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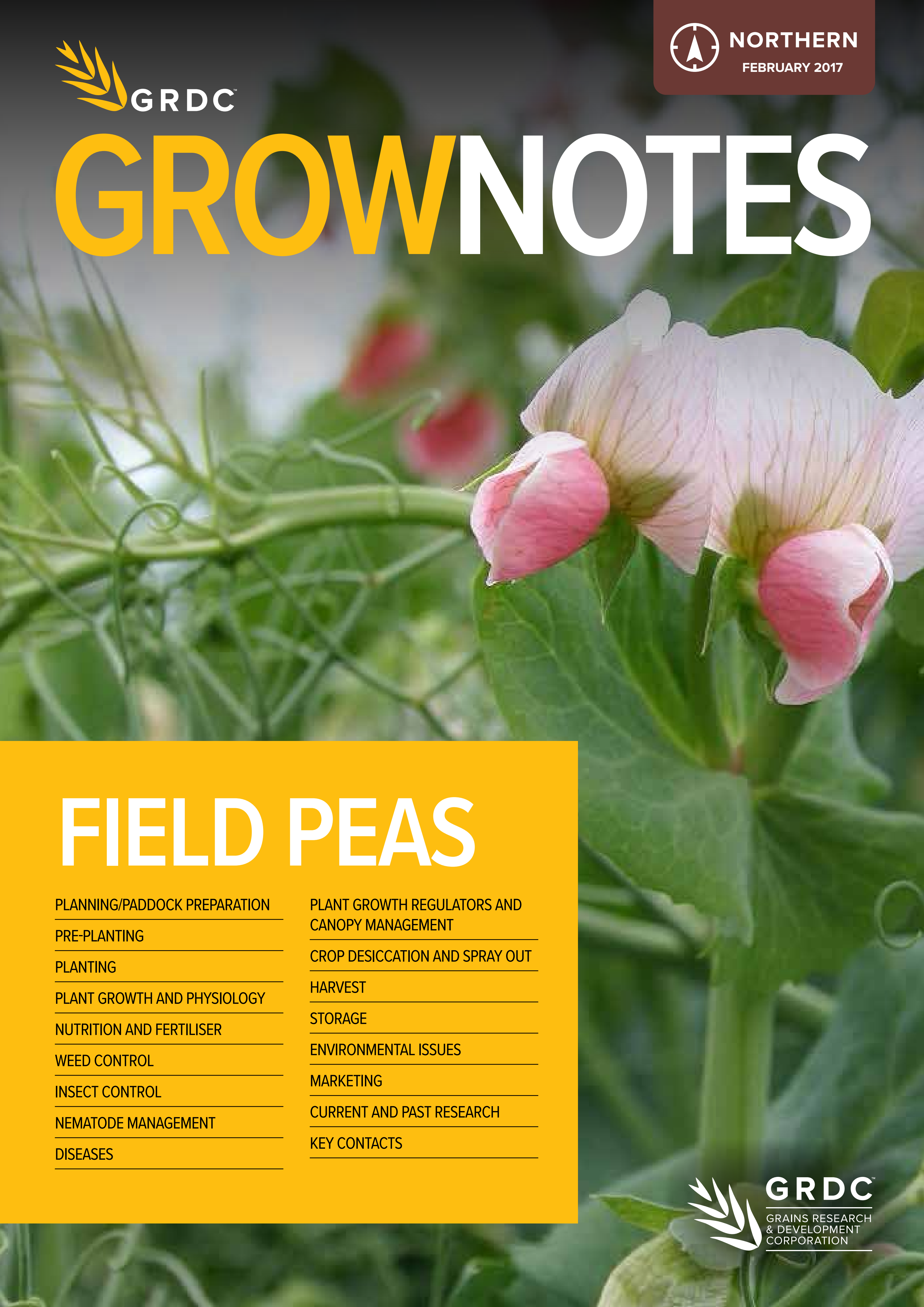

FIELD PEAS

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

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What's New

The GRDC GrowNotes are dynamic documents that are updated according to user feedback and newly available information.

This version of the GRDC Field Peas GrowNotes (updated December 2016) contains the following updates on original content published in August 2015:

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- Winter crop variety sowing guide 2016. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

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- New podcast: Long term trial measures crop practices: https://grdc.com.au/Media-Centre/GRDC-Podcasts/Ground-Cover-Radio/2015/06/Ground-Cover-Radio-Long-term-trial-measures-crop-practices
- Fixing more nitrogen in pulse crops: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Fixing-more-nitrogen-in-pulse-crops
- Impact of crop rotations on profit, nitrogen and ryegrass seed bank in crop sequences in southern NSW: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Impact-of-crop-rotations-on-profit-nitrogen-and-ryegrass-seed-bank-in-crop-sequences-in-southern-NSW
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- New information: Likely fit of summer and winter forage crop options in Central West farming systems: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Likely-fit-of-summer-and-winter-forage-crop-options-in-Central-West-farming-systems

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Introduction

MORE INFORMATION

A general summary of the Australian grain growing regions is available at Greijdanus A, Kragt M. (2014). The grains industry: An overview of the Australian broad-acre cropping

A.1 Crop overview

Field pea (*Pisum sativum L.)* has been an important grain legume crop for millennia; seeds showing domesticated characteristics dating from at least 7000 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, whose immature pods and seeds are used throughout the world as green vegetables. [1]

Field peas are a major pulse crop in Australia grown over approximately 300,000 hectares (Figure 1). In South Australia and Victoria it accounts for 40% of the area of pulses and is the second most widely grown pulse crop in Western Australia and southern New South Wales (Table 1).

Figure 1: *Close up of field pea flowers from a crop near Carrathool NSW.*

Photo: AM Photography

The majority of field pea grain grown in Australia is exported for human consumption (i.e. between 70–90%) and the rest is sold for stockfeed. All pea varieties produce grain suitable for stockfeed purposes, however segregation is required for selling to specific human consumption markets. [2]

Agronomically, field peas are often considered a reliable pulse crop, particularly in the lower rainfall margins of south-eastern Australia. [3]

The crop fixes nitrogen from the atmosphere and contributes to soil mineral nitrogen levels. It is less exploitative of soil water at depth than cereal crops, has increased flexibility for weed control, and provides a break for the cereal disease cycles. Wheat

1 I Pritchard (2014) Growing field pea. Department of Agriculture and Food, Western Australia, www.agric.wa.gov.au/field-peas/growing-field-pea

2 P Kennedy, J Brand, F Henry, M Raynes (2014) FIELD PEA. Department of Environment and Primary Industries, Victoria, http://agriculture.vic.gov.au/__data/assets/word_doc/0003/318873/Field-Pea-2016.docx

3 V Sadras (2013) Improving yield and reliability of field peas under water deficit. Grains Research & Development Corporation, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/01/Improving-yield-and-reliability-of-field-peas-under-water-deficit

yields after field pea are well above those of wheat after wheat, and increased wheat protein levels are common.

The critical management factors for producing high yields and good quality seed are optimising plant density, effective nodulation, weed control, insect control and timely harvest. [4]

Most field peas are grown for grain; however, green manuring field pea is an increasing farming system practice so it is sowing field pea for forage or hay, in particular as a non-chemical tool for herbicide resistance management.

In the traditional field pea growing regions of southern Australia, the major pea required in the market place is the dun type. The 'kaspa' dun type (no dimples) are sold into the south Indian markets for human consumption; the traditional dun type (with dimples) are sold into the Malaysia and Bangladesh markets, with other types (blue and white) filling niche markets.

Field peas are well-suited to no-till farming systems across southern and northern regions of Australia. They are preferably grown following a cereal crop (using the standing stubble as an aid to crop management), and to provide nitrogen and break crop benefits to the following cereal crop.

Like other pulses, a grass-free field pea crop will help to reduce the levels of cereal root diseases such as crown rot (*Fusarium pseudograminearum)* and Yellow leaf spot or Tan spot (*Pyrenophora tritici-repentis)*.

Field peas can also be used as an aid in herbicide resistance management as additional herbicide group options to reduce the potential development of herbicide resistance are available to this crop type. [5]

Table 1: *Field pea production 2014.* [6]

Region	Western	Southern				Northern		Australia Total
State	**WA**	**SA**	**VIC**	**S/NSW**	**Subtotal**	**QLD**	**N/NSW**	**Subtotal**
2014 Production (t)	32,800	125,400	36,000	67,400	228,800	11,700	11,700	273,300
2014 Sown area (ha)	25,300	110,000	51,200	45,000	206,200	6,000	6,000	237,500
Variation from Dec 2014 (t)	600	-1,800	-6,600	12,400	4,000	500	500	5,100
Variation from Dec 2014 (ha)	800	-300	6,000	0	5,700	0	0	6,500

Source: Pulse Australia

4 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

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

6 Australian Pulse Crop Forecast (2015). Pulse Australia, http://www.pulseaus.com.au/marketing/crop-forecast

Planning/Paddock preparation

Pulse crops should be sown as a part of a well-considered rotation. The previous crop should preferably be a cereal. This will maximise both the amount of nitrogen fixed by the field pea and the disease break offered by this pulse. Ideally, there should be standing stubble with the crop planted as no-till. This assists with minimising aphid activity within the crop, which can transmit viruses.

The standing stubble also provides structural support for the growing field pea crop with the peas using the previous year's stubble as an anchor to climb up on, which results in a crop that has greater standability at harvest. Field peas (Figure 1) can be planted with most conventional equipment used for sowing cereals. The paddock surface should be left relatively even after sowing. This will reduce the risk of damage from soil clod, sticks, and stones during the harvest operation. [1]

Figure 1: *White flowering field peas.*

Photo: Penny Heuston

1 S Moore, G Cumming, L Jenkins, J Gentry (2010). Northern region field pea management guide. Pulse Australia.

1.1 Paddock selection

Field peas have the widest adaptation to soil types of all pulse crops, from sandy loams through to heavy clays. Soils may be slightly acid to alkaline (pH $CaCl_2$ 5.5–9.0). Like all pulse crops, field peas are less productive on soils with a hardsetting surface or with heavy clay subsoils that drain poorly, but are the best suited of all the pulses to grow on these hardsetting soils.

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 hardpans should be avoided as they can create issues at harvest time with contamination of the sample, damage to machinery or an inability to be able to pick all the crop up. [2]

Hardpans can also lead to waterlogging issues. Sudden downpours or long periods of heavy rain can result in the development of perched water tables in the root zone. This can result in root disease development, poor nodulation or poor root growth. Paddocks prone to waterlogging (terrain) or heavy soil types can have the same affect.

Poor nodulation results in poor nitrogen fixation and poor crop performance. To maximise the benefits of a pulse crop in the rotation, maximising rhizobium survival and colonisation of the root system is essential. Consideration has to be given to previous herbicide use, soil pH, soil type and drainage and how this may impact on rhizobium survival and pulse crop performance. [3]

Field peas are grown in districts with 300–450 mm annual rainfall and on raised beds where annual rainfall ranges between 450–750 mm. They are the best adapted pulse to lower rainfall situations, but are prone to frost and heat stress during flowering and podding, as are most other legumes. [4]

Check list 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 hardsetting; pH $CaCl_2$ 5.5–9.0).
- Soil surface flat and free of undulations. Rolling will flatten clods, rocks and stones
- Peas not sown in the previous four 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]

1.1.1 Acidity

The ideal pH range for field peas is $CaCl_2$ 5.5–9.0. Field pea can be sensitive to high levels of exchangeable aluminium in acid soils. They will tolerate levels of 5–10% exchangeable Al%. Acid soils can significantly reduce production and profitability before paddock symptoms are noticed.

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

3 K Lindbeck (2016) Pulse diseases 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

4 Fieldpea ute guide, p10 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation, http://www.grdc.com.au/Resources/Bookshop/2009/12/Field-Peas-The-Ute-Guide

5 Fieldpea ute guide, p10 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation, http://www.grdc.com.au/Resources/Bookshop/2009/12/Field-Peas-The-Ute-Guide

Danger levels for crops are when soil pH is <5.5 (in $CaCl_2$) or 6.3 (in 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 in vulnerable 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 rhizobial initial numbers and multiplication. Field peas, faba beans, lentils, and chickpeas are vulnerable, as are vetches. Lupins are an exception because their rhizobia (Group G) are acid-tolerant. Granular inoculums seem to provide greater protection to rhizobia in acid soil conditions

1.1.2 Sodicity

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.

Some indicators of surface sodicity include:

- soils prone to crusting and sealing up
- ongoing problems with poor plant establishment
- 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 soils
- ESP <15: strongly sodic

Field peas can tolerate subsoil sodicity up to ESP ~8. [6] Sodicity adversely affects cool season pulses by reducing germination and seedling establishment with increasing ESP (15–20). Glasshouse studies and field observations suggest that chickpeas and lentils are more sensitive to sodicity than faba beans and field peas. [7]

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.

1.1.3 Salinity

Salinity is the presence of dissolved salts in soil or water. It causes iron toxicity in plants and impedes their ability to absorb water. Field peas have lower tolerance than cereal grains to salinity and water logging. These conditions cause the plants to be stunted with yellowish discoloration followed by bright red pigmentation (Figure 2).

6 C Mullen (2004) The right pulse in the right paddock at the right time. NSW Agriculture,http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/151112/the-right-pulse-in-the-right-paddock-at-the-right-time.pdf

7 K Siddique. Abiotic stresses of cool season pulses in Australia. University of Western Australia, http://www.farmtrials.com.au/trial/13486

Figure 2: *Marginal necrosis of older leaves that progresses up the plant.*

Photo: DAFWA [8]

Salinity damage varies from season to season due to variations in the soil salt concentration. Waterlogging increases salinity damage (Figure 3).

