealable silo. This standard provides assurance that the silo will perform in the intended manner.

Growers may choose to retro-seal existing farm silos rather than buying new gas-tight silos. Always ensure any retro-sealed silos comply with Australian Standard AS 2628. It is illegal to put phosphine into unsealed systems, hence the importance of retro-sealing. It is important to note that not all silos can be made gas-tight.

Sealing a silo must be carried out with care and attention to achieve a successful outcome. A haphazard approach will be costly in terms of time required to locate and repair any leaks.

Silos that are inadequately sealed lose gas through small holes. This prevents the fumigant reaching and maintaining concentrations necessary for an effective insect kill (Photo 8).

Figures 5 and 6 show how gas is lost from inadequately sealed silos, due to the effects of wind and sun.

Information on sealing and testing silos, cited in this section, is sourced from the Grain Legume Handbook (2008) (<https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook>).

Techniques have been developed that allow farm silos to be sealed to gas-tightness for effective fumigation. Any retro-sealing work undertaken must meet the Australian standard and pass the standard pressure test.

Retro-sealing of silos is not usually recommended. It is recommended to aerate older silos and purchase new silos that have been constructed from start to finish to be gas-tight and meet the standard.

Even if a silo can be sealed gas-tight for fumigation purposes, fitting aeration cooling will help immensely. Aeration, coupled with excellent hygiene, can overcome many potential problems.

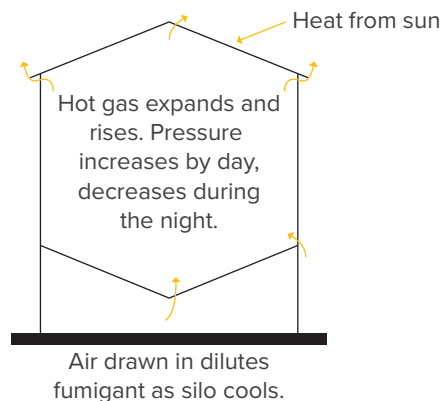


Figure 5: Gas loss through heat effects.

Source: Grains Legume Handbook (2008), <https://grdc.com.au/grainlegumehandbook>

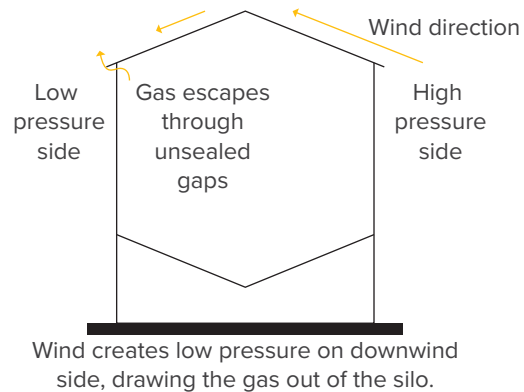


Figure 6: Gas loss through wind effects.

Source: Grains Legume Handbook (2008), <https://grdc.com.au/grainlegumehandbook>

12.15.1 Testing silos for seal

A relief valve fitted to sealable, gas-tight silos can also be used as a gauge for pressure testing. This allows for easy and regular seal tests. The relief valve should be filled to the second line (Figure 8) with light engine oil. Don't use water as it will evaporate. Vegetable oil is also unsuitable as it may react with the phosphine.

Test the silo for gas tightness using the pressure-relief valve (Figures 7 and 8) by applying a '5-minute half-life test'.

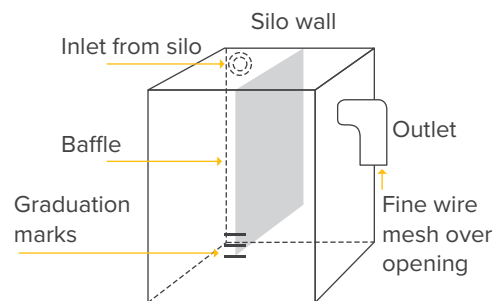


Figure 7: Pressure-relief valve.

Source: Grains Legume Handbook (2008), <https://grdc.com.au/grainlegumehandbook>

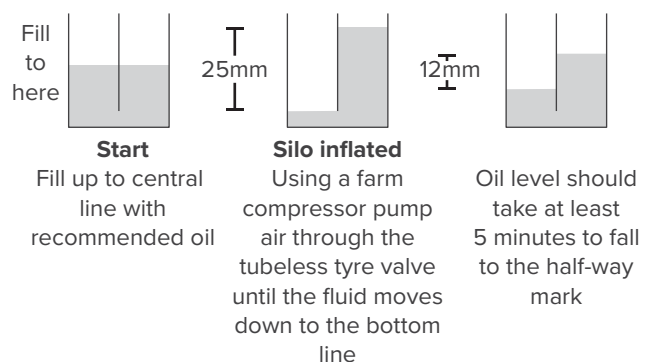


Figure 8: Testing the silo with the pressure-relief valve.

Source: Grains Legume Handbook (2008), <https://grdc.com.au/grainlegumehandbook>

Key points to note are:

- A silo sold as a 'sealed silo' needs to be pressure tested to ensure it is gas-tight.
- Check new sealable, gas-tight silos for Australian Standard pressure sealing compliance (AS2628).
- Pressure test sealed silos upon erection, annually, and before fumigating with a '5-minute half-life pressure test'.
- Maintenance of a quality, sealable, gas-tight silo is the key to ensuring a silo purchased as gas-tight maintains its gas-tight status.

Method of testing

Pressurise the silo using an air compressor, along with a tubeless tyre valve that is fitted to the silo wall.

This is done until a 25 mm difference is achieved in the heights of the fluid columns (or 250 Pascals); this should only take a few minutes.

The pressure fall to 12 mm (125 Pascals) is then timed; it should not be less than 5 minutes.

This seal test should only be conducted when weather conditions are stable, as fluctuations in the temperature, strength of sunlight or windy conditions can affect the readings. The best times for testing are early morning before heating or between 1 p.m. and 3 p.m., when temperatures are usually stable.

If the difference in fluid levels falls to 12 mm in less than 5 minutes, then this indicates an air leak. This will need to be found and sealed before fumigation can be effective.

All hatches should be checked first to ensure they are sealing properly. Then leaks in other parts of the silo can be located by applying a soapy solution to suspect areas: bubbles will indicate an air leak.

Alternatively, a boat flare may be released inside the silo (Photo 8). It is important to ensure the silo is free of grain dust as it is explosive.

When pressurising the silo, care must be taken to not exceed a difference of 30 mm in fluid levels. This high level of relief valve operation could damage the structure.

Every time sealing of a silo is undertaken, pressure testing must be done by following the above method.

When a sealable, gas-tight silo is not being used for fumigation, leave the top lid slightly open. When empty, leave the top lid and bottom hatch slightly open.⁴⁸

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

Environmental issues

Key points

- Field pea crops are most vulnerable to frost during reproductive phases of flowering, pod-set and grain-fill. Field pea varieties range in flowering time and duration, so select varieties to best suit your conditions.
- Avoid growing field pea on poorly drained soils and areas prone to waterlogging.
- Field pea respond well to minimum temperatures not less than 7°C during establishment and canopy expansion and 25°C and less during critical reproductive phases.

VIDEO

Watch GCTV20: Extreme Temperature Analysis to Better Understand Frost Events,
<https://youtu.be/Zw637FiX5PU>



VIDEO

Watch GCTV3: Frost R&D
<https://youtu.be/og9wPzjchjA>



VIDEO

Watch GCTV20: Frost's emotional impact, is it greater than its economic impact?
<https://youtu.be/GC2P2Tha5Es>



13.1 Frost issues for pulses

Radiant frost can be a major stress to crops, and one of the principal limiting factors for agricultural production worldwide, including Australia. Radiant frosts occur when plants and soil absorb sunlight during the day and radiate heat during the night when the sky is clear and the air is still. Dense, chilled air settles into the lowest areas of the canopy, where the most serious frost damage occurs. The cold air causes nucleation of the intracellular fluid in plant tissues, and this causes the plasma membrane to rupture.¹ Legumes, including chickpea, field pea, faba bean and lentil, are very sensitive to chilling and freezing temperatures, particularly at the stages of flowering, early pod formation and seed filling, although damage may occur at any stage of development.

Frosts (or isolated freezing events) are a problem for chickpea (Figure 1) in southern Australia, especially when they occur in the late vegetative and reproductive phenological (climate-induced developmental) stages, and the air temperature drops to 2°C or less on clear nights in early spring. They occur most frequently after the passing of a cold front, when the moisture and wind dissipates, leaving cold and still conditions with clear skies.

Areas of high frost risk in southern Australia include the Eyre Peninsula, Murray Mallee and Mid North of South Australia, and the Wimmera–Mallee region of Victoria. Over the past few years, the worst-affected areas have had crop production losses close to 100%.²

The occurrence and extent of frost damage tends to be affected by the microclimate, with great variability occurring within paddocks and even on the same plant. Therefore, soil type, soil moisture, position in the landscape, and crop density can have a bearing on the damage caused by a frost. In some species, crop nutrition has been shown to mitigate the effect of freezing-range temperatures on the plant. It is thought that fertilisation of the plant, and consequent fast growth rates, can exacerbate the effect of freezing, particularly on the part of the plant undergoing elongation.

13.1.1 Industry costs

Crop losses due to frost are estimated to average more than \$33 million a year in SA and Victoria, and over the whole of Australia may cost the grains industry, on average, more than \$100 million a year.³ The real cost of frost is a combination of the monetary cost due to both reduced yield and quality, and the hidden cost of management tactics used to minimise frost risk. These include:

- delaying sowing and its associated yield reduction;
- sowing less-profitable crops such as barley and oats; and
- avoiding cropping on valley floors, which are among the most productive parts of the landscape.

13.1.2 Impacts on field pea

Field pea is considered to be one of the more sensitive pulses to frost damage during reproduction.

Pod-set and grain-fill are affected by even mild frosts, so that overall frost damage can be great.

Pea varieties differ in flowering time (early to late) and duration (short to an extended flowering). Some pea varieties may escape a total loss to frost with their extended flowering (e.g. Parafield). Other late flowering varieties may escape early frost periods (e.g. Morgan^{db}, Mukta). Some varieties can occasionally be extremely vulnerable if they flower over a very short period (e.g. Kaspas^{db} as a late flowering pea, Excel as an early flowering type).

¹ A Maqbool, S Shafiq, L Lake (2010) Radiant frost tolerance in pulse crops: a review. *Euphytica* 172 (1), 1–12

² M Rebbeck, G Kneil (2007) Managing frost risk: a guide for southern Australian growers. SARDI, GRDC.

³ M Rebbeck, G Kneil (2007) Managing frost risk: a guide for southern Australian growers. SARDI, GRDC

i MORE INFORMATION

GRDC Tips and Tactics Managing frost risk (all regions), https://grdc.com.au/_data/assets/pdf_file/0027/208674/grdc-managing-frost-risk-tips-and-tactics-frost-050216-northern-southern-and-western-region.pdf.pdf

Pulse Australia (2015) Minimising frost damage in pulses. Australian Pulse Bulletin, Updated 20 November, <http://pulseaus.com.au/growing-pulses/publications/minimise-frost-damage>

W Hawthorne (2007) Managing Pulses to Minimise Frost Damage. Australian Pulse Bulletin PA 2007 #01, http://www.pulseaus.com.au/storage/app/media/crops/2007_APB-Pulses-frost.pdf

Conventional, trailing type peas in the field appear less frost sensitive than many of the shorter, erect semi-leafless types (e.g. Sturt, Parafield by comparison with Kaspá⁴).

Physical damage from traffic or herbicides on frosted peas during the pre-flowering stages can leave the peas far more vulnerable to the spread of the disease bacterial blight, an additional complication with frost damage in peas.⁴

Symptoms of frost damage in field pea (Photo 1):

- Flowers are killed by frost.
- Developing seeds in the pod are shrivelled or absent.
- White/green mottling and blistering of pods.
- Affected pods feel 'spongy' and the seeds inside turn brown/black.⁵



Photo 1: Frost-damaged seeds are shrivelled and the seeds inside pods turn brown/black.

Photo: DPIRD (2014), B Biddulph (2015) Diagnosing frost in field peas, <https://www.agric.wa.gov.au/mycrop/diagnosing-frost-field-peas>

13.1.3 Managing to lower frost risk

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 help reduce exposure to frost or impact at vulnerable growth stages of the pulse.
- Choose the appropriate crop type, variety and sowing time.
- Small changes in temperature around the critical trigger point can help avoid frost damage, so manage the pulse canopy, row spacing and any cereal stubble retained.
- Understand the impact of soil type, condition and moisture status.
- Manage crop nutrition and minimise crop stress level to lessen frost damage.
- Map the topography to show areas of greatest risk, and specifically manage these areas to minimise frost damage.⁶

Problem areas and timing

Mapping or marking areas identified as frost-prone will enable growers to target frost and crop management strategies to these high-risk areas.

Knowing when the period of greatest probability of frost occurs is also important for crop management.

⁴ W Hawthorne (2007) Managing Pulses to Minimise Frost Damage, Australian Pulse Bulletin PA 2007 #01

⁵ B Biddulph (2015) Diagnosing frost in field peas. Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/mycrop/diagnosing-frost-field-peas>

⁶ W Hawthorne (2007) Managing Pulses to Minimise Frost Damage, Australian Pulse Bulletin PA 2007 #01, http://www.pulseaus.com.au/storage/app/media/crops/2007_APB-Pulses-frost.pdf

Crop and sowing time

The main strategy used to minimise frost risk in broadacre cropping has been to sow crops later. Risks exist with delayed sowing, even though this practice can reduce the probability of crops flowering in a frost-risk period. Crops sown later can still be affected by frost. Strategies to minimise frost damage in pulses work in combinations of:

- growing a more tolerant species;
- trying to avoid having peak flowering and early podding during the period of most risk;
- extended flowering to compensate for losses to frost; and
- ensuring that most grain is sufficiently filled to avoid damage when frost occurs.

Targeting flowering and early podding to periods of the lowest probability of frost is achieved through combinations of sowing date and variety choice based on flowering time and flowering duration. Local experience will indicate the best choices. By planting for late flowering, farmers target the avoidance of early frosts, but in the absence of frost, late flowering may reduce yields if moisture is deficient or there are high temperatures. Very early flowering can allow pods to be sufficiently developed to escape frost damage, and ensure some grain yield at least before a frost occurs. Increased disease risk needs to be considered with early sowing.

Spread the risk

Match different pulses to risk areas by sowing a different variety or species into targeted areas within the same paddock. Matching the crop, variety, sowing date and subsequent inputs to the frost-risk location spreads the risk.

Have forage as an optional use. Designating hay or forage as a possible use for the pulse in paddocks with a high frost risk provides flexibility.

Mixing two pulse varieties (e.g. long and short season, tall and short) balances the risks of frost and of end-of-season (terminal) drought, and reduces the risk of losses from any one frost event. Multiple frost events can damage both varieties. If grain from both varieties is not of the same delivery grade, then only the lowest grade is achieved. The only realistic, practical options are in pea, narrow-leaf lupin, kabuli chickpea; perhaps desi chickpea are an option. Differences in flowering times are minimal in lentil and bean.

Sowing a mixture of pulse species is feasible, but not common. Complications in crop choice include achieving contrasting grain sizes, herbicide requirements, harvest timing and grain cleaning. Multiple frosts may damage both crops. Pulses grown in a mix will be suitable for feed markets only if they can be cleaned to enable purity in segregation. If these difficulties can be overcome there is an opportunity for alternate-row sowing of different pulses.

Reduce frost damage

Managing inputs. To minimise financial risk in frost-prone paddocks when growing susceptible crops, growers can:

- Apply conservative rates of fertilisers to frost-prone parts of the landscape.
- Avoid using high sowing rates.

Advantages of avoiding high inputs are:

- Less financial loss if the crop is badly frosted.
- Lower-input crops, though potentially lower yielding during favourable seasons, are less like to suffer severe frost damage than higher-input crops with a denser canopy.
- Input costs saved on the higher frost-risk paddocks may be invested in other areas where frost risk is lower.

Lower sowing rates may result in a less dense canopy that increases crop tillering and may allow more heating of the ground during the day, and transfer of this heat to the canopy at night. However, there is no hard evidence that lower sowing rates will

reduce frost damage. The main disadvantage of this practice is that in the absence of frost, lower grain yield and/or protein may be the result during favourable seasons, contributing to the hidden cost of frost. (This is a particular disadvantage in barley and wheat delivery grades.) Less-vigorous crops can also result in the crop being less competitive with weeds.

Managing nodulation and nutrition. Ensure pulse crops are adequately nodulated and fixing nitrogen. Ensure pulses have an adequate supply of trace elements and macronutrients, although supplying high levels is unlikely to increase frost tolerance. Crops deficient or marginal in potassium and copper are likely to be more susceptible to frost damage, and this may also be the case for molybdenum. Foliar application of copper, zinc or manganese may assist, but only if the crop is deficient in the element applied.

Managing the canopy. A bulky crop canopy and exposure of the upper pods may increase frost damage to pulses. Semi-leafless, erect peas may be more vulnerable than conventional, lodging types because their pods are more exposed. A mix of two varieties of differing height, maturity and erectness may also assist in reducing frost damage.

Sow in wider rows, so that frost is allowed to get to ground level and the inter-row soil is more exposed. An open canopy does not trap cold air. Wide rows require the soil to be moist to trap the heat in the soil during the day. With wide or paired rows and a wide gap, the heat can radiate up, however this may not always be effective.

Channel cold air flow away from the susceptible crop by using wide rows aligned up and down the hill or slope. Where cold air settles, a sacrifice area may be required.

The presence of cereal stubble makes the soil cooler in the root zone, worsening the frost effect compared with bare soil. Standing stubble is considered less harmful than slashed stubble as less light is reflected and the soil is more exposed to the sun. Dark-coloured stubble will be more beneficial than light-coloured types.

Rolling can help keep soils warm by slowing soil-moisture loss, but not necessarily on self-mulching or cracking soils. Note that press-wheels roll only in the seed row, and not the inter-row. With no-till practice, avoid having bare, firm, moist soil as it will lose some of its stored heat.

Claying or delving sandy soils increases the ability of the soil to absorb and hold heat by making the soil colour darker, and retaining moisture nearer the surface.

Higher carbohydrate levels in plants during frost leads to less leakage during thawing. A higher sugar content (high Brix) will also have a lower freezing point, and associated protection against frost damage. The effectiveness of various products applied to soil and plants to increase plant carbohydrates is unknown.

Better varieties coming. Through Pulse Breeding Australia, the GRDC is investing in germplasm enhancement and variety breeding to increase frost tolerance in pulses. The focus is on altered flowering time and duration to avoid frost, and screening of pulse varieties for relative levels of frost tolerance in the field. New varieties will be released when available.⁷

A 5-year research project funded by the GRDC examined the effects of agronomic practices on frost risk in broadacre agriculture in southern Australia. The researchers manipulated the soil heat bank to store heat during the day and release heat into the canopy of the crop at night. The research examined how the crop canopy could be manipulated to allow for warm air from the soil to rise and increase the temperature at crop head height (Figure 1). They have identified strategies that could be used to significantly reduce the impact of frost.

⁷ Pulse Australia (2015) Minimising frost damage in pulses. Australian Pulse Bulletin, Updated 20 November, <http://pulseaus.com.au/growing-pulses/publications/minimise-frost-damage>

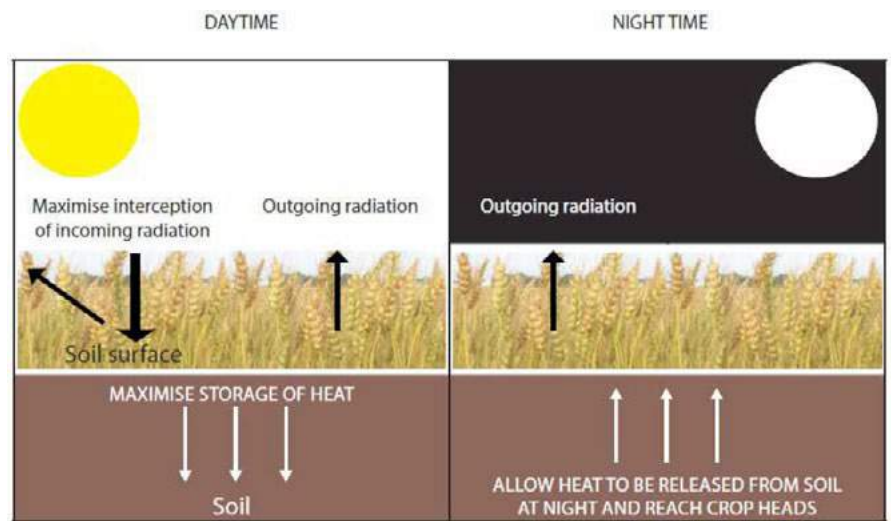


Figure 1: Temperature dynamics in a crop canopy and canopy interactions.

Source: Rebbeck and Knell (2007)

Importance of soil moisture

Soil moisture is the most important factor for storing soil heat that will be released to and through the crop canopy at night. Because water has a high specific heat, radiation cooling overnight will be reduced when moisture is present in the soil. On a daily basis, heat is transferred into and out of approximately the top 300 mm of soil. When the soil is wet, heat transfer and storage in the upper soil layer is higher, so more heat is stored during daytime for release during the night.

There is also some evidence that moist soils can retain their warming properties for more than 24 hours, allowing some scope for an accumulation of heat from sunlight for more than one day. Heavier-textured soils hold more moisture (and therefore heat) than lighter-textured soils. A more dense soil can hold more moisture within the soil surface for heat absorption and subsequent release. Darker soils also absorb more light energy than lighter soils. Water-repellent sandy soils are usually drier at the surface than normal soils, and are therefore more frost-prone. Frost studies in SA have found that crops were likely to be more damaged on lighter soil types because the soil temperature is lower as a result of lower soil moisture and the more reflective nature of these soils. On such soils, clay spreading or delving may be an option for reducing frost risk.

Use of agronomic practices

Table 1 shows the rankings of agronomic practices, adopted in both SA and WA, in order of importance. The table shows the paddock-management strategies that manipulate the soil heat bank or manipulate the canopy air flow within the paddock, followed by paddock management strategies that also may assist crops to better tolerate frost. The final column in the table shows the reduction in frost damage from adopting these various practices in frost prone regions (derived from project trials).

The frost-avoidance strategies described in [Table 1](#) are whole-farm approaches to reduce or spread risk of frost injury.⁸

8 M Rebbeck, G Knell (2007) Managing frost risk: a guide for southern Australian growers. SARDI, GRDC

SECTION 13 FIELD PEA

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[FEEDBACK](#)

Table 1: Agronomic practices to reduce frost risk ranked in order of importance.