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. [9]

A glasshouse study in Western Australia to determine the influence of salinity (0 and 6 dS/m) and boron (5 and 20 mg/kg) and the combined effects of both on the early growth of two field pea varieties, Kaspa⊕ and Parafield, found salinity to be the main inhibitor to 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. Kaspa⊕ 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. [10]

Figure 3: *Photo showing the combined effects of salinity and waterlogging.*

Photo: DAFWA

8 Diagnosing salinity damage in field peas (2015). Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-salinity-damage-field-peas

9 K Siddique. Abiotic stresses of cool season pulses in Australia. University of Western Australia, http://www.farmtrials.com.au/trial/13486

10 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

1.2 Paddock rotation and history

Pulse crops should be sown in the correct cropping sequence that takes into account the soil type, weed burden, soil fertility and potential chemical residue of the paddock and how this contributes to the overall crop mix across the farm within the season and between seasons. Do not sow a pulse after another broadleaf crop, such as pulse crops and canola, even following a drought due to the difficulties of controlling broadleaf weeds in a broadleaf crop and the potential disease carry-over fears such as Sclerotinia *(Sclerotinia sclerotiorum)* and other diseases.

Field peas are 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 maximises nitrogen fixation and helps minimise disease. Standing cereal stubble also inhibits aphid activity providing a physical barrier which inhibits the insect flying through the crop. Aphids are considered a problem as they can transmit viruses. The stubble also provides architectural support for the growing pea crop.

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

Herbicide residues and herbicide history must also be considered; herbicide residues of, for example, the Group B sulfonylurea herbicides such as chlorsulfuron (e.g. Glean®) and metsulfuron methyl (e.g. Ally®), which can be very damaging, particularly in alkaline soils after extended dry periods, can be a real issue in field peas. [11]

1.3 Benefits of field peas as a rotation crop

The impacts of a pulse crop on farm profits is a real one with results across 900 experimental comparisons showing that, on average, wheat yields increased by 0.5 tonnes per hectare following oats, 0.8 t/ha following canola and 1.0 t/ha following grain legumes (0.7 to 1.6 t/ha) compared with wheat on wheat (Table 1). This 'break crop effect' often extended to a second wheat crop in the sequence, especially following legumes (benefit of 0.2 to 0.3 t/ha), but rarely to a third except under dry conditions. [12]

Table 1: *The effect of previous crop on the initial soil moisture and mineral nitrogen levels, grain yield of wheat and rainfall use efficiency in the Mallee region of South Australia and Victoria.*

Previous crop	Initial soil moisture (mm)	Initial soil mineral N (mg/kg)	Grain yield (kg/ha)	Rainfall use efficiency (kg/ha/mm)
Grain legume	149	14.7	2320	12.0
Fallow	169	22.0	1990	13.3
Pasture	154	12.6	1840	9.3
Cereal	130	9.8	1590	9.1

Rotational benefits include:

- The ability to conserve or increase soil nitrogen levels, increased flexibility for weed control and as a break crop for cereal leaf, root and crown diseases.
- A well-nodulated field pea crop with good weed control can provide nitrogen to the crop rotation by means of fixing N through their rhizobial interaction and releasing nitrogen from crop residues. Larger benefits to the following crop in the rotation are more likely where soil fertility is low to medium as in the

11 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

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

MORE INFORMATION

Ground Cover Radio 121: Profitable break crops strengthening low rainfall zones

Ground Cover Radio 117: Long term trial measures crop practices

GRDC Update Paper: Fixing more nitrogen in pulse crops

GRDC Update Paper: Impact of crop rotations on profit, nitrogen and ryegrass seed bank in crop sequences in southern NSW

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

presence of available nitrogen field peas will be 'lazy' and utilise this nitrogen as opposed to producing their own via the symbiotic relationship with the rhizobia. The better the field pea crop, that is one that has a solid plant stand, healthy plants with good nodulation and good bulk, the greater the amount of N that will be fixed.

- The amount of N fixed is linked to biomass production with around 20–25 kg of shoot N being fixed for every tonne of legume shoot DM accumulated. [13]
- Nitrogen inputs are higher if grazed by livestock (because N is retained in the field) rather than if cut for hay or harvested for grain, where much of the N in biomass is removed. Field peas are effective fixers of atmospheric N, with 50–80% of plant N fixed. This means that a field pea crop producing 5 t DM/ha of forage would have fixed 110–170 kg of N/ha (including root material). If the crop was grazed by livestock 75–100 kg of N/ha retained in the field, while if it was harvested for grain or hay only 60–80 or 35–60 kg N/ha would be retained, respectively. [14]
- Some varieties of field pea are one of few winter legumes that are known to be resistant to root lesion nematodes. Cultivars Morgan and PBA Percy⊕ have been shown to be resistant and don't increase RLN numbers.
- Using field peas for hay making can be a useful tool for managing weed seed set in problem weeds. [15]

The amount fixed varies between legumes as set out in Table 2. Harvest index is the measure of the weight of a harvested product as a percentage of the total plant weight of a crop that is the plant's ability to effectively convert dry matter into grain. [16]

13 M Peoples, R Gault, D Herridge, M McCallym, K McCormick, R Norton, G Scammell, G Schwenke, H Hauggaard-Nielsen (2001) Contributions of fixed nitrogen by crop legumes to farming systems of eastern Australia. Australian Agronomy Conference 2001, http://www.regional.org.au/au/asa/2001/1/c/peoples.htm

14 L Bell (2015) Likely fit of summer and winter forage crop options in Central West farming systems. GRDC Update Papers 24 July 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Likely-fit-of-summer-and-winter-forage-crop-options-in-Central-West-farming-systems

15 L Bell (2015) Likely fit of summer and winter forage crop options in Central West farming systems. GRDC Update Papers 24 July 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Likely-fit-of-summer-and-winter-forage-crop-options-in-Central-West-farming-systems

16 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

Table 2: *Estimates of above-ground nitrogen fixed (kg/ha) by a pulse crop based on harvest index (HI).*

	Chickpea			Field pea, faba bean, lentil			Narrow leafed lupin			Albus lupin		
Grain yield (t/ ha)	HI 20%	HI 30%	HI 40%	HI 20%	HI 30%	HI 40%	HI 20%	HI 30%	HI 40%	HI 20%	HI 30%	HI 40%
0.40	38	21	13	35	18	10	31	15	6	28	12	3
0.60	57	32	19	52	27	14	47	22	10	42	17	5
0.80	76	42	26	69	36	19	63	30	13	56	23	6
1.00	95	53	32	87	45	24	79	37	16	71	29	8
1.20	114	64	39	104	54	29	94	44	19	85	35	10
1.40	132	74	45	121	63	34	110	52	23	99	41	11
1.60	151	85	51	139	72	39	126	59	26	113	46	13
1.80	170	95	58	156	81	43	141	66	29	127	52	15
2.00	189	106	64	173	90	48	157	74	32	141	58	16
2.20	208	116	71	191	99	53	173	81	35	155	64	18
2.40	227	127	77	208	108	58	189	89	39	169	69	19
2.60	246	138	83	225	117	63	204	96	42	184	75	21
2.80	265	148	90	242	126	67	220	103	45	198	81	23
3.00	284	159	96	260	135	72	236	111	48	212	87	24
3.20	303	169	103	277	144	77	252	118	52	226	93	26
3.40	322	180	109	294	153	82	267	126	55	240	98	28
3.60	341	191	116	312	162	87	283	133	58	254	104	29
3.80	359	201	122	329	171	92	299	140	61	268	110	31
4.00	378	212	128	346	180	96	314	148	64	282	116	32

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 peas comes from spared mineral nitrogen and the breakdown of fine roots and nodules.

The nitrogen benefits from field peas is typified by two experiments in central west NSW which measured the amount of nitrogen fixed by field peas, the effect of management on nitrogen cycling, and the response of two subsequent wheat crops (Tables 3 and 4).

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/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.

The higher yield after green manuring needs to be balanced against the income from hay or harvested grain in the legume year. Additional benefits from making hay or green/brown manuring could include the prevention of seed set in annual weeds 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. [17]

17 Integrating field peas into Central Western farming systems; Neil Fettell

Table 3: *First and second year wheat yield and protein response to crop species and management at Parkes, NSW.*

Treatment in 1997	Wheat in 1998	Wheat in 1999	
	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

Table 4: *First and second year wheat yield and protein response to crop species 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

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

Like other pulses, a grass-free field pea crop will help to reduce the levels of cereal root disease such as Crown rot (*Fusarium pseudograminearum*) and leaf diseases such as Yellow leaf spot or Tan spot (*Pyrenophora tritici-repentis*) which are a major limitation to winter cereal production in the northern region.

Field pea can also be used for weed control, by providing additional herbicide group options to reduce the potential development of herbicide resistance. [18] They are the best weed competitors of all the pulses and have more chemical options for broadleaf weed control than chickpeas.

They are the most suited pulse crop for brown/green manure, a valuable non-chemical tool in herbicide resistance management. Tall hay varieties such as Morgan compete well with weeds and provide good bulk for hay, silage or manuring purposes.

Field pea are the most versatile of the legume choices as far as soil types and soil pH are concerned. They will grow on soils from sand through to heavy clays to scalded claypan country, if establishment is successful. That is, they will grow in country where chickpeas won't. A number of growers in central west NSW have taken advantage of this in the past. Challenged with paddocks of multiple soil types, some farmers opted to put field peas in the tight, hardsetting red soils, while chickpeas were planted on the better soil types in the same paddock.

Unlike chickpea, field pea can flower and set pods in cool temperatures, so they can have a high degree of their yield set before the hot, harsh springs typical of the northern region kick in.

Harvest is normally complete before wheat harvest starts. Harvest can be undertaken at 14% moisture.

18 S Moore, G Cumming, L Jenkins, J Gentry (2010). Northern region field pea management guide. Pulse Australia.

Field pea also give growers a chance to topdress or desiccate weeds prior to harvest, providing another opportunity to reduce weed numbers, in particular grass weeds, and providing the first fallow spray for the summer, often decreasing the workload in an otherwise busy harvest/summer period.

Pea straw is a valuable commodity in its own right as a mulch, such as in the garden sector.

1.3.1 Forage production

Field peas provide a highly flexible option that can be used for either grain or forage and provide an alternative to other winter pulses (e.g. chickpea, faba beans). In poorer seasons, when forage availability is limited field peas might contribute forage to livestock, while in better seasons, when forage is more plentiful, field peas are grown for grain. One disadvantage of field pea compared to other winter forage options is that they typically have poor regrowth after grazing and are probably better suited to crash grazing (i.e. high intensity grazing over a short period of time) or cutting for hay.

CSIRO researchers have compared the forage production of several field pea types and varieties and found little difference amongst them (Figures 4 and 5). In experiments over several seasons and conditions in southern Queensland and northern NSW, field peas yielded between 4 and 8 t DM/ha. This is typically less than can be achieved from a forage cereal sown under the same conditions. Forage production of field pea is similar to common vetch but higher than the first year production of perennial legumes such as lucerne or sulla (*Hedysarum coronarium*, a short-lived winter-growing perennial legume).

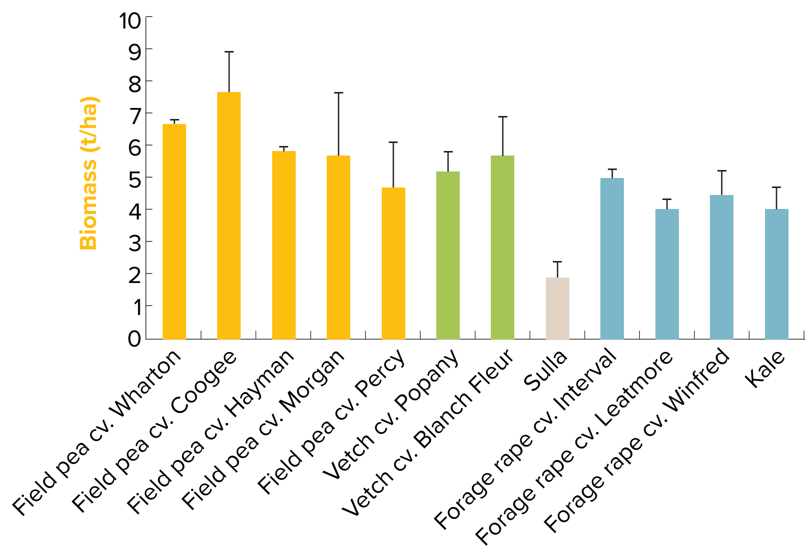

Figure 4: *Comparison of biomass production from five field pea cultivars (yellow), two vetch cultivars (green), the perennial legume sulla (grey) and four forage brassicas (blue) at Tulloona, NSW in 2013.* [19]

19 L Bell (2015) Likely fit of summer and winter forage crop options in Central West farming systems. GRDC Update Papers 24 July 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Likely-fit-of-summer-and-winter-forage-crop-options-in-Central-West-farming-systems

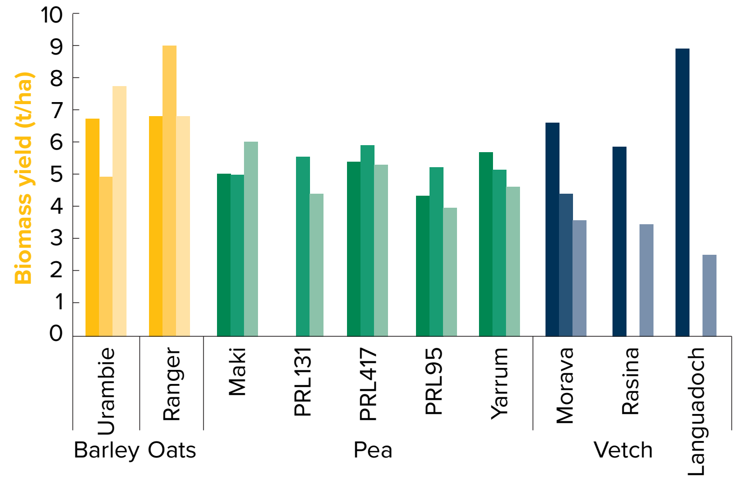

Figure 5: *Comparison of biomass production from two forage cereals (yellow), five field pea cultivars (green), and three vetch cultivars (blue) at three sites in 2010 in south-western Qld; Billa Billa sown on 10 June (darkest colour), Billa Billa sown 18 July (medium colours) and Inglestone (lightest colours).* [20]