Soil heat bank manipulation ranking	Description	Increased temp. at canopy height (average) (°C)	Reduction in frost damage
Clay delving or clay spreading	In soils with a sandy surface, clay delving increases heat storage, nutrient availability and infiltration rate. Reducing frost risk by increasing the clay content of sandy-surfaced soils is the strongest finding in South Australia.	1.0	Up to 80%
Rolling	Rolling sandy soil and loamy clay soil after seeding has reduced frost damage, although the results were not statistically significant.	0.5	Up to 18%
Removing stubble	Removing stubble had a negligible effect on yield and frost risk. The role stubble plays in retaining soil moisture could be more important.	0.5	Minimal
Manipulation of the crop canopy ranking	Description	Increased temp. at canopy height (ave) (°C)	Reduction in frost damage
Blending varieties and variety selection	Blending long and short-season wheat varieties is a way to hedge your bets against frost or end-of-season drought within a paddock. A similar risk profile occurs when sowing one paddock with each variety at the same time. Successful results have been achieved in SA and WA blending Krichauff or Wyalkatchem [®] with Yitpi [®] . Certain varieties, such as Yitpi [®] , Stiletto and Camm [®] , flower later. Long-season varieties frequently avoid frost by flowering later in the growing season, when frost incidence is less. To further reduce frost risk, these varieties should be sown towards the middle or end of a wheat sowing program rather than first.	0.0	Yitpi [®] 12% less damaged than Krichauff
Cross-sowing	Crops sown twice with half the seed sown in each run gives an even plant density and has been found to more slowly release soil heat so that it can have an impact on air temperature at head height in early morning when frosts are most severe. This practice will incur an increased sowing cost. This result is based on two trials in WA.	0.6	13%
Soil heat bank manipulation ranking	Description	Increased temp. at canopy height (average) (°C)	Reduction in frost damage
Wide row spacing	Wide row sowing (e.g. 230–460 mm spacings) were ineffective in reducing frost damage. Wide row crops consistently yield 10–15% less than the standard sowings with or without frost. In the presence of minor or severe frost, frost damage was similar for normal and wide row spacings.	0.2	0
Lower sowing rate	A lower sowing rate (35–50 kg/ha) on frost-prone paddocks has not yet been proven to minimise frost damage. In WA, the plants in thinner crops appear more robust and able to better withstand frost events. The extra tillers formed per plant spread flowering time over a longer window. However, the crop is less competitive with weeds.	0.0	0

Source: Rebbeck and Knell (2007)

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FEEDBACK

VIDEO

Watch Managing the effects of frost
https://youtu.be/z_QN6MvnIss



MORE INFORMATION

GRDC Tips and Tactics: Managing frost risk (all regions),
https://grdc.com.au/_data/assets/pdf_file/0027/208674/grdc-managing-frost-risk-tips-and-tactics-frost-050216-northern-southern-and-western-region.pdf.pdf

13.1.4 Managing frost-affected crops

There are a number of options available for managing crops that have been frosted (Table 2). The following table highlights these options and the pros and cons of each. The suitability of each option will depend on the severity of the frost and analysis of costs versus returns.⁹

Table 2: Options for managing frosted crops.

Option	Advantages	Disadvantages
Harvest	No damage estimates required. Salvage remaining grain. Condition stubble for seeding.	Costs may be greater than returns. Need to implement weed control. Threshing problems. Need to remove organic matter.
Hay / silage	Stubble removed. Weed control.	Cost per hectare. Quality may be poor (especially wheat).
Chain / rake	Retains some stubble and reduces erosion risk. Allows better stubble handling.	Cost per hectare. Time taken.
Graze	Feed value. Weed control.	Inadequate stock to utilise feed. Remaining grain may cause acidosis. Stubble may be difficult to sow into.
Spray	Stops weed seedset. Preserves feed quality for grazing. Gives time for decisions. Retains feed. Retains organic matter.	Difficulty getting chemicals onto all of the weeds with a thick crop. May not be as effective as burning. Boom height limitation. Cost per hectare. Some grain still in crop.
Plough	Recycles nutrients and retains organic matter. Stops weed seed set. Green manure effect.	Requires offset discs to cut straw. Soil moisture needed for breakdown and incorporation of stubble.
Swath	Stops weed seedset. Windrow can be baled. Regrowth can be grazed. Weed regrowth can be sprayed.	Relocation of nutrients to windrow. Low market value for straw. Poor weed control under swath. Cost per hectare.
Burn	Recycles some nutrients. Controls surface weed seeds. Permits recropping with disease control. Can be done after rain.	Potential soil and nutrient losses. Fire hazard. Organic matter loss.

Source: DPIRD, <https://www.agric.wa.gov.au/frost/managing-frost-risk>

⁹ DPIRD (2017) Frost and cropping, <https://www.agric.wa.gov.au/frost/managing-frost-risk>

13.2 Waterlogging

Field pea is susceptible to waterlogging. Crops sown on hard-setting soils can suffer from waterlogging as they tend to be poor draining. Waterlogging causes insufficient oxygen in the soil pore space for plant roots to adequately respire. Root-harming gases such as carbon dioxide and ethylene also accumulate in the root zone and affect the plants.¹⁰

Germinating seed is very susceptible to waterlogging. Poor crop establishment is common when waterlogging occurs at seedling emergence. Waterlogging 6 days after germination of field pea can delay the emergence by up to 5 days and reduce the final plant density by 80%. Waterlogging depresses vegetative growth of plants but affects root growth more than shoot growth.¹¹

Plants can show symptoms of iron and or nitrogen deficiency. Plants can appear to survive waterlogging then die prematurely in spring because damaged root systems cannot access subsoil moisture. Nodulation may be affected due to extended waterlogging. Roots have reduced growth then turn brown and die (Photo 2). The plant can compensate with new roots emerging from the hypocotyl.

13.2.1 Minimising waterlogging in field pea

Management strategies may include:

- Avoid growing field pea on poorly drained soils and areas prone to waterlogging.
- Improve drainage and movement of water away from the pea paddock.
- Delay sowing in higher rainfall areas.
- Sow into raised beds.¹²



Photo 2: Brown roots may have poor nodulation and root death.

Photo: DPIRD (2015), D Bakker (2015) Diagnosing waterlogging in narrow-leaved lupins and field peas, Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-narrow-leaved-lupins-and-field-peas>

Plants are more susceptible to root and foliar diseases, and may be more affected by aphids when subjected to waterlogging.

Salinity magnifies the effects of waterlogging, with more marked stunting and leaflets on oldest leaf tip dying back from the tip.¹³

¹⁰ D Bakker (2015) Diagnosing waterlogging in narrow-leaved lupins and field peas. Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-narrow-leaved-lupins-and-field-peas>

¹¹ K Siddique. Abiotic stresses of cool season pulses in Australia. University of Western Australia, <http://www.farmtrials.com.au/trial/13486>

¹² GRDC (2009) Field Pea: The Ute Guide, Southern region. GRDC Ground Cover Direct

¹³ D Bakker (2015) Diagnosing waterlogging in narrow-leaved lupins and field peas. Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-narrow-leaved-lupins-and-field-peas>

13.3 Moisture and heat stress

Moisture stress is a major constraint in all pulse-growing regions of Australia, particularly in the low rainfall areas. From a practical point of view, it is difficult to separate moisture stress and heat stress and they generally occur simultaneously. The types of moisture stress that affect pulse production in Australia are: lack of or low opening rainfall at planting, intermittent moisture stress by breaks in winter rainfall and the terminal moisture stress, resulting from receding soil moisture and increasing high temperature in spring.

Terminal moisture stress is the most common form of moisture stress experienced by cool season pulses in Australia. The severity of terminal moisture stress depends upon the amount and distribution of rainfall, capacity of the soil to store moisture and the evaporative demand of the atmosphere. There are two major effects of moisture stress on pulse productivity: failure to establish the desired plant stand; and reduction in growth and yield due to suboptimal soil moisture availability.

Moisture stress during vegetative stages of growth rarely occurs in winter crops when vegetative growth occurs during cooler periods of the year and when plant moisture demand is low. Flowering is the most sensitive stage to moisture stress.¹⁴

Field pea is one of the better legumes at tolerating drought or moisture limiting conditions. However, a lack of growing-season rainfall can lead to poor establishment, growth (lower biomass) and very short crops, resulting in harvesting difficulties.

Warm, windy weather with dry conditions in spring can result in reduced flower-set, poor grain-fill, smaller grain and low yield, particularly under low soil moisture conditions.¹⁵

Detailed studies of field pea have showed a negative correlation between grain number, the main yield component and the cumulative temperature over 25°C between beginning of flowering and the final stage in seed abortion for the last seed-bearing phytomer.¹⁶



Photo 3: Field pea prematurely wilted by hot winds.

Photo: W. Hawthorne, formerly Pulse Australia

14 K Siddique (1999) Abiotic stresses of cool season pulses in Australia. University of Western Australia, <http://www.farmtrials.com.au/trial/13486>

15 GRDC (2009) Field Pea: The Ute Guide, Southern region. GRDC Ground Cover Direct

16 V Sadras, L Lake, K Chenu, L McMurray, A Leonforte (2012) Water and thermal regimes for field pea in Australia and their implications for breeding. Crop and Pasture Science, Jan 2012, https://www.researchgate.net/profile/Victor_Sadras/publication/230626089_Water_and_thermal_regimes_for_field_pea_in_Australia_and_their_implications_for_breeding/links/0c960525f4091c3f83000000.pdf

It should be pointed out that the Kaspas-type field pea varieties are resistant to shattering because of their sugar-pod trait. However, the pod walls do break down over time and expose the seed inside the pod to weather damage. Kaspas[®] grain has been sun and heat burnt when left unharvested in the pod (Photo 4).



Photo 4: Kaspas[®] field pea grain that has been sun and heat burnt through the sugar-pod wall. Normal grain (top) and with different severities of burn (below).

Photo: W. Hawthorne, formerly Pulse Australia

13.3.1 Minimising effects of drought

Management strategies may include:

- sow early in the sowing period in early-maturing areas;
- sow early-maturing varieties; and
- retain stubble cover from previous crops (standing or mulch) to minimise moisture loss.¹⁷



Photo 5: *Field pea droughted and affected by frost.*

Photo: Hawthorne, formerly Pulse Australia



Photo 6: *Field pea sown into stubble to minimise soil moisture loss.*

Photo: W. Hawthorne, formerly Pulse Australia

¹⁷ GRDC (2009) Field Pea: The Ute Guide, Southern region. <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/04/field-peas-the-ute-guide>

13.4 Other environmental issues

13.4.1 Salinity

One of the most significant causes of soil degradation in Australia is salinity, which is the presence of dissolved salts in soil or water. It occurs when the watertable rises, bringing natural salts to the surface. In sufficient quantity, the salts become toxic to most plants. They cause iron toxicity in plants and impede their ability to absorb water. Salinity, a major abiotic stress, is a major environmental production constraint in many parts of the world. In Australia, saline soils have

been caused by extensive land clearing, predominantly for agricultural purposes.

Field pea is sensitive to waterlogging and moderately sensitive to soil salinity. Soil salinity affects plant growth by reducing the roots' ability to extract water from the soil. Soil salinity damage varies from season to season due to variations in soil salt concentration. Waterlogging increases salinity damage. See [Section 2.1.4 Salinity](#).

13.4.2 Soil pH

Soil acidity is measured in pH units. Soil pH is a measure of the concentration of hydrogen ions in the soil solution. The lower the pH of soil, the greater the acidity. pH is measured on a logarithmic scale from 1 to 14, with 7 being neutral. A soil with a pH of 4 has 10 times more acid than a soil with a pH of 5 and 100 times more acid than a soil with a pH of 6.

The ideal pH range for field pea is (water) 6.0–9.0. Field pea can be sensitive to high levels of exchangeable aluminium (Al) in acid soils. They will tolerate levels of 5–10% exchangeable aluminium. Acid soils can significantly reduce production and profitability before paddock symptoms are noticed.

Low soil pH often leads to poor or ineffective nodulation in pulses because acid soil conditions affect rhizobia survival in the soil. Field pea, faba bean, lentil and chickpea are vulnerable, as are vetches.¹⁸

For more information, see [Section 4.8 Inoculation](#).

Acid soils

Acid soils can significantly reduce production and profitability before paddock symptoms are noticed. Danger levels for crops are when soil pH is <5.5 (in CaCl₂) or 6.3 (in water). Monitor changes in soil pH by testing the soil regularly. If severe acidity is allowed to develop, irreversible soil damage can occur. Prevention is better than cure, so apply lime regularly in vulnerable soils. The most effective liming sources have a high neutralising value and a high proportion of material with a particle size <0.25 mm. More lime is required to raise pH in clays than in sands. Liming can induce manganese deficiency where soil manganese levels are already marginal. Low soil pH often leads to poor or ineffective nodulation in pulses because acid soil conditions affect initial numbers and multiplication of rhizobia. Field pea, faba bean, lentil and chickpea are vulnerable, as are vetches. Lupin is an exception because its rhizobia (Group G) is acid-tolerant. Granular inoculums seem to provide greater protection to rhizobia in acid soils.

Between pH 5.5 and 8 (CaCl₂) is the ideal pH range for plants. Soil pH targets are 5.5 in the topsoil (0–10 cm) and >4.8 in the subsurface soil (10 cm and below). At pH 4.8 (CaCl₂) or lower, levels of aluminium in the soil become toxic ([Figure 2](#)). Free aluminium has a large impact on crop yield. It reduces root growth, which in turn reduces the depth of soil the plant has access to.

¹⁸ GRDC (2015) Field pea GrowNotes™, Northern. <https://grdc.com.au/GrowNotes>

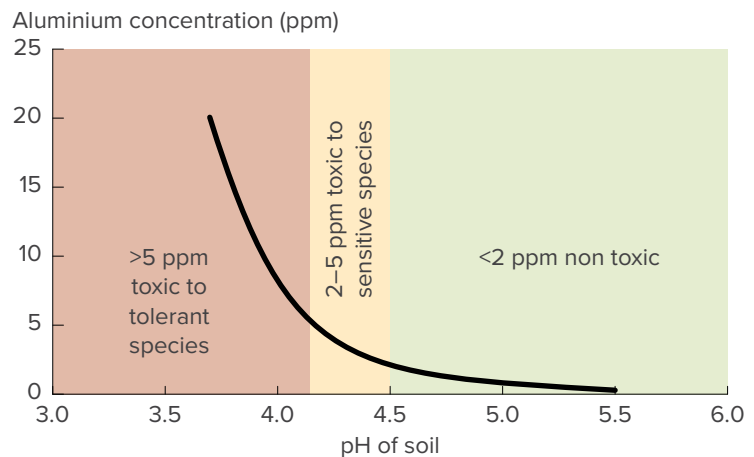


Figure 2: Aluminium (Al) and pH graph with rule of thumb Al toxicity.

Source: Soil quality (2017), P Caszey (2017). Soil Acidity Fact Sheet. Soilquality, <http://soilquality.org.au/factsheets/soil-acidity>

In terms of lime movement through the soil, a pH of 5.5 is required in the top 0–10 cm of soil before lime can influence any soil deeper than this. Lime applied to the surface will be worked in with the traffic of the seeding implement. This creates a layer where the pH is ameliorated to the depth of the seeding point but no further. Lime must be in contact with the soil of low pH in order to react. This layering effect has an impact on yield potential of rotation crops and pastures. An ameliorated surface, above pH 5.5 (CaCl_2), and subsurface with pH below 4.8 (CaCl_2) reduces the yield potential of rotation crops and the efficacy of N fixation. After lime has been applied, the subsurface pH will remain unchanged until the lime is able to leach through the profile.

It is difficult to make the correct decisions on soil treatment and crop choice if you do not have full knowledge of the soil pH to depth. This is particularly so when the crop is susceptible to low pH or aluminium toxicity, as are break crops such as field pea. Poor yields of these rotation crops may be the result of low pH at depth, in spite of good pH at the surface.¹⁹

Alkaline soils

Soil alkalinity is mainly caused by bicarbonates and carbonates, although phosphates, borates and some organic molecules can also contribute. In a soil with pH 7.0–8.2, bicarbonates and carbonates of calcium and magnesium dominate.

Calcareous soils contain from 1–90% lime material as calcium carbonates, and these sparingly soluble salts cause the soil to have a pH of 8.0–8.2, which is not a severe problem for plant growth or agricultural production.

Problems are encountered in alkaline soils when sodium occurs or accumulates and forms salts such as sodium bicarbonate and sodium carbonate. These are highly soluble and increase the soil pH above 8.

When the pH is more than 9, the soils are considered to be highly alkaline and often have toxic amounts of bicarbonate, carbonate, aluminium and iron. The high amount of exchangeable sodium in these soils reduces soil physical fertility, and nutrient deficiency is also likely to be a major problem.

In alkaline soils, the abundance of carbonates and bicarbonates can reduce crop growth and induce nutrient deficiencies. The presence of free lime has a major impact on lupin growth, inducing iron and manganese deficiency, which cannot be corrected by foliar sprays of those nutrients.²⁰

¹⁹ GRDC (2017) Chickpea GrowNotes™, Southern. <https://grdc.com.au/GrowNotes>

²⁰ P Rengasamy (n.d.) Soil pH—South Australia. Fact sheet. Soilquality, <http://www.soilquality.org.au/factsheets/soil-ph-south-austral>

Managing soil pH

- Growers are applying more lime per hectare than in the past but, in many cases, much more lime is needed to replenish the soil profile.
- Liming to remove soil acidity as a production constraint can also bring the benefits of increasing yields, increasing crop and pasture choice, and helping to protect the soil resource.

Soil acidification is an ongoing issue

Soil acidification is an ongoing and unavoidable result of productive agriculture. The main practices that cause soil acidification include the removing of products by harvest (Photo 6) and the leaching of nitrate from soil. Because soil acidification is an ongoing consequence of farming, management also needs to be ongoing.²¹



Photo 7: Hay production, especially legume hay, is one of the most acidifying practices.

Photo: Soil Quality Pty Ltd, <http://www.soilquality.org.au/factsheets/managing-soil-acidity-western-australia>

Acid soils

Acid soils can be economically managed by the addition of agricultural lime, usually in the form of crushed limestone. Sufficient lime should be added to raise the pH to above 5.5. The amount of lime required to ameliorate acid soils will vary, depending mainly on the quality of the lime, the soil type and how acidic the soil has become.

Soils prone to becoming acidic will need liming every few years. Seek advice on an appropriate liming regime from your local agricultural adviser.

Alkaline soils

Treating alkaline soils by the addition of acidifying agents is not generally a feasible option due to the large buffering capacity of soils and uneconomic amounts of acidifying agent (e.g. sulfuric acid, elemental sulfur or pyrites) required.

Gypsum will reduce sodicity and this can reduce alkaline pH to some extent. Growing legumes in crop rotations may help in sustaining any reduction in pH.

In high-pH soils, using alkalinity-tolerant species and varieties of crops and pasture can reduce the impact of high pH.²²

²¹ C. Grazev, J. Carson (n.d.) Managing soil acidity—Western Australia Fact sheet. Soilquality

²² P. Rengasamy (n.d.) Soil pH—South Australia. Fact sheet. Soilquality, <http://www.soilquality.org.au/factsheets/soil-ph-south-austral>

13.4.3 Sodicty

Sodic soils occupy almost one-third of the land area of Australia. Sodicty has serious impacts on farm production, as well as significant off-site consequences such as:

- surface crusting;
- reduced seedling emergence;
- reduced soil aeration;
- increased risk of run-off and erosion;
- less groundcover and organic matter; and
- less microbial activity.

Sodic soils are known as dispersive clays and reduce seedling emergence (Figure 4). Sodic soils are can lead to tunnel erosion: they turn to slurry when wet, and channels are easily created through them by moving water.²³

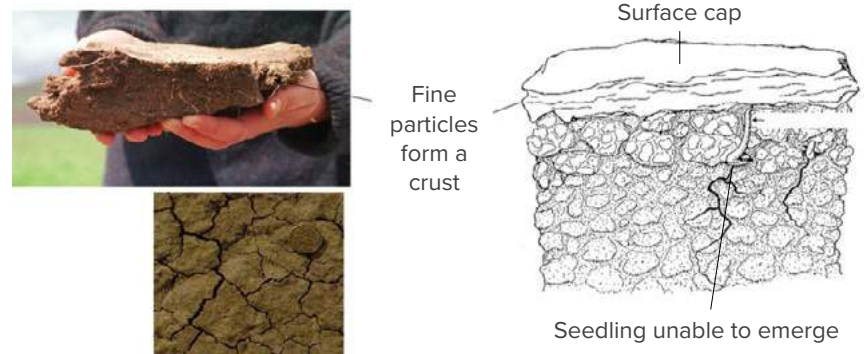


Figure 3: *The impact of sodic soils on seedling emergence: surface crusting and dispersive clay limit emergence.*

Source: Corangamite CMA, http://www.ccmaknowledgebase.vic.gov.au/brown_book/04_Sodic.htm

Soils high in sodium are structurally unstable, with clay particles dispersing when wet. This subsequently blocks soil pores, which reduces water infiltration and aeration, and retards root growth. On drying, a sodic soil becomes dense and forms a hard surface crust up to 10 mm thick. This can restrict seedling emergence. Some indicators of surface sodicty include:

- soils being prone to crusting and sealing up;
- ongoing problems with poor plant establishment; and
- the presence of scalded areas in adjoining pasture.

Exchangeable sodium percentage (ESP) is the measure for sodicty and soils are rated as:

- ESP <3 – non-sodic soil
- ESP 3–14 – sodict soil
- ESP >15 – strongly sodict soil.²⁴

Field pea can tolerate subsoil sodicty up to approximately 5 ESP in the surface layer and 8 ESP in the subsoil.²⁵

Sodicty adversely affects cool season pulses by reducing germination and seedling establishment with increasing ESP (15–20). Glasshouse studies and field observations suggest that chickpea and lentil are more sensitive to sodicty than faba bean and field pea.²⁶

²³ Corangamite CMA (2013) How do I manage the impact of sodict soils? Corangamite CMA, http://www.ccmaknowledgebase.vic.gov.au/brown_book/04_Sodic.htm

²⁴ GRDC (2017) Northern Field pea GrowNotes™. <https://grdc.com.au/GrowNotes>

²⁵ C Mullen (2004) The right pulse in the right paddock at the right time. NSW Agriculture, <http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/general-information/right-pulse>

²⁶ K Siddique. Abiotic stresses of cool season pulses in Australia. University of Western Australia, <http://www.farmtrials.com.au/trial/13486>

Soils that are sodic in the topsoil have the greatest impact on crop performance. Sodic layers deeper in the soil profile are not as great a concern, but can still affect yields by restricting root development and water extraction from depth.²⁷

Managing sodic soils

- Growers need to correctly identify the problem first and ensure that the soils are in fact sodic.
- Sodic soils can be directly treated through the application of gypsum (particularly on the surface), which serves to replace the excess sodium in the soil with calcium.
- In southern Victoria, typical application rates of gypsum are around 2.5 t/ha and applied every 3–5 years.
- The application of lime to sodic soils acts in a similar manner to gypsum, but is much slower acting and less effective.
- Although the application of gypsum can effectively counter sodicity in the short run, longer-term management strategies need to be in place to increase, and then maintain, organic matter in soils. Increased organic matter can improve hard-setting soils, and it can also enhance the effect of gypsum.
- Sodicity can also be reduced by maintaining adequate vegetation cover, leaf litter or stubble on the soil surface.
- Trials in the high-rainfall zone of southern Victoria have shown that the amelioration of dense sodic subsoil using organic amendments can increase wheat yield more than using gypsum.²⁸

²⁷ Pulse Australia (2013) Northern Chickpea—Best Management Practices Training Course Manual. Pulse Australia

²⁸ Pulse Australia (2013) Northern Chickpea—Best Management Practices Training Course Manual. Pulse Australia

i MORE INFORMATION

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) released its latest report in mid June 2017,

http://data.daff.gov.au/data/warehouse/aucrpd9abcc003/aucrpd9aba_20170614_uPOax/AustCropRrt20170614_v1.0.0.pdf

Australian Crop Report: June 2017 No. 182 is a quarterly report with a consistent and regular assessment of crop prospects for major field crops, forecasts of area, yield and production and a summary of seasonal conditions on a state by state basis.

It reports that the area planted to cereal crops is expected to decrease, but the area planted to canola, chickpea and lentil is forecast to increase.

For details on national receival standards please see [Section 11.11 Receival standards](#) or visit http://www.pulseaus.com.au/storage/app/media/markets/20160801_Pulse-Standards.pdf

Marketing

The final step in generating farm income is converting the tonnes produced into dollars at the farm gate. This section provides 'best in class' marketing guidelines for managing price variability to protect income and cash flow.