1.4 Disadvantages of field peas as a rotation crop

Compared to cereals, field pea provide little ground cover over the summer period but would leave more residues than chickpea or lentil. 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. [21]

- Field pea are less productive on soils with a hardsetting surface, or heavy clay subsoils
- They will not tolerate waterlogging at sowing or at the seedling phase
- Susceptible to insect attack, especially *Helicoverpa*
- Sand blasting by wind can severely damage seedling crops
- Crops can lodge prior to harvest
- Weed control, particularly broadleaf weeds, can be an issue, in particular for weeds such as medic and clover
- Harvest is slow and expensive
- Marketing of the crop can be challenging but some new avenues have emerged in the past few years

1.5 Fallow weed control

Field pea are poor competitors with weeds when they are in the early stages of their growth. The best form of weed control is rotation and careful selection of paddocks largely free from winter weeds—for example, double-cropped from sorghum or cotton, or areas with a sequence of clean winter fallows. Having a well thought-out rotational plan 3–5 years going forward helps determine what paddocks will be

20 L Bell (2015) Likely fit of summer and winter forage crop options in Central West farming systems. GRDC Update Papers 24 July 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Likely-fit-of-summer-and-winter-forage-crop-options-in-Central-West-farming-systems

21 I Pritchard (2014) Field pea stubble: wind erosion control and grazing management. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/field-pea-stubble-wind-erosion-control-and-grazing-management?page=0%2C0

sown to pulses so broadleaf weed control in cereals in the precedings years can be thorough.

Knowledge of your paddock and early control of weeds are important for good control of fallow weeds. Timeliness is everything when it comes to summer weed control.

Benefits of fallow weed control are significant:

- Conservation of summer rain and fallow moisture (this can include moisture stored from last winter or the summer before in a long fallow) is integral to winter cropping in the northern region, particularly so as the climate moves towards summer-dominant rainfall.
- Modelling studies show that the highest return on investment in summer weed control is for lighter soils, or where soil water is present that would support continued weed growth. [22]
- Summer fallows conserve valuable nutrients for the crop being sown, not wasted on weeds.

1.6 Fallow chemical plant-back effects

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

MORE INFORMATION

Australian Pulse Bulletin: Residual herbicides and weed control

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

Figure 6: *Peas on leaf showing the SU (chlorsulfuron) damage versus a healthy plant on the right.*

Photo: DAFWA

Refer to the labels for recommendations on plant-back periods for pulses following use of any herbicides. Be especially wary under conditions of limited rainfall since herbicide application. Usually Glean® or Logran® damage is not serious when these products are used as directed and plant-backs adhered to, although there is an increased risk of damage given:

- very dry or drought conditions
- highly alkaline (pH >8.5) soils
- excessive overlapping during application

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 (Figure 6).

Picloram (e.g. Tordon® 75-D) residues from spot-spraying can stunt any pulse crop grown in that area. This damage is especially marked in faba beans, where plants are twisted and leaves are shrunken. 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 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. [23] [24]

In wheat–field pea rotations the use of fallow and in-crop residual herbicides such as Broadstrike®, Eclipse®, Flame® Grazon®DS, Lontrel® and metsulfuron (Ally®, Associate®, Lynx®) Harmony®M should be avoided, particularly during the summer fallow or weed-control period (after November).

23 GRDC Chickpea GrowNotes, http://www.grdc.com.au/GrowNotes

24 GRDC (2008) Grain Legume Handbook update 7 Feb 2008. Grain Legume Handbook Committee, supported by the Grains Research and Development Corporation (GRDC)

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.

Table 5 shows the half-life and residual persistence of some common pre-emergent herbicides.

Table 5: *Residual persistence of common pre-emergent herbicides, and noted residual persistence in broadacre trials and paddock experience.* [25]

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 (*Eragrostis* spp.) and to a lesser extent broadleaf weeds such as 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

1.7 Important weeds in northern cropping systems

Weed management, particularly in reduced tillage fallows, has become an increasingly complex and expensive part of cropping in the northern grains region. Heavy reliance on glyphosate has selected for species that were naturally more glyphosate-tolerant or has selected for glyphosate-resistant populations.

The four key weeds that are causing major cropping issues are:

1. Awnless barnyard grass (*Echinochloa colona*)
2. Flaxleaf fleabane (*Conyza bonariensis*)
3. Feathertop Rhodes grass (FTR) (*Chloris virgata*)
4. Windmill grass (*Chloris truncata*)

25 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

1.7.1 Awnless barnyard grass

Figure 7: *Awnless barnyard grass.*

Photo: Rachel Bowman.

Awnless barnyard grass (ABYG) (Figure 7) has been a major summer grass problem for many years. It is a difficult weed to manage for at least three main reasons:

1. It has multiple emergence flushes (cohorts) each season.
2. It is easily moisture-stressed and shallow-rooted leading to inconsistent knockdown control.
3. Glyphosate-resistant populations are increasingly being found.

Key points:

- Glyphosate resistance is widespread. Tactics against this weed must change from glyphosate alone.
- Use residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.
- Try to ensure that a double-knock of glyphosate followed by paraquat is used on one of the larger early-summer flushes of ABYG.
- Restrict Group A herbicides to management of ABYG in-crop and aim for strong crop competition.

Resistance levels

Prior to summer 2011–12, there were 21 cases of glyphosate-resistant ABYG. Collaborative surveys were conducted by NSW DPI, QDAF, and NGA in summer 2011–12 with a targeted follow-up in 2012–13. Agronomists from the Liverpool Plains to the Darling Downs and west to areas including Mungindi collected ABYG samples, which were tested at the Tamworth Agricultural Institute with Glyphosate CT at 1.6 L/ha (a.i. 450 g/L) at a mid-tillering growth stage. Total application volume was 100 L/ha. The main finding from this survey work was that the number of 'confirmed' glyphosate-resistant ABYG populations had nearly trebled. Selected populations were also evaluated in a separate glyphosate rate-response trial. The experiment showed that some of these populations were suppressed only when sprayed with 12.8 L/ha.

Growers can no longer rely on glyphosate alone for ABYG control.

Residual herbicides (fallow and in-crop)

A range of active ingredients is registered in either summer crops, e.g. metolachlor (e.g. Dual Gold®) and atrazine, or fallow, e.g. imazapic (e.g. Flame®), and these provide useful management of ABYG. The new fallow registration of isoxaflutole (Balance®) can provide useful suppression of ABYG but has stronger activity against other problem weed species. Few (if any) residuals give consistent, complete control. However, they are important tools that need to be considered to reduce the weed population exposed to knockdown herbicides, as well as to alternate the herbicide chemistry being employed. Use of residuals together with camera spray technology (for escapes) can be a very effective strategy in fallow.

Double-knock control

This approach uses two different tactics applied sequentially. In reduced-tillage situations, it is frequently glyphosate first followed by a paraquat-based spray as the second application or 'knock'. Trials to date have shown that glyphosate followed by paraquat has given effective control even on glyphosate-resistant ABYG. Note that the most effective results will be achieved from paraquat-based sprays by using higher total application volumes (100 L/ha) and finer spray quality and by targeting seedling weeds. Even on glyphosate-resistant ABYG, a glyphosate followed by paraquat double-knock is an effective tool.

Timing of the paraquat application for ABYG control has generally proven flexible. The most consistent control is obtained from a delay of ~3–5 days, when lower rates of paraquat can also be used. Longer delays may be warranted when ABYG is still emerging at the first application timing; shorter intervals are generally required when weed size is larger or moisture stress conditions are expected. High levels of control can still be obtained with larger weeds but paraquat rates will need to be increased to 2.0 or 2.4 L/ha. Water rates should be robust.

Several Group A herbicides (e.g. Verdict® and Select®) are effective on ABYG but should be used in registered summer crops (e.g. mungbeans). Note that Group A herbicides appear more sensitive to ABYG moisture stress. Application on larger, mature weeds can result in very poor efficacy.

1.7.2 Flaxleaf fleabane

There are three main species of fleabane in Australia: *Conyza bonariensis* (flaxleaf fleabane), *C. canadensis* (Canadian fleabane), and *C. albida* (tall fleabane). There are two varieties of *C. canadensis*: var. *canadensis* and var. *pusilla*. Of the three species, flaxleaf fleabane is the most common across Australia. [26]

For more than a decade, flaxleaf fleabane (*C. bonariensis)* has been the major weed-management issue in the northern cropping region, particularly in reduced-tillage systems. Fleabane is a wind-borne, surface-germinating weed that thrives in situations of low competition. Germination flushes typically occur in autumn and spring when levels of surface soil moisture stay high for a few days. However, emergence can occur at nearly all times of the year.

26 M Widderick, H Wu. Fleabane. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/grains-research-development/fleabane

Figure 8: *Fleabane enjoying the little competition offered by wide rows.*

Photo: Penny Heuston

An important issue with fleabane is that knockdown control of large plants in the summer fallow is variable and can be expensive due to reduced control rates.

Key points:

- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.
- This weed thrives in situations of low competition; avoid wide row cropping unless effective residual herbicides are included (Figure 8).
- 2,4-D is a crucial tool for consistent double-knock control.
- Successful growers have increased their focus on fleabane management in winter (crop or fallow) to avoid expensive and variable salvage control in the summer.

Resistance levels

Glyphosate resistance has been confirmed in fleabane. There is great variability in the response of fleabane to glyphosate, with many samples from non-cropping areas still well controlled by glyphosate, whereas fleabane from reduced-tillage cropping situations shows increased levels of resistance. The most recent survey has focused on non-cropping situations, with a large number of resistant populations found on roadsides and railway lines where glyphosate alone has been the principal weed management tool employed.

Residual herbicides (fallow and in-crop)

One of the most effective strategies to manage fleabane is the use of residual herbicides during fallow or in-crop. Trials have consistently shown good efficacy from a range of residual herbicides commonly used in sorghum, cotton, chickpeas, and winter cereals. There are now at least two registrations for residual fleabane management in fallow.

Additional product registrations for in-crop knockdown and residual herbicide use, particularly in winter cereals, are still being sought. A range of commonly used winter cereal herbicides exists with useful knockdown and residual fleabane activity. Trials to date have indicated that increasing water volumes from 50 to 100 L/ha may help the consistency of residual control, with application timing to ensure good herbicide/soil contact also important.

Knockdown herbicides (fallow and in-crop)

Group I herbicides have been the major products for fallow management of fleabane, with 2,4-D amine the most consistent herbicide evaluated. Despite glyphosate alone generally giving poor control of fleabane, trials have consistently shown a benefit from tank mixing 2,4-D amine and glyphosate in the first application. Amicide® Advance at 0.65–1.1 L/ha mixed with Roundup® Attack at a minimum of 1.15 L/ha and then followed by Paraquat at 1.6–2.0 L/ha is a registered option for fleabane knockdown in fallow. Sharpen is a product with Group G mode of action. It is registered for fallow control when mixed with Roundup Attack at a minimum of 1.15 L/ha but only on fleabane up to a maximum of six leaves.

Double-knock control

The most consistent and effective double-knock control of fleabane has included 2,4-D in the first application followed by paraquat as the second. Glyphosate alone followed by paraquat will result in high levels of leaf desiccation but plants nearly always recover.

Timing of the second application in fleabane is generally aimed at ~7–14 days after the first application. However, the interval to the second knock appears quite flexible. Increased efficacy is obtained when fleabane is actively growing or if rosette stages can be targeted. Although complete control can be obtained in some situations (e.g. summer 2012–13), control levels will frequently reach only ~70–80%, particularly when targeting large, flowering fleabane under moisture-stressed conditions. The high cost of fallow double-knock approaches and inconsistency in control level of large, mature plants are good reasons to focus on proactive fleabane management at other growth stages. [27] [28]

1.7.3 Feathertop Rhodes grass

Figure 9: *Feathertop Rhodes grass.*

Photo: Rachel Bowman

Feathertop Rhodes (FTR) grass (Figure 9) has emerged as an important weed-management issue in southern Queensland and northern NSW since ~2008. This is another small-seeded weed species that germinates on, or close to, the soil surface. It has rapid early growth rates and can become moisture stressed quickly. Although

27 Field pea GRDC Chickpea GrowNotes, http://www.grdc.com.au/GrowNotes

28 S Walker. Northern IWM fact sheet. Queensland Alliance for Agriculture and Food Innovation, https://www.daf.qld.gov.au/__data/assets/pdf_file/0005/65903/Flaxleaf-fleabane.pdf

FTR is well established in central Queensland, it remains largely an 'emerging' threat further south. Patches should be aggressively treated to avoid whole-of-paddock blow-outs.

Key points:

- Glyphosate alone or glyphosate followed by paraquat has generally poor efficacy.
- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.
- A double-knock of Verdict followed by paraquat can be used in Queensland prior to planting mungbean where large spring flushes of FTR occur.
- Treat patches aggressively, even with cultivation, to avoid paddock blow-outs.

Residual herbicides (fallow and in-crop)

This weed is generally poorly controlled by glyphosate alone even when sprayed under favourable conditions at the seedling stage. Trials have shown that residual herbicides generally provide the most effective control, a similar pattern to that seen with fleabane. Currently registered residual herbicides are being screened and offer promise in both fallow and in-crop situations. The only product currently registered for FTR control is Balance (isoxaflutole) at 100 g/ha for fallow use.