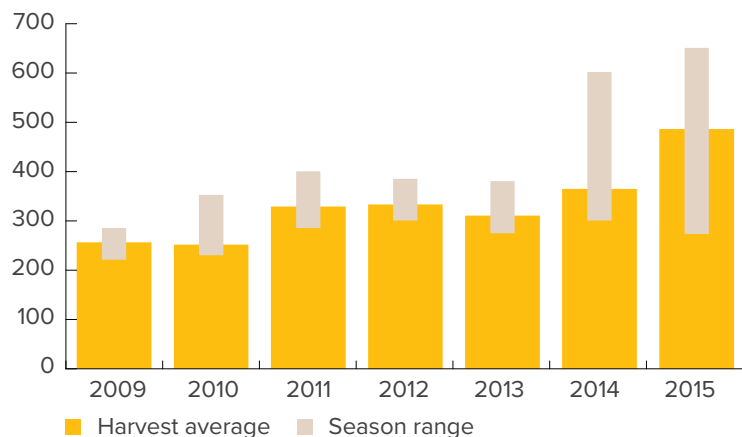


Figure 1: Intra-season variance of Port Adelaide field pea values.

Note: Port Adelaide field pea values have varied from A\$60–\$370/t over the past 7 years (representing variability of 30–60%). For a property producing 200t of field pea this means \$12,000–\$74,000 difference in income, depending on timing of sales. Source: Profarmer Australia

14.1 Selling principles

The aim of a selling program is to achieve a profitable average price (the target price) across the entire business. This requires managing several unknowns to establish the target price and then working towards achieving that target price.

Unknowns include the amount of grain available to sell (production variability), the final cost of that production and the future prices that may result. Australian farm-gate prices are subject to volatility caused by a range of global factors that are beyond our control and difficult to predict.

The skills growers have developed to manage production unknowns can be used to manage pricing unknowns. This guide will help growers manage and overcome price uncertainty.

14.1.1 Be prepared

Being prepared and having a selling plan is essential for managing uncertainty. The steps involved are forming a selling strategy and a plan for effective execution of sales.

A selling strategy consists of when and how to sell:

1. When to sell

This requires an understanding of the farm's internal business factors including:

- production risk
- a target price, based on cost of production and a desired profit margin
- business cash-flow requirements.

2. How to sell?

This is more dependent on external market factors including:

- time of year determines the pricing method
- market access determines where to sell
- relative value determines what to sell.

Figure 2 lists key selling principles when considering sales during the growing season.

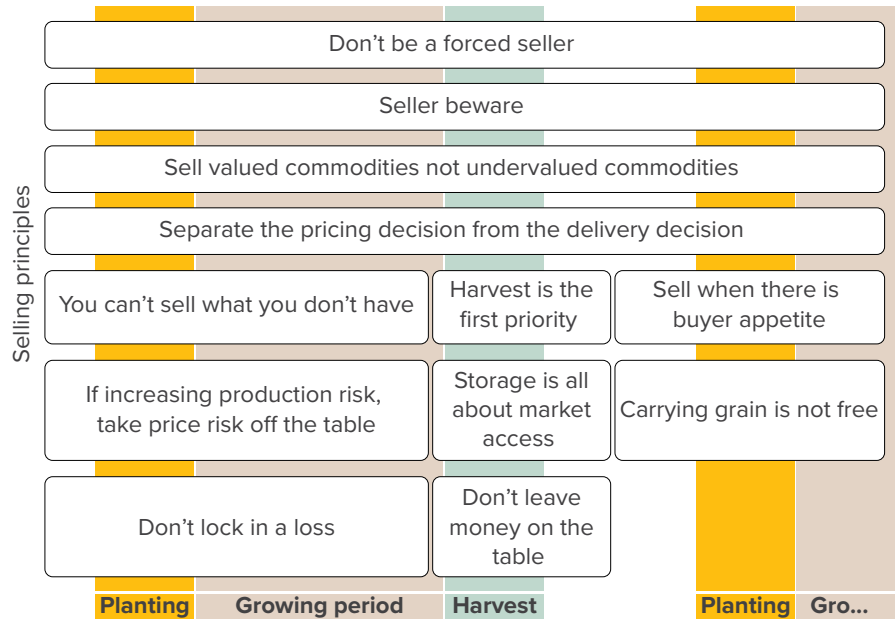


Figure 2: *Grower commodity selling principles timeline.*

Note: The illustration demonstrates the key selling principles throughout the production cycle of a crop.

14.2 Establish the business risk profile (when to sell)

Establishing your business risk profile allows the development of target price ranges for each commodity and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify those risks during the production cycle are described in Figure 3.

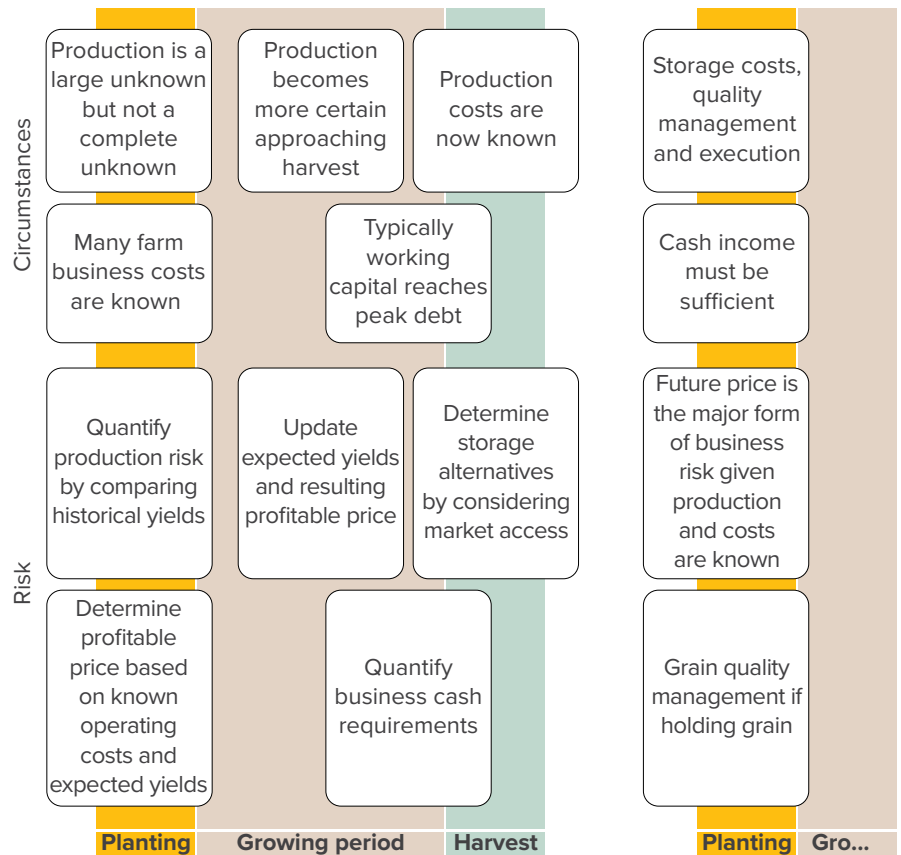


Figure 3: Typical farm business circumstances and risk.

When does a grower sell their grain? This decision is dependent on:

- Does production risk allow sales? And what portion of production?
- Is the price profitable?
- Are business cash requirements being met?

14.2.1 Production risk profile of the farm

Production risk is the level of certainty around producing a crop and is influenced by location (climate and soil type), crop type, crop management and time of the year.

Principle: 'You can't sell what you don't have' – don't increase business risk by overcommitting production.

Establish a production risk profile by:

- Collating historical average yields for each crop type and a below-average and above-average range.
- Assess the likelihood of achieving average based on recent seasonal conditions and seasonal outlook.
- Revising production outlooks as the season progresses.

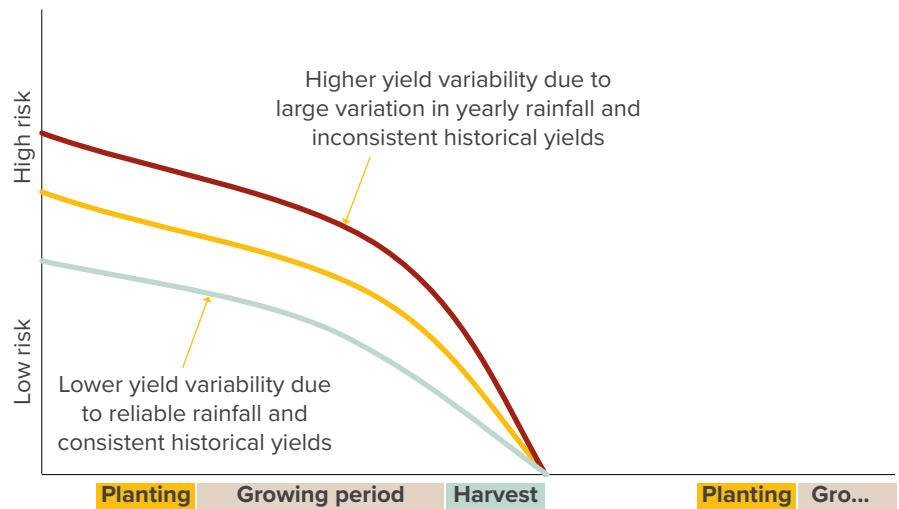


Figure 4: Typical production risk profile of a farm operation.

Note: The quantity of crop grown is a large unknown early in the year, however not a complete unknown. 'You can't sell what you don't have' but it is important to compare historical yields to get a true indication of production risk. This risk reduces as the season progresses and yield becomes more certain. Businesses will face varying production risk level at any given point in time with consideration to rainfall, yield potential soil type, commodity etc.

14.2.2 Farm costs in their entirety, variable and fixed costs (establishing a target price)

A profitable commodity target price is the cost of production per tonne plus a desired profit margin. It is essential to know the cost of production per tonne for the farm business.

Principle: 'Don't lock in a loss' – if committing production ahead of harvest, ensure the price is profitable.

Steps to calculate an estimated profitable price based on total cost of production and a range of yield scenarios is provided in the GRDC's *Farming the Business*. This manual also provides a cost of production template and tips on grain selling v. grain marketing (<http://www.grdc.com.au/FarmingTheBusiness>).

14.2.3 Income requirements

Understanding farm business cash-flow requirements and peak cash debt enables grain sales to be timed so that cash is available when required. This prevents having to sell grain below the target price to satisfy a need for cash.

Principle: 'Don't be a forced seller' – be ahead of cash requirements to avoid selling in unfavourable markets.

A typical cash flow to grow a crop is illustrated in [Figure 5](#). Costs are incurred upfront and during the growing season with peak working capital debt incurred at or before harvest. This will vary depending on circumstance and enterprise mix. The second figure demonstrates how managing sales can change the farm's cash balance.

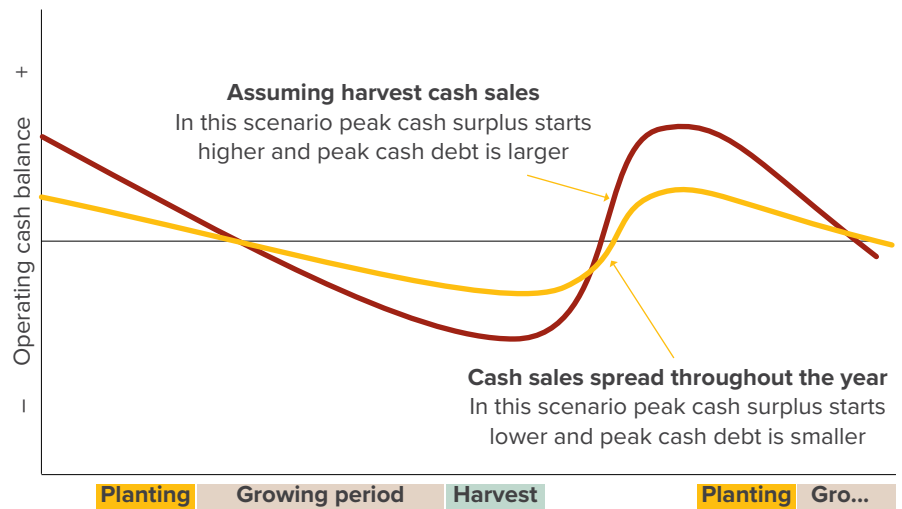


Figure 5: Typical farm operating cash balance.