Double-knock control

Whereas a glyphosate followed by paraquat double-knock is an effective strategy on ABYG, the same approach is variable and generally disappointing for FTR management. By contrast, a small number of Group A herbicides (all members of the 'fop' class) can be effective against FTR but need to be managed within a number of constraints:

- Although they can provide high levels of efficacy on fresh and seedling FTR, they need to be followed by a paraquat double-knock to get consistent high levels of final control.
- Group A herbicides have a high risk of resistance selection, again requiring follow-up with paraquat.
- Many Group A herbicides have plant-back restrictions to cereal crops.
- Group A herbicides generally have a narrower range of weed growth stages for successful use than herbicides such as glyphosate; that is, Group A herbicides will generally give unsatisfactory results on flowering and/or moisture-stressed FTR.
- Not all Group A herbicides are effective on FTR.

For information on a permit (PER12941) issued for Queensland only for the control of FTR in summer-fallow situations prior to planting mungbean, see www.apvma.gov.au.

Timing of the second application for FTR is still being refined, but application at ~7–14 days generally provides the most consistent control. Application of paraquat at shorter intervals can be successful, when the Group A herbicide is translocated rapidly through the plant, but has resulted in more variable control in field trials. Good control can often be obtained up to 21 days after the initial application. [29] [30]

29 GRDC Chickpea GrowNotes, http://www.grdc.com.au/GrowNotes

30 APVMA (2014) Search for a permit. Australian Pesticides and Veterinary Medicine Authority, http://apvma.gov.au/node/46

1.7.4 Windmill grass

Figure 10: *Windmill grass.*

Photo: Maurie Street

While FTR has been a grass weed threat coming from Queensland and heading south, windmill grass is more of a problem in central NSW and is spreading north. Windmill grass (Figure 10) is a perennial, native species found throughout northern NSW and southern Queensland. The main cropping threat appears to be from the selection of glyphosate-resistant populations, with control of the tussock stage providing most challenges to management.

Key points:

- Glyphosate alone or glyphosate followed by paraquat has generally poor efficacy.
- Preliminary data suggest that residual chemistry may provide some benefit.
- A double-knock of quizalofop-p-ethyl (e.g. Targa) followed by paraquat can be used in NSW.

Resistance levels

Glyphosate resistance has been confirmed in windmill grass, with three documented cases in NSW, all located west of Dubbo. Glyphosate-resistant populations of windmill grass in other states have all been collected from roadsides, but in central-western NSW, two were from fallow paddock situations.

Residual herbicides (fallow and in-crop)

Preliminary trials have shown a range of residual herbicides with useful levels of efficacy against windmill grass. These herbicides have potential for both fallow and in-crop situations. Currently, no products are registered for residual control of windmill grass.

Double-knock control

Similar to FTR, a double-knock of a Group A herbicide followed by paraquat has provided clear benefits compared with the disappointing results usually achieved by glyphosate followed by paraquat. Constraints apply to double-knock for windmill grass control similar to those for FTR.

For information on a permit for NSW only for the control of windmill grass in summer fallow situations, visit www.apvma.gov.au.

Timing of the second application for windmill grass is still being refined, but application at ~7–14 days generally provides the most consistent control. Application of paraquat at shorter intervals can be successful, when the Group A herbicide is translocated rapidly through the plant, but has resulted in more variable control in field trials and has been clearly antagonistic when the interval is 1 day or less. Good control can often be obtained up to 21 days after the initial application. [31]

1.8 Seedbed requirements

Table 6: *Guidelines for pulse crop soil requirements on central NSW soils.* [32]

Crop	Soil type	Soil pHCa	Exchangeable Al% range	Drainage tolerance (1–5)**	Sodicity in root zone (90 cm) (ESP) +
Lupin – narrow leaf	Sandy – loams	4.2–6.0	20% Tolerant	Sensitive (2)	< 1 surface < 3 surface
Lupin – albus	Sandy – loams – clay loams	4.6–7.0	Up to 8%	Very sensitive (1)	< 1 surface < 3 subsoil
Field pea	Sand – loams – clays	4.6–8.0	Up to 5–10%	Tolerant (3)	< 5 surface < 8 subsoil
Chickpeas	Loams – self mulching clay loams	5.2–8.0	Nil	Very sensitive (1)	< 1 surface < 5 subsoil
Faba beans	Loams – clay loams	5.4–8.0	Nil	Very tolerant (4)	< 5 surface < 10 subsoil
Canola*	Loams – clay loams	4.8–8.0	0–5%	Tolerant (3)	< 3 surface < 6 subsoil
Lucerne*	Loams – clay loams	5.0–8.0	Nil	Sensitive – tolerant (1–3) dependent on variety	< 3 surface < 5 subsoil

* Non-pulse comparison

** No hardpans and good drainage (i.e. no puddles after 24 hours from a 50 mm rain event). Hardpans – can aggravate waterlogging and cause artificial waterlogging.

+ Exchangeable sodium %

Trouble-free harvesting requires an even soil surface at sowing. This can be achieved via a number of techniques including rolling, the use of a disc seeder, rolling harrows mounted on the sowing rig, or even the use of finger harrows or a dragged railway line can provide enough soil shift to create a more level surface come harvest time Guidelines for pulse crop soil requirements are presented in Table 6.

Rolling is best done straight after sowing, as long as the soil surface is not too moist (Figure 11). However, field pea can be rolled after emergence, when it is best between the 3 and 10 node stages. [33] The disadvantage of this technique is that it requires a second pass over the paddock in a labour-intensive period and many growers do not possess this piece of machinery.

31 R Daniel. Weeds and resistance — considerations for awnless barnyard grass, Chloris spp and fleabane management. Northern Grower Alliance, http://www.nga.org.au/module/documents/download/225

32 *Agnote DPI 446* C Mullen (2004) The right pulse in the right paddock at the right time. *(Revised May 2004)* NSW Agriculture,http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/151112/the-right-pulse-in-the-right-paddock-at-the-right-time.pdf

33 Field pea: crop management and production (2015) Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/field-pea-crop-management-and-production

Figure 11: *Rolling harrows on a zero-till rig setup for field pea sowing, Collie NSW.*

Photo: Penny Heuston

Field pea harvest is a slow process with the header generally 'on the deck' or at the soil level to help pick up plants that have lodged.

Sticks are a hazard as they can result in damage to expensive harvest machinery, not to mention valuable 'down time' at harvest when repairs are necessary.

Soil in the sample can result in either downgrading of the sample or expensive grading to remove the soil from the grain. Foreign material must not exceed 3% by weight, of which no more than 0.3% can be soil.

An uneven soil surface can result in a physical impediment to being able to harvest all of the crop if the machine cannot travel close to the soil surface. Gilgais and paddock undulation could result in this impediment. They can also lead to uneven crop maturity due to variation in soil water supply. Melon-holes or gilgais usually store more water than the mounds, and the crop in the wetter areas will often continue to flower and pod when the rest of the crop is already drying down. Similarly, contour banks retain more moisture after rain, and prolong crop maturity relative to the rest of the crop late in the crop.

1.9 Yield and targets

1.9.1 Seasonal outlook

The online tool CropMate was developed by NSW DPI and can be used in pre-season planning to analyse average temperature, rainfall and evaporation. It provides seasonal forecasts and information about influences on climate, such as the impact of Southern Oscillation Index (SOI) on rainfall.

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

Queensland Alliance for Agriculture & Food Innovation produces regular, seasonal outlooks for wheat producers in Queensland. These high-value reports are written in an easy-to-read style and are free. Download the 'Seasonal Crop Outlook—wheat, May 2015' at: https://qaafi.uq.edu.au/industry/crop-outlook

For tips on understanding weather and climate drivers, including the SOI, visit the Climate Kelpie website. Case studies of 37 farmers across Australia recruited as

'Climate Champions' as part of the Managing Climate Variability R&D Program can also be accessed at the Climate Kelpie website: http://www.climatekelpie.com.au/

Australian CliMate is a suite of climate analysis tools delivered on the web, and on 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 Nino Southern Oscillation status. It is designed for decision makers such as farmers whose businesses rely on the weather.

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

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

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

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

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

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. [34]

The Bureau of Meteorology has recently moved from a statistics-based to a physics-based (dynamical) model for its seasonal climate outlooks. The new system has better overall skill, is reliable, allows for incremental improvements in skill over time, and provides a framework for new outlook services including multi-week/monthly outlooks and the forecasting of additional climate. [35]

1.9.2 HowWet?

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

HowWet?

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

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

34 Australian CliMate—Climate tools for decision makers, www.australianclimate.net.au

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

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

Questions this tool answers:

- How much longer should I fallow? If the soil is near full, perhaps the fallow can be shortened.
- Given my soil type and local rainfall to date, what is the relative soil moisture and nitrate-N accumulation over the fallow period compared with most years? Relative changes are more reliable than absolute values.
- Based on estimates of soil water and nitrate-N accumulation over the fallow, what adjustments are needed to the N supply? [36]

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 HowOften?

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

Reliability

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

Soil descriptions are based on generic soil types with standard organic carbon (C) and C/N ratios, and as such should be regarded as indicative only and best used as a measure of relative water accumulation and nitrate mineralisation. [37]

1.9.3 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. As a farmer, you have some control over the stored soil water; you can measure how much you have before planting the crop. Long-range forecasts and tools such as the SOI can indicate the likelihood of the season being wet or dry; however, they cannot guarantee that rain will fall when you need it. [38]

Measure stored soil moisture depth

Soil moisture probes, like any other component of precision agriculture, can help people confirm decisions or take decision making to another level.

Plant available water capacity (PAWC)

PAWC is a measure of the ability of a soil to store water for later crop production. Figure 12 shows the water states 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, 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.

36 Australian CliMate: HowWet/N, http://www.australianclimate.net.au/About/HowWetN

37 Australian CliMate: HowWet/N, http://www.australianclimate.net.au/About/HowWetN

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

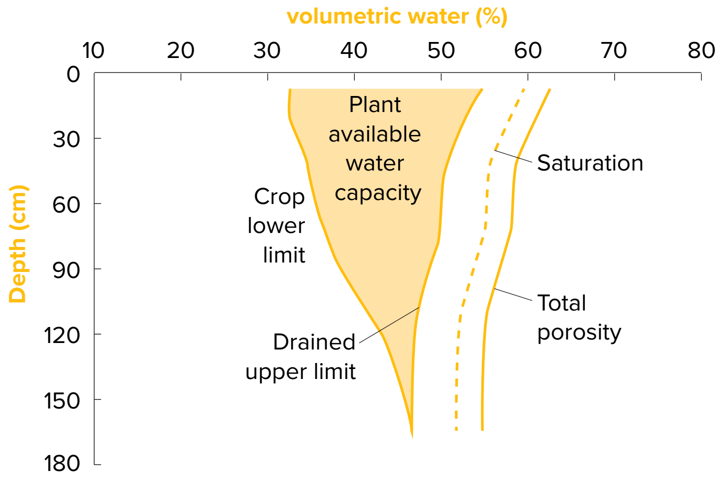

Figure 12: *A typical storage profile for a heavy-textured clay soil showing the potential water storage of the soil, PAWC, as defined by the drained upper limit (DUL-blue shading), crop lower limit (CLL), saturation (SAT), and total porosity (PO).* [39]

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 of the order of 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 region where rainfall shows a strong summer incidence. 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 cases standing stubble may enhance evaporative losses. In contrast, on clay soils in southern Australia, fallow efficiencies 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. [40]

1.9.4 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.

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

40 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/Resources/Publications/2012/07/Water-use-efficiency-of-grain-crops-in-Australia

WUE relies on:

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

Water is the principal limiting factor in rain-fed cropping systems in northern Australia. The objective of rain-fed cropping systems is to maximise the proportion of rainfall that crops use, and minimise water lost through runoff, drainage and evaporation from the soil surface and to weeds. Best practices are outlined in Table 7.

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

Storing water in fallows between crops is the most effective tool growers have to manage the risk of rainfall variability, as in-season rainfall alone—in either summer or winter—is rarely enough to produce a profitable crop, especially given high levels of plant transpiration and evaporation (Table 8). Fortunately, many cropping soils in the northern region have the capacity to store large amounts of water during fallow. [41]

Table 7: *Key best practices for maximising the conversion of rainfall into grain.* [42]

Practice	Impact
Zero tillage	Maintain high cover levels, maximise water infiltration and minimise evaporation and soil loss, extend planting windows
Crop rotation	Regularly include crops that produce high stubble cover, for example cereals on narrow row spacing or a summer cover crop
Controlled traffic farming Opportunity cropping	Reduced soil compaction maximises water infiltration and plant growth Capitalise on planting opportunities and minimise fallow length
Know your plant available water (PAW) and plant available water capacity (PAWC)	Assist in determining yield potential
Assess yield potential and likely crop profitability at planting	Assist in making the decision whether to plant now or wait until the next opportunity
Invest in a planter with the required capabilities and capacity Manage weeds in fallow and crop	Enable planting of adequate areas when opportunities arise – requires capability to handle stubble, moisture seek, achieve good establishment in less than optimal conditions and apply required fertilisers at planting
Good management of other aspects of crop agronomy	Maximise fallow efficiencies and minimise in-crop competition for water Maximise crop Water Use Efficiency

41 Water Use Efficiency fact sheet: northern region (2009). Grains Research & Development Corporation, http://www.grdc.com.au/uploads/documents/GRDC_Water%20Use%20Efficiency%20North%20version%20231009.pdf

42 Water Use Efficiency fact sheet: northern region (2009). Grains Research & Development Corporation, http://www.grdc.com.au/uploads/documents/GRDC_Water%20Use%20Efficiency%20North%20version%20231009.pdf

Table 8: *Water Use Efficiency based on total biomass (WUEdm) or grain yield (WUEgy) of different crops. Water Use Efficiency is based on the biomass or yield per mm of crop water use. Values are mean and range.*

Crop	Region	WUEdm	WUEgy (kg/ha.mm)	Source
Canola	Victoria	24.0 (17.1–28.4)	6.8 (4.7–8.9)	Norton and Wachsmann 2006
Canola*	NSW		13.4	Robertson and Kierkegaard 2005
Chickpeas	Western Australia	16.0 (11.1–18.3)	6.2 (2.6–7.7)	Siddique et al. 2001
Lentils		12.7 8.5–16.7)	6.7 (2.4–8.5)	
Lupins		17.3 (9.3–22.3)	5.1 (2.3–8.3)	
Faba beans		24.2 (18.7–29.6)	10.4 (7.7–12.5)	
Peas		26.2 (17.6–38.7)	10.5 (6.0–15.9)	
Vetch		18.2 (13.4–22.4)	7.5 (5.6–9.6)	
Chickpeas	Tel Hadya, Syria	13.7 (9.4–18.1)	3.2 (2.1–5.2)	Zhang et al. 2000
Lentils		8.7 (5.0–14.2)	3.8 (1.9–5.5)	
Wheat	South Australia	36.1 (21.2–53.1)	15.9 (9.2–23.2)	Sadras et al. (unpublished)
	South-east Australia		9.9 (max =22.5)	Sadras and Angus 2006

Source: Sadras et al (2002)
* Based on simulated estimate of crop water use

1.10 Disease status of paddock

Selecting the paddock with the lowest disease risk for field peas is the first step to maximising yield and profit.

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 which cause Brown leaf spot and Pleiochaeta root rot in lupins, and Black spot in field peas. Leave at least four 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 move into adjacent paddocks on infected trash and dust, even if the paddock has never grown a pulse 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 peas the previous year as spores will travel on the prevailing winds. Spores can also move on water; hence 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 hardsetting crusting soils, which can result in poor crop growth and promote infection from pathogens. [43]

1.10.1 Soil testing for disease

PreDicta B (B = broadacre) is a DNA-based soil testing service to identify 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

43 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

- take-all (*Gaeumannomyces graminis* var. *tritici* (Ggt) and *G. graminis* var. *avenae* (Gga))
- Rhizoctonia barepatch (Rhizoctonia solani AG8)
- crown rot (*Fusarium pseudograminearum*)
- root-lesion nematode (RLN) (*Pratylenchus neglectus* and *P. thornei*)
- stem nematode (*Ditylenchus dipsaci*)

Northern region grain producers can access PreDicta B via Crown Analytical Services or agronomists accredited by the South Australian Research and Development Institute to interpret the results and provide advice on management options to reduce the risk of yield loss. PreDicta B samples are processed weekly from February to mid-May (prior to crops being sown) to assist with planning the cropping program.

PreDicta B is not intended for in-crop diagnosis. That is best achieved by sending samples of affected plants to your local plant pathology laboratory. [44] [45]

1.10.2 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.

1.11 Nematode status of paddock

Root-lesion nematodes (RLN, *Pratylenchus thornei* and *Pratylenchus neglectus*) are migratory root endoparasites that are widely distributed in the wheat-growing regions of Australia and can reduce grain yield by up to 50% in many current wheat varieties.

P. thornei is the most damaging species and occurs commonly in the northern grain region. *P. neglectus* occurs less frequently than *P. thornei* but is still quite common. A third nematode is *Merlinius brevidens* (stunt nematode). The RLN *Pratylenchus thornei* (Pt) is widespread in cropping soils through central and northern NSW, with lower levels of *Pratylenchus neglectus* found in the more southern parts of the region.

Pratylenchus thornei costs the wheat industry A$38 million annually. Including the secondary species, *P. neglectus*, RLN was found in three-quarters of all paddocks tested. [46]

Symptoms:

In the field, symptoms include stunted growth, uneven patches or waviness across the paddock.

Unlike chickpeas which can endure yield losses of 20–30% in intolerant varieties, field peas are resistant to *P. thornei* and *P. neglectus*. Resistant lines minimise nematode multiplication for following crops. [47]

The two main root symptoms include lesions or discoloration of the roots and lack of branching along the main roots. Unlike CCN, root lesion nematodes do NOT cause the roots to swell or knot and no cysts are produced.

1.11.1 Effects of cropping history on nematode status

Rotating with resistant crops keeps root lesion nematodes at low levels.

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44 GRDC Chickpea GrowNotes, http://www.grdc.com.au/GrowNotes

45 Grains: Information and Services. Primary Industries and Regions South Australia (PIRSA), http://pir.sa.gov.au/primary_industry/crops_and_pastures/information_and_services

46 K Owen, J Sheedy, N Seymour. Root Lesion Nematode—Queensland. Queensland Department of Agriculture, Fisheries, and Forestry, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

47 Root Lesion Nematode (2014) Department of Environment and Primary Industries, Victoria, www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/root-lesion-nematode

RLN numbers build up steadily under susceptible crops and cause decreasing yields over several years. Yield losses >50% can occur in some wheat varieties, and up to 20% in some chickpeas varieties. The amount of damage caused will depend on:

- numbers of nematodes in the soil at sowing
- tolerance of the variety of the crop being grown
- environmental conditions

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

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

Growing resistant crops is the main tool for managing nematodes. In the case of crops such as wheat or chickpeas, choose the most tolerant variety available and rotate with resistant crops to keep nematode numbers at low levels. Information on the responses of crop varieties to RLN is regularly updated in state based planting guides. Note that crops and varieties have different levels of tolerance and resistance to *Pt and P. neglectus*.

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

Growing resistant crops is the main tool for managing nematodes. In the case of crops such as wheat or chickpeas, choose the most tolerant variety available and rotate with resistant crops to keep nematode numbers at low levels. Information on the responses of crop varieties to RLN is regularly updated in grower and QDAF planting guides. Note that crops and varieties have different levels of tolerance and resistance to *Pt* and *P. neglectus* (Table 9).

Summer crops have an important role in management of RLN. Research shows when Pt is present in high numbers, two or more resistant crops in sequence are needed to reduce populations to low enough levels to avoid yield loss in the following intolerant, susceptible wheat crops. [48]

Table 9: *Susceptibility and resistance of various crops to root lesion nematodes.*

RLN species	Susceptible	Intermediate	Resistant
P. thornei	wheat, chickpea, faba bean, barley, mungbean, navy bean, soybean, cowpea	Canola, mustard, triticale. Durum wheat, maize, sunflower	Canary seed, lab lab, linseed, oats, sorgum, millet, cotton, pigeon pea
P. neglectus	wheat, canola,chickpea, mustard, sorghum-grain, sorghum-forage	Barley, oat, canaryseed, durum wheat, maize, navy bean	Linseed, field pea, faba bean, triticale, mungbean, soybean

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

1.12 Insect status of paddock

1.12.1 Insect sampling of soil

Soil-dwelling insect pests can seriously reduce plant establishment and populations, 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.

48 K Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes. GRDC Update Papers, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Impact-from-Pratylenchus-thornei

Soil insects include:

- cockroaches
- crickets
- earwigs
- black scarab beetles
- cutworms
- false wireworm
- true wireworm

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

- Weedy fallows and volunteer crops encourage soil insect build-up.
- Insect numbers decline during a clean long fallow due to lack of food.
- Summer cereals followed by volunteer winter crops promote the build-up of earwigs and crickets.
- High stubble levels on the soil surface can promote some soil insects due to 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. [49]

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

Pre-planting

When a paddock is to be sown to a pulse crop, broadleaf weed pressure should be low and the weed seed bank should have been reduced in previous crops. Avoid problem weed paddocks, considering both weeds which 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, dependent 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]

2.1 Varietal performance and ratings yield

Field pea varieties grown in Australia can be divided into five groups, with the most common of these being Dun followed by white and blue/green pea:

Dun: greenish-brown (dun) coloured seed with yellow cotyledons. Traditionally dimpled, but rounded types exist now. Increased seed hardness can occur in Dun types under certain climatic conditions which can result in a lower germination. Used for human consumption and stockfeed.

White (also called yellow peas in North America and Europe): cream-coloured seed with yellow cotyledons and rounded seed. Large whites are used for human consumption—split and flour. White peas do not have a hard seed component due to their white seed coat.

Maple: brown, smooth or dimpled, mottled or speckled seed with yellow cotyledons. Used for stockfeed and bird feed.

Blue/green: 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. [2]

http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/winter-crop-variety-sowing-guide

2.1.1 Yielding ability

The most accurate predictor of a variety's performance is a stable yield in many locations over several years.

Yield results from Pulse Breeding Australia (PBA) and National Variety Trials (NVT) are available from the NVT website, www.nvtonline.com.au, as well as from the specific

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 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation. http://www.grdc.com.au/Resources/Bookshop/2009/12/Field-Peas-The-Ute-Guide

Pulse Variety Management Package (VMP) brochure at http://www.grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

Table 1 shows the long-term (2011–15) NVT results for the north west NSW region for field peas. Figure 1 shows adjusted average yield for south east NSW.

http://www.nvtonline.com.au/nvt-results-reports/

Table 1: *Field pea variety trial results.* [3]

Variety name	Predicted avg yield (t/ha)	Total no. Trials
CRC Walana	1.940	6
PBA Wharton(b)	1.901	14
PBA Pearl(b)	1.823	14
PBA Oura(b)	1.792	14
Yarrum	1.783	10
Maki	1.768	6
SW Celine	1.753	4
PBA Twilight(b)	1.749	12
PBA Gunyah(b)	1.734	12
PBA Percy(b)	1.712	14
Sturt	1.667	8
Kaspa(b)	1.574	14
Morgan	1.513	11

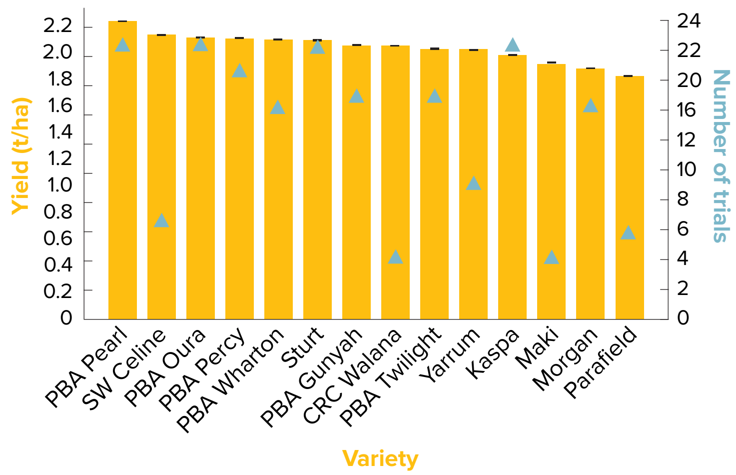

Figure 1: *Adjusted average yield 2011–15 for south east NSW trials.* [4]

3 Long term yield report, Field pea, Main season, N/W, http://www.nvtonline.com.au/nvt-results-reports/

4 Long term yield report, Field pea, Main season, S/E, http://www.nvtonline.com.au/nvt-results-reports/

NSW GOVERNMENT Primary Industries

Field Peas: Short Fallow (No-till)
Central Zone - West **Winter 2012**

1. GROSS MARGIN BUDGET:

		No-Till Standard Budget $/ha	Your Budget $/ha
INCOME:			
1.80 tonnes/ha @ $290.00 /tonne (on farm)		$522.00	
	A. TOTAL INCOME $/ha:	**$522.00**	
VARIABLE COSTS: See opposite page for detail			
	Sowing	$136.22	
	Fertiliser	$72.10	
	Herbicide	$0.00	
	Insecticide	$20.57	
	Contract-harvesting	$50.00	
	Levies	$5.30	
	Crop Insurance	$9.10	
	Cartage, grading & bagging	$0.00	
	B. TOTAL VARIABLE COSTS $/ha:	**$293.28**	
	C. GROSS MARGIN (A-B) $/ha:	**$228.72**	

2. EFFECT OF YIELD AND PRICE ON GROSS MARGIN PER HECTARE:

YIELD tonnes/ha	ON FARM PRICE ($/tonne) $230 /t	$260 /t	$290 /t	$320 /t	$350 /t
0.90	- $78	- $51	- $25	$1	$27
1.20	- $11	$25	$60	$95	$130
1.50	$57	$100	$144	$188	$232
1.80	$124	$176	**$229**	$281	$334
2.10	$191	$252	$313	$375	$436
2.40	$258	$328	$398	$468	$538
2.70	$325	$404	$483	$561	$640

Gross Margin ($/ha)

PRODUCT TRADE NAMES
The product trade names in this publication are supplied on the understanding that no preference between equivalent products is intended and that the inclusion of a product does not imply endorsement by NSW DPI over any other equivalent product from another manufacturer.

Figure 2: *Typical Gross Margin for field peas in central west NSW.*

Source: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/386617/dryland-central-west-fieldpeas.pdf

MORE INFORMATION

GRDC Update Paper: New opportunities for pulses in the Mallee

2.1.2 Varieties

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 them 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]

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

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 control.

In association with Pulse Australia and its commercial seed partners, PBA launches its new varieties at targeted pulse field days during the spring field-day circuit. This gives growers and advisors 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. The 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 funded by the GRDC in conjunction with the PBA partner agencies, combined with yield data from variety trials conducted by both PBA and NVT. [6]

Field pea varieties range in growth habit from trailing to erect at maturity. The trailing growth type can be difficult to harvest but the semi-leafless/semi-dwarf forms of field pea—where leaves have been modified into tendrils—can have a better standability, aiding harvest. Plant height at flowering is affected by temperature and light, as well as variety.