Note: The chart illustrates the operating cash flow of a typical farm assuming a heavy reliance on cash sales at harvest v. a farm business that spreads sales out over the year.

When harvest sales are more heavily relied upon costs are incurred during the season to grow the crop, resulting in peak operating debt levels at or near harvest. Hence at harvest there is often a cash injection required for the business. An effective marketing plan will ensure a grower is not a 'forced seller' in order to generate cash flow.

By spreading sales throughout the year a grower may not be as reliant on executing sales at harvest time in order to generate required cash flow for the business. This provides a greater ability to capture pricing opportunities in contrast to executing sales in order to fulfil cash requirements.

14.3 When to sell revised

The 'when to sell' steps above result in an estimated production tonnage and the risk associated with that tonnage, a target price range for each commodity and the time of year when cash is most needed.

14.4 Ensuring access to markets

Once the selling strategy of when and how to sell is sorted, planning moves to the storage and delivery of commodities to ensure timely access to markets and execution of sales. At some point growers need to deliver the commodity to market. Hence planning where to store the commodity is important in ensuring access to the market that is likely to yield the highest return.

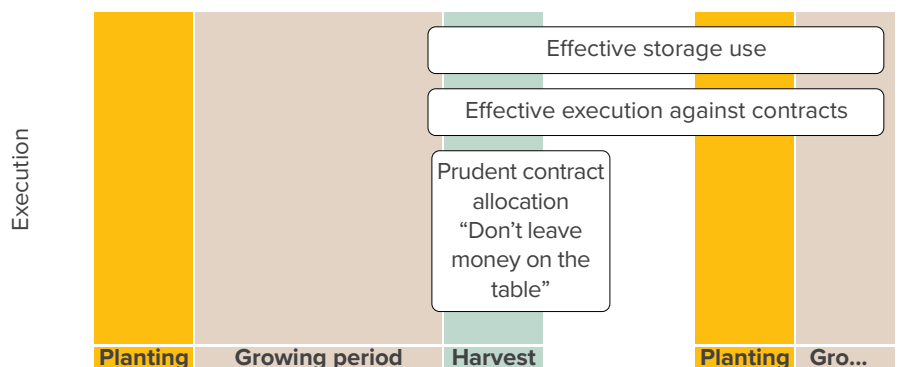


Figure 6: Effective storage decisions.

Once a grower has made the decision to sell the question becomes how they achieve this. The decision on how to sell is dependent upon:

- the time of year determines the pricing method
- market access determines where to sell
- relative value determines what to sell.

14.4.1 Storage and logistics

Return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access to maximise returns as well as harvest logistics.

Storage alternatives include variations around the bulk-handling system, private off-farm storage and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity.

Principle: ‘Harvest is the first priority’ – getting the crop in the bin is most critical to business success during harvest, hence selling should be planned to allow focus on harvest.

Bulk export commodities requiring significant quality management are best suited to the bulk-handling system. Commodities destined for the domestic end-user market (e.g. feed lot, processor or container packer) may be more suited to on-farm or private storage to increase delivery flexibility.

Storing commodities on-farm requires **prudent quality management** to ensure delivery at agreed specifications and can expose the business to high risk if this aspect is not well planned. Penalties for out-of-specification grain on arrival at a buyer’s weighbridge can be expensive. The buyer has no obligation to accept delivery of an out-of-specification load. This means the grower may have to incur the cost of taking the load elsewhere while also potentially finding a new buyer. Hence there is potential for a distressed sale, which can be costly.

On-farm storage also requires **prudent delivery management** to ensure commodities are received by the buyer on time with appropriate weighbridge and sampling tickets.

Principle: ‘Storage is all about market access’ – storage decisions depend on quality management and expected markets.

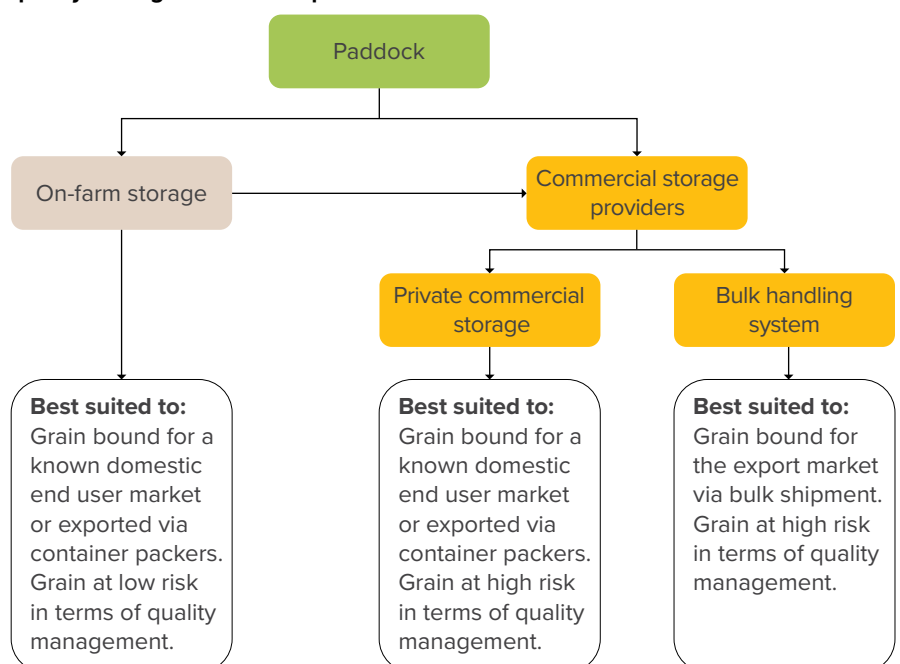


Figure 7: Grain storage decision-making.

Note: Decisions around storage alternatives of harvested commodities depend on market access and quality management requirements.

14.4.2 Cost of carrying grain

Storing grain to access sales opportunities post-harvest invokes a cost to 'carry' grain. Price targets for carried grain need to account for the cost of carry.

Carry costs consist of:

- monthly storage fee charged by a commercial provider OR capital cost allocation where on-farm storage is utilised; and
- the interest associated with having wealth tied up in grain rather than cash or against debt.

The price of carried grain therefore needs to be higher than what was offered at harvest. The cost of carry applies to storing grain on-farm as there is a cost of capital invested in the farm storage plus the interest component

Principle: 'Carrying grain is not free' – the cost of carrying grain needs to be accounted for if holding grain and selling it after harvest is part of the selling strategy.



Figure 8: Cash values v. cash adjusted for the cost of carry.

Note: if selling a cash contract with deferred delivery, a carry charge can be negotiated into the contract. For example, in the case of a March sale for March–June delivery on the buyer's call at \$300/t + \$3/t carry per month, if delivered in June this contract would generate revenue of \$309/t delivered.

14.3 Ensuring market access revised

Optimising farm-gate returns involves planning the appropriate storage strategy for each commodity to improve market access and cover carry costs in pricing decisions.

14.5 Executing tonnes into cash

This section provides guidelines for converting the selling and storage strategy into cash by effective execution of sales.

14.5.1 Set up the tool box

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox includes:

1. Timely information

This is critical for awareness of selling opportunities and includes:

- market information provided by independent parties;
- effective price discovery including indicative bids, firm bids and trade prices; and
- other market information pertinent to the particular commodity.

MORE INFORMATION

The link below provides current financial members of Grain Trade Australia including buyers, independent information providers, brokers, agents, and banks providing over-the-counter grain derivative products (swaps), <http://www.graintrade.org.au/membership>

2. Professional services

Grain selling professional service offerings and cost structures vary considerably. An effective grain-selling professional will put their clients' best interest first by not having conflicts of interest and investing time in the relationship. Return on investment for the farm business through improved farm-gate prices is obtained by accessing timely information, greater market knowledge and greater market access from the professional service.

14.5.2 How to sell for cash

Like any market transaction, a cash grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components with each component requiring a level of risk management:

Price

Future price is largely unpredictable hence devising a selling plan to put current prices into the context of the farm business is critical to manage price risk.

Quantity and quality

When entering a cash contract you are committing to delivery of the nominated amount of grain at the quality specified. Hence production and quality risk must be managed.

Delivery terms

Timing of title transfer from the grower to the buyer is agreed at time of contracting. If this requires delivery direct to end users it relies on prudent execution management to ensure delivery within the contracted period.

Payment terms

In Australia the traditional method of contracting requires title of grain to be transferred ahead of payment, hence counterparty risk must be managed.

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Grain Trade Australia is the industry body ensuring the efficient facilitation of commercial activities across the grain supply chain. This includes contract trade and dispute resolution rules. All wheat contracts in Australia should refer to GTA trade and dispute resolution rules.

Quantity (tonnage) and quality (bin grade) determine the actuals of your commitment. Production and execution risk must be managed.


Price is negotiable at time of contracting. Price basis or price point is important as it determines where in the supply chain the transaction will occur and so what costs will come out of the price before the growers net return.

Timing of delivery (title transfer) is agreed upon at time of contracting. Hence growers negotiate execution and storage risk they may have to manage.

Whilst the majority of transactions are on the premise that title of grain is transferred ahead of payment this is negotiable. Managing counterparty risk is critical.

GTA Contract No.3 CONTRACT CONFIRMATION

GTA Trade Rules and Dispute Resolution Rules apply to this contract



This Contract is confirmation between:

BUYER Contract No: _____ Name: _____ Company: _____ Address: _____ Buyer ABN: _____ NGR No: _____	SELLER Contract No: _____ Name: _____ Company: _____ Address: _____ Seller ABN: _____ NGR No: _____
--	--

The Buyer and Seller agree to transact this Contract subject to the following Terms and Conditions:

Commodity: _____ Grade: _____ Quantity: _____ Packaging: _____ Price: _____ Price Basis: _____	GTA Commodity Reference: _____ Inspection: _____ (Origin - Destination) Tolerance: _____ (Refer over) Weights: _____ (Origin - Destination) Excl/Incl/Free GST _____
Delivery/Shipment Period: _____ (Delivered, Shipped, Free In Store, Free On Board, Ex-Farm, etc.) Delivery Point and Conveyance: _____ (Road, Rail, Delivered Container Terminal, Freight, Rated Steep Point, Loading Weight requirements if applicable)	
Payment Terms: The buyer agrees to pay the seller within _____, in the absence of a declaration, payment will be 30 days end of week of delivery.	
Levies and Statutory Charges: Any industry, statutory or government levies which are not included in the price shall be deducted as required by law.	
Disclosures: Is any of the crop referred to in this contract subject to a mortgage, Encumbrance or lien and/or Plant Breeders Rights and/or EPR liabilities and/or registered or unregistered Security Interest? <input type="radio"/> NO <input type="radio"/> YES (Please <input type="checkbox"/> appropriate box) If "yes" please provide details: _____	
Other Special Terms and Conditions: _____	

All Contract Terms and Conditions as set out above and on the reverse of this page form part of this Contract. Terms and Conditions written on the face of this Contract Confirmation shall override all printed Terms and Conditions on the reverse with which they conflict to the extent of the inconsistency. This Contract comprises the entire agreement between Buyer and Seller with respect to the subject matter of this Contract.

Recipient Created Tax Invoice (RCTI). To assist with the processing of the Goods and Services Tax compliance, the buyer may prepare, for the seller, a Recipient Created Tax Invoice (RCTI). If the seller requires this service they are required to sign this authorisation. <input type="checkbox"/> Please issue a RCTI (Please <input type="checkbox"/>)	Incorporation of GTA Trade & Dispute Resolution Rules: This contract expressly incorporates the GTA Trade Rules in force at the time of this contract and Dispute Resolution Rules in force at the commencement of the arbitration, under which any dispute, controversy or claim arising out of, relating to or in connection with this contract, including any question regarding its existence, validity or termination, shall be resolved by arbitration.
---	---

Buyer's Name: _____ (PRINT NAME) Buyer's Signature: _____ Date: _____	Seller's Name: _____ (PRINT NAME) Seller's Signature: _____ Date: _____
---	---

This Contract has been executed and this form serves as confirmation and should be signed and a copy returned to the buyer/seller immediately. 2014 Edition
©GTA. For GTA member use only.