The individual varieties have different coloured flowers from all white to pink and white to purple and pink (Figures 3–5).

http://www.grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

Figure 3: *The white flowers of the Maki field pea.*

Photo: Penny Heuston

6 Pulse Breeding Australia. PBA Varieties and brochures. GRDC Major Initiatives, http://www.grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

Figure 4: *The pink and purple flowers of Morgan field peas.*

Photo: Penny Heuston

Figure 5: *The white and pink flower of the Kaspa field pea.*

Photo: DAFWA

Seed pod types fall into the normal pod type or the non-shattering sugar-pod types, which are logically less prone to shatter at harvest.

Field peas are characterised into groups based on their seed coat colour, with the bulk of the Australian crop falling into the dun, white or blue-green categories.

Dun field peas

Dun peas constitute the greatest portion of varieties grown, with Australia being the major exporter of dun type peas. A dun pea has a yellow cotyledon with a greenish-brown or dun-coloured seed coat. Older dun varieties, such as Morgan and Yarrum, have a 'dimpled' seed coat that is undesirable in the human consumption market as it makes for an unaesthetically pleasing split product for this market. Some newer dun types (e.g. PBA Twilight and Kaspa) have a more spherical seed. The bulk of the dun peas would be used in the stockfeed industry.

Over 95% of Australian production is from dun types of which more than 90% is now 'Kaspa type' (e.g. Kaspa, PBA Gunyah, PBA Twilight). Kaspa type grain is preferred for snack food in southern India over other pea grain 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. [7]

PBA Coogee: http://www.pulseaus.com.au/storage/app/media/crops/2013_VMP-Dunfieldpea-PBACoogee.pdf

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

7 P Kennedy, J Brand, F Henry, M Raynes (2014) FIELD PEA. Department of Environment and Primary Industries, Victoria, http://agriculture.vic.gov.au/__data/assets/word_doc/0003/318873/Field-Pea-2016.docx

PBA Percy⯑: http://www.pulseaus.com.au/storage/app/media/crops/2011_VMP-Dunfieldpea-PBAPercy.pdf

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

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

PBA Gunyah⯑: http://www.pulseaus.com.au/storage/app/media/crops/2012_VMP-Kfieldpea-PBAGunyah.pdf

PBA Twilight⯑: http://www.pulseaus.com.au/storage/app/media/crops/2011_VMP-Kfieldpea-PBATwilight.pdf

PBA Wharton⯑: http://www.pulseaus.com.au/storage/app/media/crops/2013_VMP-Kfieldpea-PBAWharton.pdf

Morgan: http://www.hartbrosseeds.com.au/all-products/morgan-field-pea.aspx

White field peas

Round-white peas (called yellow peas in North America and Europe) are also grown in significant quantities. These types generally have white flowers, yellow cotyledons, and a white-creamy seed coat. Canada and France dominate world export markets and produce mainly white peas. [8]

White peas have a white seed coat and are suitable for both the human consumption and stockfeed industries

Walana: http://porkcrc.com.au/Walana-2011.pdf

Pearl⯑: http://www.pulseaus.com.au/storage/app/media/crops/2012_VMP-Wfieldpea-PBAPearl.pdf

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

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

Blue field peas

Blue or green peas have a blue/green seed coat with a green cotyledon with a round seed and have the potential to fill human niche markets, such as that developed in the central-west of NSW over the last few years.

Maki: http://www.pulseaus.com.au/storage/app/media/crops/2010_VMP-Fieldpea-Maki.pdf

Varieties suited to green/brown manuring

Two varieties (PBA Hayman⯑ and PBA Coogee⯑) have been released for suitability to forage (hay/silage) or green/brown manuring. 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) (Figure 6). Results to date show:

- The ideal timing of hay cutting for both maximum biomass production and ease of drying (i.e. before pod set) is likely to be approximately 7–14 days after commencement of flowering (i.e. early pod development).
- Varieties with later flowering and pod set (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.

8 I Pritchard (2014) Growing field pea. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/growing-field-pea

MORE INFORMATION

Ground Cover Issue 116: Brown manure legumes lower total crop risk

- PBA Coogee(D) may not produce more biomass than Kaspa(D) or Morgan at the early pod stage.
- PBA Hayman(D) 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(D) and PBA Coogee(D) produce significantly higher grain yield than Morgan or PBA Hayman(D).
- PBA Hayman(D) 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 (averages 14 g/100 compared with 20–25 g/100 seeds in other varieties); seed requirements for sowing will be significantly lower than other varieties. [9]

For information on using pulses for forage, see the Australian Pulse Bulletin at http://www.pulseaus.com.au/growing-pulses/publications/using-pulses-forage

Figure 6: *Morgan field peas cut and baled as silage as a tool to control herbicide-resistant ryegrass.*

Photo: Penny Heuston

2.1.3 Protein or other quality traits

The main differing feature between varieties for quality traits amongst field peas is the seed coat colour. This coat colour determines the market and end point usage for the grain.

Table 2 expressed the nutritional value of field peas as a source of stockfeed for the seed portion of the crop. [10]

9 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, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Pulse-varieties-and-agronomy-update-Ballarat

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

Table 2: *Average nutritive value of common feeds.*

Feed	Dry matter %	Crude protein %	Metabolisable energy (Mj/kg DM)
Field pea	90	23	14
Lupin	90	30	13
Faba bean	90	25	13
Chickpea	90	19	15
Mungbean	90	24	11
Triticale	90	12	13
Barley	90	11	13
Wheat	90	12	13
Oats	90	8	11
Soybean meal	90	47	12

2.1.4 Maturity

See variety maturity rankings in NSW DPI Crop variety sowing guide 2015, page 106:

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

Table 3: *Variety characteristics and reaction to diseases.*

							Disease				Yield % Kaspa⍉				Yield % Yarrum*	
											South east		South west		North west	
Variety	PBR	Standing at maturity	Leaf type	Height	Maturity	Shatter resistance	Bacterial blight# (*Pseudomonas syringae* pv *syringae*)	Downy mildew (Parafield strain)	Powdery mildew	Seed size (g/100 seeds)	%	No. Trials	%	No. Trials	%	No. Trials
Dun field peas											Kaspa⍉= 2.48 t/ha		Kaspa⍉= 1.76 t/ha		Yarrum= 2.14 t/ha	
Kaspa⍉	Yes	4	SL	M	8	R	S	MR	S	22	100	16	100	19	80	12
Morgan	Yes	3	SL	T	9	MR	MR	R	S	18	98	13	102	15	80	9
Parafield	No	2	C	T	7	MR	MR–MS	S	S	23	93	9	99	13	78	3
PBA Coogee⍉	Yes	2	C	T	8	MR	MS–MR	–	R	20	87	6	101	10	83	7
PBA Gunyah⍉	Yes	4	SL	M	5	R	S	R	S	22	102	16	102	19	89	12
PBA Oura⍉	Yes	4	SL	M	5	MR	MR	MR	S	22	110	16	112	19	95	12
PBA Percy⍉	Yes	2	C	T	5	MR	R	S	S	23	107	16	113	19	89	12
PBA Twilight⍉	Yes	4	SL	M	4	R	S	R	S	22	100	16	100	19	89	12
PBA Wharton⍉	Yes	4	SL	M	5	R	S	R	R	23	104	16	107	19	99	12
Yarrum	Yes	4	SL	M–S	5	MR	MR–MS	S	R	22	115	11	107	13	100	10
Blue field peas																
Excell	No	6	SL	M	6	S	S	MR	S	22	94	4	89	8	n.d.	n.d.
Maki	Yes	4	SL	M	3	MS	S	MR–MS	R	22	101	6	99	9	96	6
White field peas																
CRC Walana	Yes	4	SL	M	3	MS	–	–	R	18	108	3	99	5	103	5
PBA Hayman⍉	Yes	3	C	T	9	MR	MR	MR–R	R	13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PBA Pearl⍉	Yes	5	SL	M	4	MR	MS	R	S	22	115	16	120	19	95	12
Sturt	Yes	2	C	T	5	MR	MR–MS	MS	S	19	105	14	119	17	86	7
SW Celine	Yes	5	SL	M	4	MR–MS	S	MR–MS	S	22	112	8	107	11	85	5

2.2 Planting seed quality

High quality seed is essential to ensure the best start for your crop. Grower-retained seed 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, consider purchasing registered or certified seed from a commercial supplier and always ask for a copy of the germination report.
- Careful attention should be paid to the harvest, storage, and handling of grower-retained seed intended for sowing.
- Calculate seeding rates in accordance with seed quality (germination, vigour and seed size).

MORE INFORMATION

Ground Cover Radio 119: Objective measurement for seed quality

Good establishment through correct plant density and good seedling vigour is important to maximise yields of pulse crops (Figure 7). 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 huge difference in the calculated seeding rates required to achieve a satisfactory target plant density.

Figure 7: *Example of a good plant stand in field peas sown in central west NSW.*

Photo: Penny Heuston

Many seed buyers are unaware that the minimum germination requirement for certified pulse seed is 70%, which is far less than the 90% or greater often obtained in pulse seed. Many believe that this minimum should be raised to 80%, as not all growers or retailers request seed test results of certified pulse seed. Test results must be made available under the Seeds Act and Australian Seeds Federation guidelines, so ask for it.

Often, seed quality problems only emerge if the crop is not 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.

Seed with low germination rates and poor seedling vigour can result in sparse establishment and a weak crop, which then becomes more vulnerable to viruses, fungal disease infection and insect attack, and is less competitive with weeds. Inevitably, this will result in significantly lower yields. The crop may also have variable maturity rates, making it difficult to manage.

Poor seed germination or low seed germination of pulse crops predominately occurs when the seed crop has been desiccated or top dressed before it has achieved full physiological maturity prior to harvesting.

A rotary header and a belt elevator are ideally suited to pulse grain and can reduce seed damage, which can result in abnormal seedlings that germinate but do not develop further.

Under ideal conditions, abnormal seedlings may emerge but lack vigour, making them vulnerable to other rigours of field establishment. Factors such as low temperature, disease, insects, seeding depth, and soil crusting and compaction are more likely to affect the establishment of weak seedlings. Those that do emerge are unlikely to survive for long, will produce little biomass, and make little or no contribution to final yield. [11]

2.2.1 Grower-retained planting seed

Grower-retained sowing seed should always be harvested from the best part of the crop where weeds and diseases are absent and the crop has matured evenly. Seed should be harvested first to avoid low-moisture grain, which is more susceptible to cracking. Seed moisture of 11–13% is ideal. Weeds, other grains, or disease contamination from other pulse crops should be avoided when selecting parts of the paddock for seed harvest.

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

Seed-borne diseases have the potential to lower germination levels. Testing of seed can be conducted by specialist laboratories for the presence of a number of diseases such as Cucumber mosaic virus in narrow leaf lupins, bacterial blight in field peas and ascochyta blight in chickpeas.

Seed with 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. Germination, normal seedling count, and vigour are affected by its use. Read the glyphosate label.

The only way to accurately know the seed's germination rate, vigour, and disease level is to have it tested. [12]

2.2.2 Seed size

As for most pulses, seed size varies between varieties and within varieties. Sowing rates for varieties with considerably smaller seed size should be adjusted accordingly. Growers should do a seed count on each batch of seed they wish to sow to determine the weight in grams of 100 seeds to determine an accurate sowing rate.

The larger the seed, the better it will be as a sowing source as it will have more energy and vigour to push out of the ground at germination time. [13]

Ideally, only pulse seed with >80% germination should be used and testing for germination and vigour should be conducted by an accredited laboratory.

The best time to sample is at or just after seed cleaning. It also provides an ideal way to get a good representative sample and see if any weed seeds have made it into the sample after the cleaning process that may cause a concern come sowing.

However, if a seed lot is likely to have reduced germination, such as can occur with a wet harvest or heat stress at crop flowering, testing should be done before seed cleaning. This minimises expenses and provides time to obtain replacement seed. [14]

A laboratory seed test for germination should be carried out before seeding to calculate seeding rates. However, a simple preliminary test on-farm can be done in soil after harvest or during storage (Figure 8). Results from a laboratory germination and vigour test should be used in seeding rate calculations.

Field pea differ from other pulse crops when carrying out home seed germination test. When attempting to do your own field pea seed germination test it is

11 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013, Pulse Australia Limited.

12 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013, Pulse Australia Limited.

13 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

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

recommended to soak the peas overnight, then using a flat shallow seeding tray about 5 cm deep. Place three to four pieces of paper toweling or newspaper on 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 (Figure 8).

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

During the test, keep the soil moist, but not wet. Overwatering will result in fungal growth and possible rotting. After 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 in part a form of inbuilt vigour testing because it is done in soil. To further establish vigour under more adverse conditions, a second germination test done under colder or wetter conditions could be used as a comparison with the normal germination test, done at the same time.

http://www.grdc.com.au/uploads/documents/GRDC_FS_RetainingSeed2.pdf

Figure 8: *For a germination test place 10 rows of 10 seeds on the smoothed surface of free draining soil and push to the correct seeding depth with a marked pencil. Lightly cover with more soil and keep moist in a cool location. Count emerged seedlings after 7 to 10 days.*

Photo: Emma Leonard

2.2.3 Seed testing for disease

Seed-borne diseases such as Cucumber mosaic virus in field peas, lupins and lentils, along with Black spot in field peas, 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 common diseases.

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.

2.2.4 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 sclerotes (fruiting bodies of the fungus which causes sclerotinia) which would otherwise be sown with the seed. [15]

2.2.5 Safe storage of seed

Storing pulses successfully requires a balance between ideal harvest and storage conditions. Harvesting at 14% moisture content captures grain quality and reduces mechanical damage to the seed but requires careful management 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, seed viability and be less attractive to insect pests. [16]

Retained seed needs to be stored safely to ensure its quality is maintained. Safest storing conditions for pulses are at 20°C and at 12.5% moisture content.