Figure 9: Typical cash contracting as per Grain Trade Australia standards.

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. [Figure 10](#) shows the terminology used to describe pricing points along the grain supply chain and the associated costs to come out of each price before growers receive their net farm-gate return.

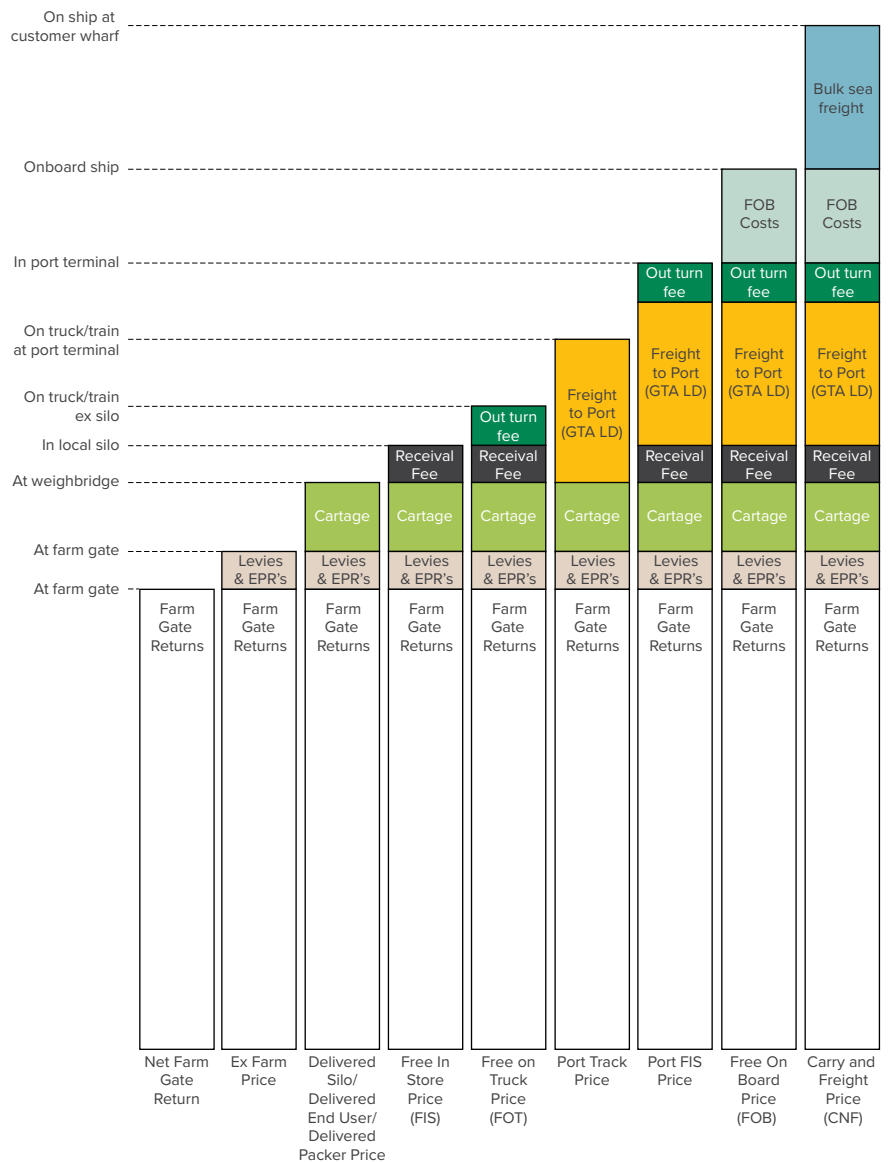


Figure 10: Costs and pricing points throughout the supply chain.

Cash sales generally occur through three methods:

Negotiation via personal contact

Traditionally prices are posted as a 'public indicative bid'. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and available for all commodities.

Accepting a 'public firm bid'

Cash prices in the form of public firm bids are posted during harvest and for warehoused grain by merchants on a site basis. Growers can sell their parcel of grain immediately by accepting the price on offer via an online facility and then transfer the grain online to the buyer. The availability of this depends on location and commodity.

Placing a firm offer

Growers can place a firm offer price on a parcel of grain by approaching buyers with a set tonnage and quality at a pre-determined price. The buyers do not have to accept the offer and may simply say no or disregard the offer.

There are increasingly more channels via which to place a firm offer.

One way this can be achieved anonymously is using the Clear Grain Exchange, which is an independent online exchange. If the firm offer and firm bid matches, the parcel transacts via a secure settlement facility where title of grain does not transfer from the grower until funds are received from the buyer. The availability of this depends on location and commodity.

Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

Some bulk-handler platforms are also providing facilities for sellers to place firm offers to the market, including GrainCorp via their CropConnect product.

Finally a grower can place a firm offer directly with an individual buyer.

14.5.3 Counterparty risk

Most sales involve transferring title of grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

Principle: ‘Seller beware’ – there is not much point selling for an extra \$5/t if you don’t get paid.

Counterparty risk management includes:

1. Dealing only with known and trusted counterparties.
2. Conducting a credit check (banks will do this) before dealing with a buyer they are unsure of.
3. Only selling a small amount of grain to unknown counterparties.
4. Considering credit insurance or letter of credit from the buyer.
5. Never delivering a second load of grain if payment has not been received for the first.
6. Not parting with title of grain before payment or request a cash deposit of part of the value ahead of delivery. Payment terms are negotiable at time of contracting, alternatively the Clear Grain Exchange provides secure settlement whereby the grower maintains title of grain until payment is received by the buyer, and then title and payment is settled simultaneously.

Above all, act commercially to ensure the time invested in a selling strategy is not wasted by poor counterparty risk management. Achieving \$5/t more and not getting paid is a disastrous outcome.

14.5.4 Relative values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well and hold commodities that are not well priced at any given time. That is, give preference to the commodities of the highest relative value. This achieves price protection for the overall farm business revenue and enables more flexibility to a grower’s selling program while achieving the business goals of reducing overall risk.

Principle: ‘Sell valued commodities, not undervalued commodities’ – if one commodity is priced strongly relative to another, focus sales there. Don’t sell the cheaper commodity for a discount.

14.5.5 Contract allocation

Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (price, premiums discounts, oil bonuses etc) and optimising your allocation reflects immediately on your bottom line.

Consideration needs to be made based on the quality or grades you have available to deliver, the contracts you already have in place and how revenues will be calculated on each contract. Key considerations include: does the contract calculate revenues based on a sliding scale or on predetermined quality 'buckets'. Whenever you have more grain to allocate than pre-committed to contracts, don't forget to consider the premiums and discounts available in the current cash market as part of your contract allocation decision.

Principle: 'Don't leave money on the table' – contract allocation decisions don't take long and can be worth thousands of dollars to your bottom line.

14.5.6 Read market signals

The appetite of buyers to buy a particular commodity will differ over time depending on market circumstances. Ideally growers should aim to sell their commodity when buyer appetite is strong and stand aside from the market when buyers are not that interested in buying the commodity.

Appetite in pulse markets can be fickle, erratic and the buy-side can be illiquid. Hence monitoring market signals is critical to achieving the best possible returns.

Principle: 'Sell when there is buyer appetite' – when buyers are chasing grain, growers have more market power to demand a price when selling.

Buyer appetite can be monitored by:

- The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate buyer appetite is strong. However, if there is one buyer \$5/t above the next best bid, it may mean cash prices are susceptible to falling \$5/t if that buyer satisfies their buying appetite. In pulse markets the spread between the highest and the second highest bidder can be more than \$100/t at times.
- 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.

14.6 Sales execution revised

The selling strategy is converted to maximum business revenue by:

1. Ensuring timely access to information, advice and trading facilities.
2. Using different cash market mechanisms when appropriate.
3. Minimising counterparty risk by effective due diligence.
4. Understanding relative value and selling commodities when they are priced well.
5. Thoughtful contract allocation.
6. Reading market signals to extract value from the market or prevent selling at a discount.

14.7 Southern field peas – market dynamics and execution

14.7.1 Price determinants for southern field peas

Field pea pricing is highly volatile by nature, with a large variation both within and between seasons. Factors contributing to price volatility include subcontinental market dynamics and trading culture, chickpea/field pea substitution, as well as the chickpea and field pea crop size of Australia, competitor countries and the subcontinent, which is discussed in more detail below.

Field pea pricing influences affecting southern growers stem from both global human consumption market forces and domestic feed market forces.

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Factors determining field pea stockfeed demand and feed quality price include:

1. The price of field pea relative to other sources of protein and energy that make up a least cost ration. Imported soybean meal (protein) and cereal grain prices (energy) are the major factors.
2. Export price opportunities. High export demand and prices of field pea flow through to domestic pricing.
3. Australian dollar. A low Australian dollar increases the import price of soybean meal and increases the export price of field pea.

Global influences on Australian field pea pricing are listed below (see also Figure 11):

1. Canadian field pea planting intentions.
2. Indian domestic rabi season (harvest April/May) pulse production. Any negative influences will increase the need for imports of either chickpea or field pea.
3. Canadian production totals.
4. Canadian, US and European excess production in the previous season, i.e. stocks on hand or carryover.
5. The world price of chickpea. Field pea is purchased as a substitute pulse when the chickpea price is high.
6. Timing of festivals in importing countries. Ramadan, which occurs in the ninth month of the Islamic calendar and lasts for 29 days, is the most important festival. Ramadan occurs around June then May for the next few years then will get closer to the end of the Australian harvest. This is favourable for supplying the Ramadan market post-harvest.

The primary end use of southern field pea is the export market, with the majority of exports conducted via containers rather than bulk. However, the domestic stockfeed industry remains important, particularly in Victoria where field pea is an important source of protein in feed rations, alongside alternative pulse crops and imported soybean meal.

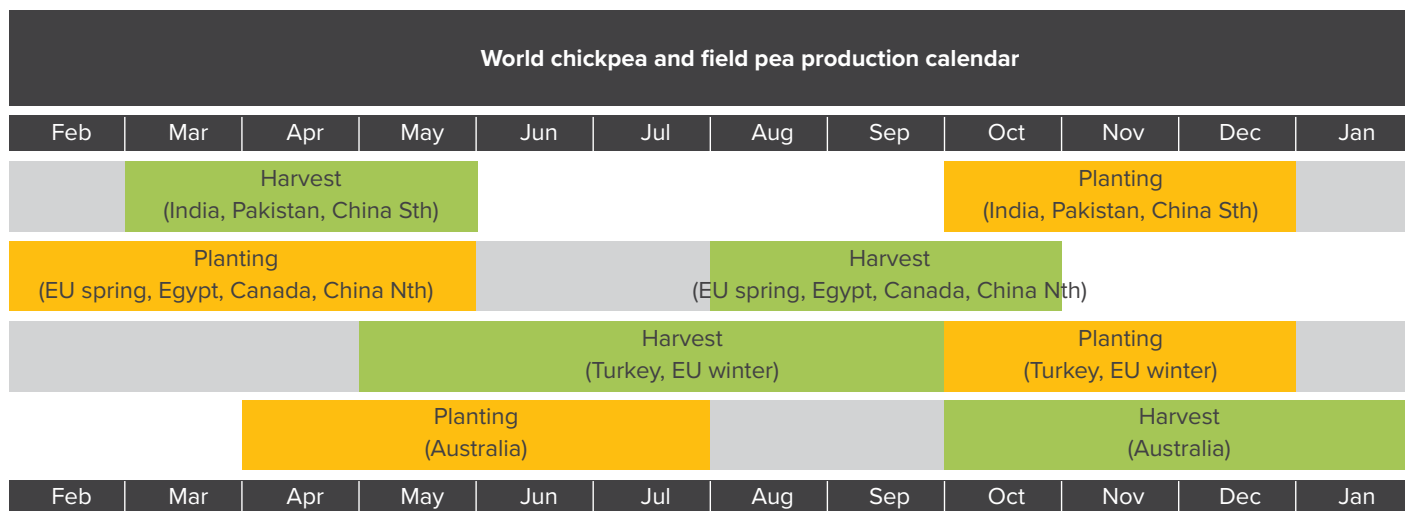


Figure 11: Global field pea production calendar.