Like other grain, field pea seed quality deteriorates in storage. Most rapid deterioration occurs under conditions of high temperature and moisture. Crops grown from seed that has been stored under such 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 as the seed pulls away from the seed-coat.

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

Reducing temperature in grain silos:

- Paint the outside of the silo with white paint. This reduces storage temperature by as much as 4–5°C and can double 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 sowing seed should be limited to temperatures ≤40°C. [17]

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15 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

16 P Burrill, P Botta, C Newman, C Warrick (2012) Storing pulses. GRDC Fact Sheet, March 2012, http://www.grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

17 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

For more information, see GRDC GrowNotes (Field peas) Section 13, Storage.

2.2.6 Safe rates of fertiliser sown with the seed

All pulses can be affected by fertiliser toxicity. Lupin are especially susceptible. Higher rates of phosphorus (P) fertiliser can be toxic to lupin 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 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, such as in northern NSW with rates of P at 50 kg/ha of DAP on 1 m rows with 4 cm of in-row disturbance.

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

The use of starter 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 lupins, or else broadcasting and incorporating, drilling pre-seeding or splitting fertiliser applications so that lower rates or no P is in contact with the seed. [18]

18 GRDC (2008) Grain Legume Handbook update 7 Feb 2008. Grain Legume Handbook Committee, supported by the Grains Research and Development Corporation

MORE INFORMATION

Australian Pulse Bulletin: Pulse inoculation techniques

Planting

Field pea are well suited to no-till, reduced tillage and stubble retention systems. Sow at the depth equivalent to wheat (3–5 cm) to ensure seed-to-soil contact for good emergence and improved safety to post-sow pre-emergent herbicides. Field peas can be successfully dry sown, if problem weeds such as medic are not an issue.

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 hardsetting, surface crusting soils. The previous year's stubble can also offer an anchor for the peas to grip hold of with their tendrils which will result in better standability at harvest. Stubble clumps cause seed placement and harvesting difficulties. A flat surface can also assist harvest by ensuring clods or stones don't enter the harvester. [1]

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.

3.1 Inoculation

Symbiotic nitrogen fixation is the mutually beneficial relationship between the pulse host and rhizobium bacteria. These bacteria colonise roots during seed germination then multiply rapidly to form root nodules within 4–10 weeks. They are dependent on the host plant for water, nutrients and energy, but in return supply the plant with nitrogen (ammonium, $NH4^{+}$) for direct uptake. This 'fixed' nitrogen is derived from the enormous N_2 gas resources of the earth's atmosphere (around 80%). [2]

Nitrogen fixation by pulse crops does not happen as a matter of course. Compatible, effective rhizobia must be in the soil in which the legume is growing before nodulation and nitrogen fixation can occur. When a pulse is grown for the first time in a soil, 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. [3] When the legume germinates, the rhizobia enter the plant's roots, multiply rapidly and form a nodule. Effective nodule formation and function for the all-important 'N fix' requires good growing conditions, the appropriate rhizobia, and a host plant.

FAQ

Group E inoculant is preferred for field pea, but Group F can be used in its place as it is only marginally less effective. [4]

1 Fieldpeas ute guide, p20 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation

2 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

3 E Drew, D Herridge, R Ballard, G O'Hara, R Decker, M Denton, R Yates, G Gemell, E Hartley, L Phillips, N Seymour, J Howieson, N Ballard (2012) Inoculating legumes: A practical guide. Grains Research & Development Corporation, http://www.grdc.com.au/GRDC-Booklet-InoculatingLegumes

4 E Drew, D Herridge, R Ballard, G O'Hara, R Decker, M Denton, R Yates, G Gemell, E Hartley, L Phillips, N Seymour, J Howieson, N Ballard (2012) Inoculating legumes: A practical guide. Grains Research & Development Corporation, http://www.grdc.com.au/GRDC-Booklet-InoculatingLegumes

Seed should be sown within three days of inoculation, as the inoculum has only a limited life span on dry seed. [5]

Many failures with nitrogen fixation have been associated with improper application techniques. Thorough coverage of the seed is critical since seeds not exposed to the bacteria will result in plants unable to fix nitrogen.

If seed is to be treated with a fungicide, carry out this operation first and then apply the inoculant separately, immediately prior to planting. Avoid inoculating directly into the airseeder bin as newly inoculated seed is often sticky and does not flow properly, causing uneven seed flow, resulting in patchy establishment across the paddock. [6]

Rotation lengths of 3–4 years are recommended between successive field pea crops as a disease management strategy (i.e. Black spot). At this re-cropping interval, sufficient levels of surviving Group F rhizobia are unlikely for effective nodulation of leaving a positive N balance in the soil for proceeding crops.

Average amounts of N fixed annually by crop and pasture legumes are ~110 kg N/ha (ranging from close to zero to >400 kg N/ha). The actual amount fixed depends on the species of legume grown, the site and the seasonal conditions as well as agronomic management of the crop or pasture. The legume crop uses this N for its own growth and may fix significantly more than needed, the amount of N fixed by a legume increases as legume biomass increases but is reduced by high levels of soil nitrate. In general, legume reliance on N fixation is high when soil nitrate levels are <50 kg N/ha in the top 1 m of soil. Above 200 kg N/ha, N fixation is generally close to zero. The fixed N is used for the growth of the legume itself (saving fertiliser application of the legume crop) as well as potentially leaving residual N for the following cereal or oilseed crop and providing a break from cereal stubble and soil-borne diseases. [7]

3.1.1 Storing inoculants

For maximum survival, peat inoculant should be stored in a refrigerator at ~4°C until used. If refrigeration is not possible, store in a cool, dry place (i.e. an esky) away from direct sunlight. Granules and other forms also need to be stored in a cool place out of direct sunlight. Do not store an opened inoculum packet, as it will deteriorate rapidly. Discard the inoculant after the expiry date.

3.1.2 Inoculum survival

Moist peat provides protection and energy while the unopened packet is being stored. Inoculated seed should be sown directly into moist soil. 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.

Most peat inoculants now contain an adhesive, which delays drying and increases survival of the rhizobia. Use a peat slurry mixture within 24 hours. Sow seed inoculated with peat slurry as soon as possible, but certainly within 12 hours, being sure to keep the seed in a cool place, away from sunlight.

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

The rhizobia survive for longer in granules than when applied on 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 distributing or retaining rhizobia uniformly on seed. Under some conditions, rhizobial

5 I Pritchard (2015) Field pea: crop management and production. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/field-pea-crop-management-and-production?page=0%2C2

6 S Moore, G Cumming, L Jenkins, J Gentry (2010) Northern region field pea management guide. Pulse Australia.

7 N Seymour, RCN Rachaputi, R Daniel, (2014) Management impacts on N fixation of mungbeans and chickpeas. GRDC Update Papers March 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Management-impacts-on-N-fixation-of-mungbeans-and-chickpeas

death is so rapid where dry-dusting is used that no rhizobia remain alive by the time the seed reaches the soil. [8]

3.1.3 Inoculation methods

Slurry inoculation with water is the most common form of inoculation. The inoculant is mixed with cool water and then mechanically mixed (with a cement mixer, feed mixer, auger or recirculating grain dryer) to evenly coat the seed (Figure 1).

Most inoculants now contain a pre-mixed sticker. When mixing the slurry do not use hot or chlorinated water. Add the appropriate amount of the inoculant group to the solution and stir quickly. Mix into a heavy paste with a small amount of water prior to adding to the main solution. Add the inoculant suspension (slurry) to the seed and mix thoroughly until all seeds are evenly covered.

How to apply slurry to the seed:

- in a cement mixer (practical for small lots only unless a cement truck is used)
- through an auger
- through a tubulator

When applying via an auger, make sure the auger is turning as slowly as possible. Reduce the height of the auger to minimise the height of seed fall. Perhaps add a slide (e.g. tin) to the outlet end of the auger to stop seed falling and cracking. Meter the slurry in, according to the flow rate of the auger (remember 250 g packet per 100 kg seed). Too much water means sticky seed and blockage problems in the planter. [9] Note, high saline water will kill the rhizobium that live in the peat. Use a neutral to low alkaline water.

Figure 1: *Cross section of legume roots showing effective nodulation. The blood-red colour is a sign of good health for the rhizobia.*

3.1.4 Water injection

This method places a band of inoculum suspended in water in the seed furrow. The germinating seeds' roots grow through the band of inoculated soil. Results are generally good except under very dry conditions. Water rates vary depending on row spacing. Conventional water injection equipment can be used.

3.1.5 Dry inoculation

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.

8 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

9 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

3.1.6 Granular inoculants

Granular inoculants are applied like fertiliser as a solid into the seed furrow, near to the seed or below. They avoid many of the compatibility problems of rhizobia with fertilisers and fungicides. They also eliminate the need to inoculate seed before sowing. Granulars may also be better where dry sowing is practiced or sowing into acidic soils because the rhizobia survive better than on seed. A third, small seed box is required to apply granular inoculum. This is because rhizobial survival is jeopardised if the granular inoculum is mixed with fertiliser. If it is mixed with the seed, then distribution of both seed and inoculum is affected, causing either poor and uneven establishment and/or patchy nodulation.

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

It is preferable not to mix fertilisers and insecticides with inoculum or inoculated seed, as many pesticides are toxic to rhizobia. [11]

Growers should check their fields to determine if inoculation was successful. Normally, nodules will form on the roots 4–6 weeks after emergence.

To check for nodulation, carefully dig up a number of plants and gently wash out the root mass (FIgure 2). Nodules should be present on both the primary and lateral roots. Split the nodules with a sharp knife—effective nodules will be a pink-to-red colour inside. If nodulation does not occur and soil nitrogen levels are low, an application of nitrogen fertiliser may be required to optimise yields. [12]

Further information on inoculating legumes can be found in the GRDC publication, Inoculating legumes.

10 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

11 Nutrition—inoculation of legumes (2010). Department of Agriculture and Fisheries, Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/inoculation

12 S Moore, G. Cumming, L Jenkins, J Gentry (2010). Northern Region Field Pea Management Guide. Pulse Australia.

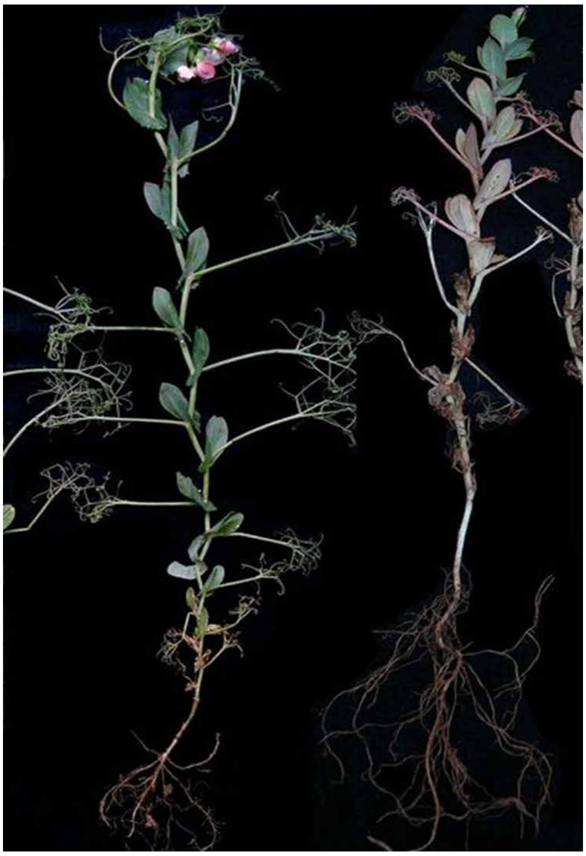

Figure 2: *A well-nodulated field pea plant on the left versus poorly nodulated on the right. Note the difference in green colour in the foliage.*

Photo: DAFWA

3.2 Seed treatments

Fungicide seed dressing is cheap insurance for good crop establishment. By treating seed with fungicide prior to sowing, seedlings will be protected from a number of fungal pathogens for the first four to six weeks after sowing. Some fungal pathogens may also be present on the seed coat, and by treating seed, levels of inoculum can be reduced. When seed treatment is used in conjunction with stubble retention, blackspot infection in field peas is greatly reduced. [13]

http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/winter-crop-variety-sowing-guide

FAQ

3.3 Time of sowing

Planting time should be adjusted to allow flowering to commence from mid-to-late August to avoid the main frost period. Planting earlier than recommended can result in a bulky plant biomass and more prone to diseases, frost damage and higher yield potential, later than recommended planting dates can potentially result in yield loss due to increases in the risk of moisture stress and high temperatures during the critical grainfilling stage. [14]

Field pea are one of the few pulse crops that can be late sown in dry autumns plus an extended pre-sowing weed control period. Suggested sowing times shown in

13 K Lindbeck (1999) Pulse Point 7: Reducing disease risk. NSW Agriculture and Grains Research & Development Corporation, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157144/pulse-point-07.pdf

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

Table 1 apply to average to wet years. Grower experience and research trials over the last decade clearly show yield responses from sowing up to two weeks earlier in dry seasons when diseases in spring have not been a problem.

There is now a wider range of varieties available with differing maturities and some with shatter-resistant pods. Growers should consider their preferred sowing window 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, as frost damage to pods is not a concern. [15]

Table 1: *Optimum sowing times for southern Australia.* [16]

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

, Marginal areas or low disease risk areas; , Preferred planting time; ,For high disease risk areas.
* Preferred sowing time for spring sown field peas in south eastern Australia is August-September

FAQ

3.4 Targeted plant population

Don't skimp on seed—correct plant population is important. Aim for a minimum plant population of 60 plants/m. Plant populations of 30 plants/m or less can result in significant yield losses and cause harvest difficulties due to lodging.