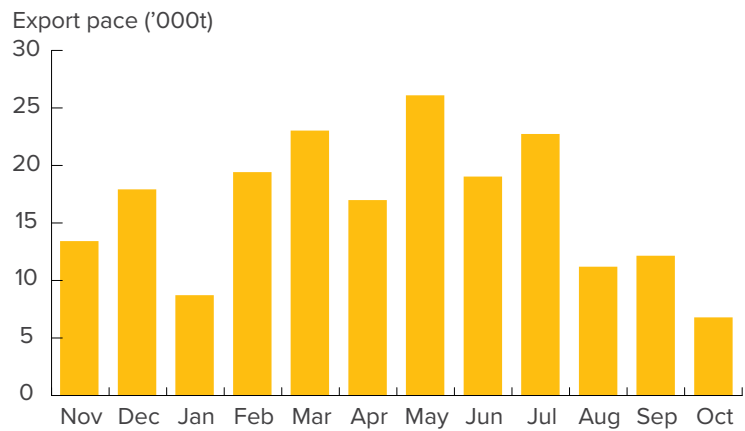


Figure 12: Five-year average monthly export pace ('000t) Australian field pea.

Source: Australian Crop Forecasters

14.7.2 Southern field pea marketing and seed type

The majority of field pea grain (70–90%) is exported for human consumption, with the rest sold for stockfeed. The market demand for field pea varies according to the type. At receival, traditional dun pea types are usually segregated from 'Kaspa' dun types. White and blue peas also need to be segregated, and usually require a specialised marketer to accept delivery.

More than 90% of Australian production is from dun types (i.e. grain that has a dun-coloured seed coat), of which more than 85% is now the 'Kaspa type' (e.g. Kaspa[®], PBA Gonyah[®], PBA Twilight[®] and PBA Wharton[®]). Kaspa-type seed is preferred for snack food in southern India over other pea seed types and attracts a price premium. To avoid limiting the marketing of Kaspa-type grain for export, growers should avoid sowing seed contaminated with Parafield or other dun types.

Most field pea markets in India now prefer the Kaspa dun type because it is easier to remove the seed coat from a round seed than the dimpled seed of the traditional dun type (e.g. PBA Oura[®]). There are markets in India and Sri Lanka that still buy the dun-type field pea. White field pea markets are further developing into China and Sri Lanka and growers of the high-yielding PBA Pearl[®] should ensure they have access to traders of these white peas.

Domestically all field pea varieties, dun and Kaspa types, are sought after for the splitting market, including PBA Wharton[®], PBA Twilight[®], PBA Oura[®], PBA Percy[®] and PBA Gonyah[®].¹

¹ J Couchman, K Hollaway (2017) NVT Victorian Winter Crop Summary 2017. Department of Economic Development, Jobs, Transport and Resources, www.grdc.com.au/NVT-Victorian-Winter-Crop-Summary

14.7.3 Ensuring market access for southern field pea

The major food markets for field pea are in southern India and Sri Lanka. However, field pea in these markets face strong competition from Canadian yellow pea and chickpea.

In domestic markets field pea is an important source of protein in stock feed rations, and in this instance face competition from alternate protein sources including other pulses and imported soybean meal.

By and large, whether finding homes in export (generally via container) or domestic markets, private commercial storage and on-farm storage both provide efficient paths to market.

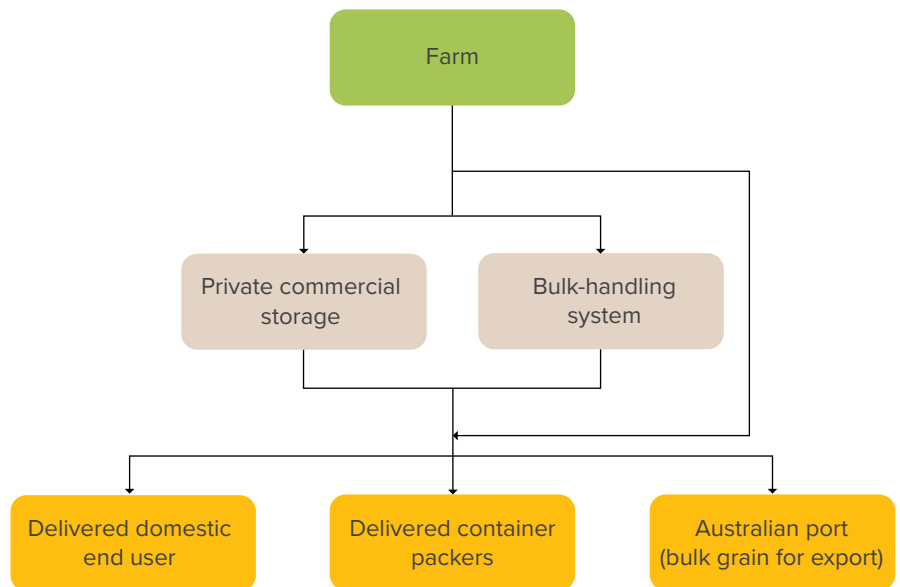


Figure 13: Australian supply chain flow.

Note: Storage decisions should be determined by assessing market access.
Source: Profarmer Australia

14.7.4 Executing tonnes into cash for southern field pea

Field pea marketability commences in the paddock ensuring:

- chemical withholding periods have been met;
- weed control has been adequate to minimise weed seed contamination;
- insect and disease control to ensure a good quality pea; and
- harvest technique to minimise seed damage.

Selling options for field pea include:

1. Store on-farm then sell – most common occurrence. Field pea are relatively safe to store and require less maintenance than cereal grains. It does however remain important to monitor and maintain quality, with field pea required to meet strict quality specifications for export in order to avoid being discounted at the time of delivery. Must consider cost of storage in target pricing.
2. Cash sale at harvest – least preferred option as buyer demand does not always coincide with harvest. Values can come under pressure at harvest time if an influx of grower selling occurs in a small window, subsequently providing buyers with confidence they can meet their short/medium-term commitments.
3. Warehouse then sell – this provides flexibility for sales if on-farm storage is not available. Must consider warehousing costs in cost of production and target prices. It is unlikely this will be a selling avenue available to northern growers with the major bulk handlers not providing this option due to the low volume of production. Availability of this option from ‘packers’ within the ‘delivered’ market will vary depending on each individual buyer.

As with all sales, counterparty risk and understanding the contract of sale is essential. Counterparty risk consideration is especially important for pulse marketing as there is often a higher risk of contract default in international pulse markets than for canola or cereals, this is due to the markets they are traded into, lack of appropriate price risk tools (such as futures) and often the visual and subjective nature of quality determination. This can place extra risk on Australian-based traders endeavouring to find homes for your product.

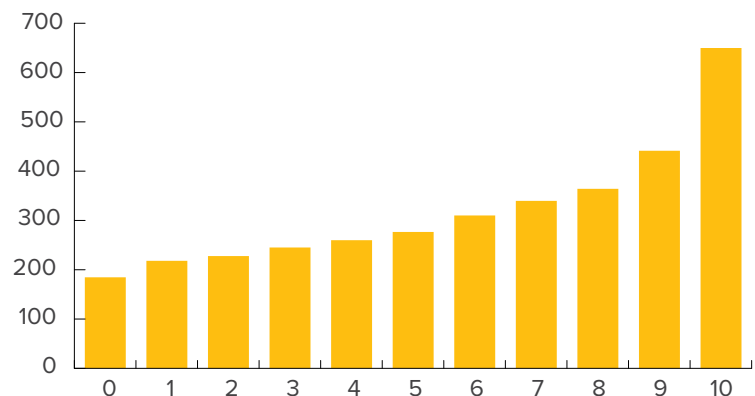


Figure 14: Port Adelaide field pea deciles.

Source: Profarmer Australia

i MORE INFORMATION

A good reference for marketing is at: http://www.pulseaus.com.au/storage/app/media/members_only/2015_PulseCropPosters_A1sizeLR.pdf

A GRDC market/receival standards paper 'Pulse market and receivals update' by W. Hawthorne (formerly of Pulse Australia) is at: <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2012/08/pulse-market-and-receivals-update>

Details on how to develop a pulse marketing plan to meet customer demand is at: <https://grdc.com.au/news-and-media/news-and-media-releases/south/2015/02/develop-a-pulse-plan-to-meet-customer-demand>

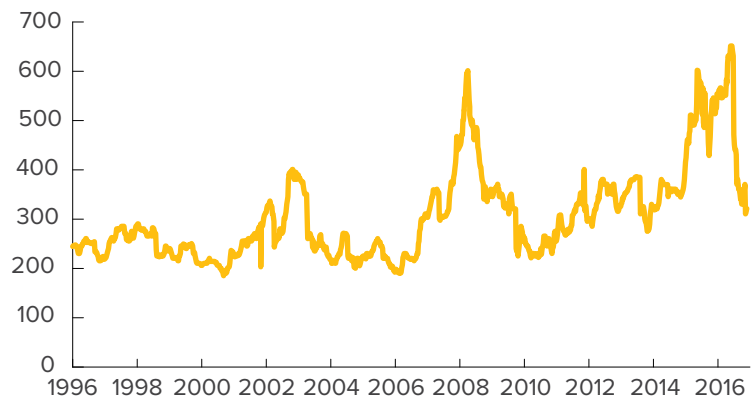


Figure 15: Long-term Port Adelaide field pea price history.

14.7.5 Marketing planning

Growers should consider their pulse-marketing plan at the start of the season for the best decision-making and results. A pulse-marketing plan starts before a single seed is sown. A plan should contain:

- the pulse, and the best variety type to be grown.
- the marketer(s) to engage.
- timing and schedule of delivery over the season.
- delivery point and quality required for that product.
- requirement for a forward contract.
- ability to achieve the quality grade expected.
- fall-back position if the quality grade cannot be achieved.

Global pulse markets are driven by factors each season in the major pulse growing countries, including Australia, Canada, France and the UK. The varieties planted, the environmental conditions and exchange rates will affect the prices – if there’s an oversupply of one commodity the price could potentially drop while demand and price could increase on another commodity.

Being aware and informed of the market trends means growers can make the best choices for their situation. For example, in some seasons, lentil and faba bean prices have increased towards and post-harvest. However, this is coincidental and is not always likely to occur.

In these instances the prices have been driven upwards due to a combination of drought in parts of Australia along with international factors. It’s important to keep abreast of these kinds of fluctuations in prices, so that growers can sell their product at the optimal time.

Engaging a pulse marketer can help growers get the best returns by developing answers to the following questions:

- **Who is your target customer?** Knowing your customer helps to direct efforts and costs towards what’s actually important to them, so you can receive the best financial return.
- **Who is your competitor?** Consider both domestic and international competitors and what can be done to deliver a better proposal to the customer.
- **When is the best time to sell your product?** Does it make sense to build extra storage on-farm to sell at the highest price point? Alternatively are there cost-effective local storage options?
- **What is your desired customers’ quality specification?** Quality is one of the best ways to set yourself apart from competitors. What farm practices should be put in place to ensure quality specifications are met?

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Pulse growers are encouraged to build relationships with their grain marketer to understand global trends and be advised on the best-selling options. Growers will benefit from knowing which varieties will be in demand, timing of the sale to meet a gap in supply, and the commodities quality specifications to target to get the best return.

Certain premium or niche pulse products with limited markets can only realistically be grown through a relationship with a marketer who can identify the market to ensure the product can be sold.

Most importantly, pulse marketing is extremely unpredictable and growers should perform due diligence to ensure they're selecting an appropriate marketing company. Know whether the marketing company is a member of Grain Trade Australia (GTA); who is backing that company; and confirm that they are financially secure.

Current research

Project Summaries

<https://grdc.com.au/research/projects>

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 (ie northern, southern or western).

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/research/projects

Final Report Summaries

<https://grdc.com.au/research/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://grdc.com.au/research/reports>

Online Farm Trials

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.

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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 Online trials – <http://www.farmtrials.com.au>

Key contacts

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