The planting rate required for an individual seed line will depend on the germination and establishment percentages and seed weight. [17] A typical planting rate range is 80–120 kg/ha.

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 hardsetting soils.

Higher plant populations are required for varieties of short to medium height and lower vigour due to their lower biomass and the need for tendrils to intertwine to keep the crop upright in semi-leafless varieties.

Semi-leafless varieties lose yield more rapidly in most southern Australian areas with plant densities <45–55 plants/m. Target densities tend to be lower in NSW and higher in Victoria than other areas. [18]

NSW DPI Winter crop variety sowing guide

Pulse Point

15 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

16 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation.

17 S Moore, G Cumming, L Jenkins, J Gentry. (2010). Northern Region Field Pea Management Guide. Pulse Australia.

18 Fieldpeas ute guide, p15 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation.

3.4.1 Calculating seed requirements

The planting rate is calculated using the following equation:

$$\text{Seeding rate in kg/ha} = \frac{\text{Target density (plants/m)} \times \text{100 seed weight (g)} \times 1000}{\text{Germination \%} \times \text{Establishment \%}}$$

* Establishment percentage: 80% is a reasonable estimate, unless sowing into adverse conditions. [19]

3.5 Sowing depth

Field peas should be sown under most conditions at a depth of 3–5 cm. They will emerge from deeper sowing (up to 7 cm) provided moisture is adequate for consistent germination. Do not dry-sow or moisture-seek field pea at depth if uneven moisture is present, as crops will germinate unevenly, causing management difficulties (such as herbicide timing) for the crop. Crops sown later in the sowing window (for example due to a delay in sowing rainfall) should be sown shallower to assist germination under cold conditions. [20]

3.6 Row spacing

MORE INFORMATION

Australian Pulse Bulletin: Wide row pulses and stubble retention

Planting into standing stubble is encouraged, with row widths ranging from 15 cm to a maximum of 35 cm. Row widths should be reduced to 25 cm or less in bare fallows. Sowing on wide rows (e.g. 50 to 60 cm) is not advised as it increases susceptibility to lodging and clumping at harvest. [21]

Wider rows are only used if sowing is into standing cereal stubble. Some growers use medium-wide row spacing (25–36 cm) to suit trash clearance, intra-row weed control, or to allow more air movement between the rows in the belief that blackspot disease risk is reduced. [22]

3.7 Sowing equipment

Success with pulses may depend on the type of sowing equipment used. The large size and high sowing rate of pulses can make sowing with conventional seeders difficult.

If your seeder is not suitable for sowing a particular pulse (usually larger seeded types) in standard form there are several options available. The machine may be adapted by minor modifications such as:

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

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

3.8 Dry sowing

Dry sowing is a means of getting crops sown on time in seasons with a delayed break. The crop must be sown on time to get the best yield, so if the time comes and it hasn't rained, consider sowing dry.

19 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

20 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

21 GRDC New South Wales Grains Research Update for Advisers, Grain Research & Development Corporation, https://grdc.com.au/Resources/Publications/2014/02/GRDC-Grains-Research-Update-for-Advisers-NSW-2014

22 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation.

- The biggest risk of failure when dry sowing pulse crops is the survival of rhizobia and subsequent nodulation.
- Broadleaf weed control is the other key factor to consider when dry sowing.
- Herbicide residue can also affect pulse crops in the following year.

Normal paddock selection criteria apply. Look at soil pH, soil drainage, and weed burden. The best results from dry sowing occur on freely draining, well-structured soils but it is also successful on other soil types. Avoid hardsetting 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. There needs to be enough tine break-out pressure to penetrate the soil and maintain even seeding depth. Narrow seeding points with tungsten give better results and trash flow is often better when stubble is dry.

Start dry sowing at the beginning of the normal sowing window for that species and variety. As a guide, sow no earlier than the third week of April for low rainfall zones, and the fourth week of April for high rainfall zones.

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 rhizobium survival. Row spacing can be increased to handle heavy stubbles with minimal reduction in yield. [23]

23 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

Plant growth and physiology

Field pea varieties range in growth habit from trailing to erect at maturity (Figures 1–2). The trailing growth type can be difficult to harvest but the semi-leafless/semi-dwarf forms of field pea—where leaves have been modified into tendrils—can have a better standing ability, aiding harvestability. Plant height at flowering is affected by temperature and light as well as variety. [1]

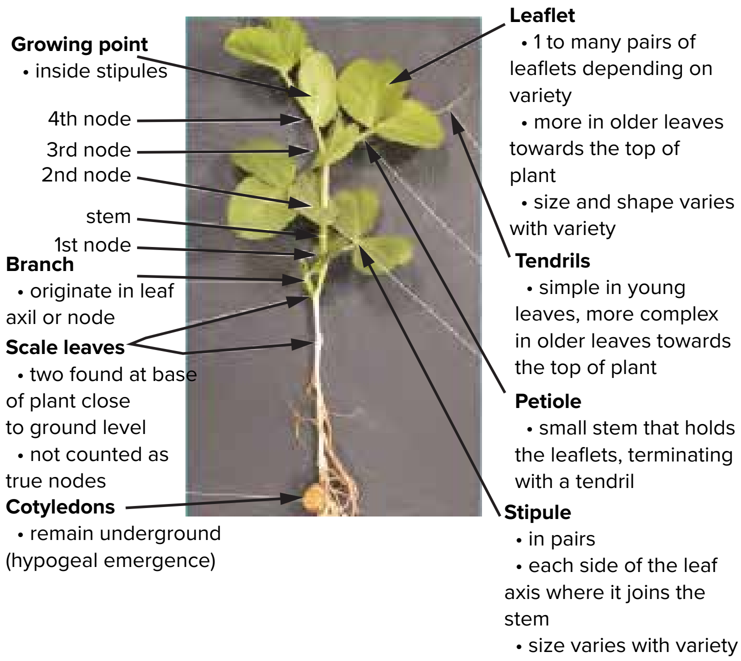

Figure 1: *Field pea – conventional type (Pisum sativum) e.g. PBA Percy(D), Parafield, Alma.*

Photo: NSW DPI. [2]

1 Field Pea (2015) Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/field-pea

2 G Brooke, C McMaster (2015) Weed control in winter crops 2015: NSW DPI Management Guide. NSW Government Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/weed-control-winter-crops

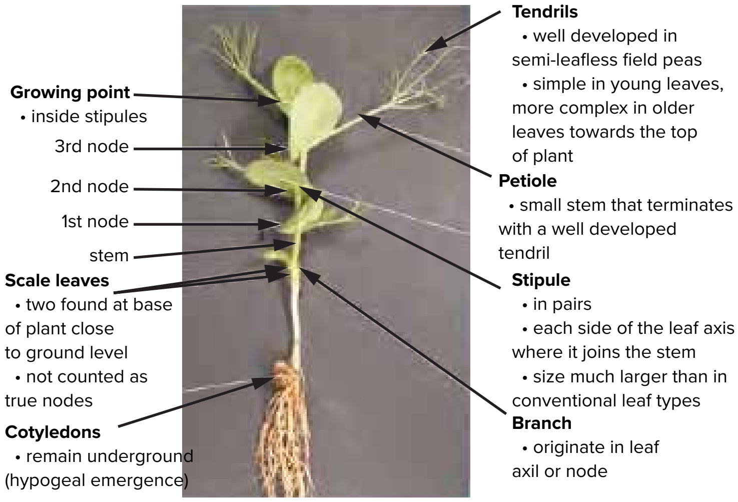

Figure 2: *Field pea – semi-leafless type e.g. PBA Wharton⫮, PBA Twlight, PBA Gunyah⫮, PBA Pearl⫮, PBA Oura⫮ and Kaspa⫮.*

Photo: NSW DPI. [3]

4.1 Germination and emergence issues

The seed must have ample soil coverage to ensure that there is some separation of seed from the pre-emergence chemical applied. Deep furrows are created when growers have moisture-seeked or sown the seed deep to chase the moisture. This can pose a problem for seed–chemical separation as many herbicides are applied pre-sowing with the effect of planting to throw the treated dirt out of the furrow allowing the seedling to germinate through a soil band containing little herbicide. If heavy rain occurs post-sowing but pre-emergence, the treated soil can wash back into the furrow, often in a high concentration, and cause damage to the seedling, which will often now be in a cooler, wetter environment. Wheel tracks will commonly be sown shallower due to their extrinsic compacted nature and subsequently more chemical damage can be apparent in these parts of the paddock.

The emerging plant has no trouble through stubble as it is quite a vigorous seedling (Figure 3).

3 G Brooke, C McMaster (2015) Weed control in winter crops 2015: NSW DPI Management Guide. NSW Government Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/weed-control-winter-crops

Figure 3: *Field peas germinating through stubble well at Nyngan, NSW.*

Photo: Penny Heuston

Field pea have hypogeal emergence where the cotyledon comes out below surface, as with chickpea. Hypogeal crops are more suited to deeper sowing than epigeal crops like lupins which require a lot of energy to push the cotyledon above the ground surface.

4.2 Effect of temperature, photoperiod, climate effects on plant growth and physiology

Field pea flower in low temperatures and fill seed rapidly which is important in hot/dry/droughty springs. Correlations between yield and temperature indicated two distinct stages. In the first stage, 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. [4]

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.

Field pea are also sensitive to drought and yield losses vary from 21–54%. However, field pea with the correct phenology have the ability to escape drought and produce respectable yield when compared with other pulses. They have, in fact, the highest harvest index of the pulse crops. Harvest index is calculated as the ratio of grain to total dry matter (and is sometimes expressed as a percentage).

Waterlogging six days after germination of field peas can delay the emergence by up to five days and reduce the final plant density by 80%. Waterlogging depresses vegetative growth of plants but affects root growth more than shoot growth. [5]

4 V Sadras (2013) Improving yield and reliability of field peas under water deficit. Grains Research & Development Corporation, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/01/Improving-yield-and-reliability-of-field-peas-under-water-deficit

5 K Siddique. Abiotic stresses of cool season pulses in Australia. University of Western Australia, http://www.farmtrials.com.au/trial/13486

4.3 Plant growth stages

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. When field pea emerges, two small scale or scar leaves appear. The scar leaves do not form stipules. [6]

Eighty per cent of the field pea yield is off the main stem. The differing varieties will start to flower at differing node numbers up the main stem of the plant.

Today's commercial varieties generally start flowering at node 12 through to 18, and this is a genetic characterisation of a variety.

In semi-leafless types, the leaf actually loses its leaflets and the tendril becomes much more vigorous. The internode (stem section between two nodes) can be short or long.

The growing point is cupped within two stipules just above this first flower. Within this growing point are all the future sites of flowering nodes housing primordia (or buds), and these can keep going on in an indeterminate fashion depending on the season. However, plants generally develop from 6–15 flowering nodes above this depending on the season (in the 2002 drought, there were only 2–3 flowering nodes in many varieties due to terminal drought). Up to 18 flowering nodes at Wagga have been recorded in a good long cool season.

The important thing is the effective set along this reproductive portion of the stem, and this is where the pod-mapping exercise focuses on. The first flower will form the bottom pods, and because they are the first and most advanced, are the fullest at any moment in time. Development of pods at the flowering nodes becomes sequentially later as you 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 frosting event can have greatest impact on the node flowering at the time. Therefore, sequential podding along a stem provides a good time-line and map of 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 and important site for yield. This is a bit like tillering in wheat and is variety, seasonally and density dependent. A strongly branching type can make up for a lower seedling density. These branches also develop the typical node structure identical to the main stem, can 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. [7]

4.4 Nodulation failure

The signs of nodulation failure are when plants become yellow or pale green with restricted growth, especially during cold wet periods through the seedling stages. Oldest leaves are the worst affected. There are none or few nodules on the roots, or nodules lack red pigmentation inside. Plants can appear normal until flowering on soils with moderate to high nitrogen levels when they become pale green, with older leaves being affected most and first.

The easier and best way to identify nodulation failure is to dig several plants up, all roots including lateral roots intact. Be careful as root nodules are very fragile and will break off easily. Wash off any residue soil and stones very carefully not to knock off nodules. Simply slice the nodules open with a pocket knife or thumb nail to look at the centre colour of the nodules. Red and pink coloured interior nodules depict healthy crops fixating nitrogen. Yellow, green, black or brown interior nodulate colour depicts poor nodulation.

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6 I Pritchard (2014) 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

7 Growth and Development of the Field Pea Plant, Eric Armstrong, Research Agronomist, Wagga Wagga

As a salvage operation, apply nitrogen to affected crops if economic.

Ensure future crops are adequately covered with viable Group E inoculum.

In assessing the effectiveness of nodulation, the more nodules and the earlier the infection (i.e. on the tap and crown roots) the better. Nodules need to be pink/salmon to be effective. [8]

4.5 Crop lodging

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 and fleabane.

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. [9] Narrower row spacings and higher sowing rates can also aid in standability.

8 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation, p77

9 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation, p115

Nutrition and fertiliser

5.1 Declining soil fertility

The natural fertility of cropped agricultural soils is declining over time, and so growers must continually review their management programs to ensure the long-term sustainability of high quality grain production. Paddock records, including yield and protein levels, fertiliser test strips, crop monitoring, and soil and plant tissue tests all assist in the formulation of an efficient nutrition program.

Pasture leys, legume rotations and fertilisers all play an important role in maintaining and improving the chemical, biological and physical fertility of soils, 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. The higher yielding the crop, the greater the amount of nutrient removed. Increasing fertiliser costs means growers are increasing pulses within their crop rotation and even the use of ley pastures to complement their fertiliser programs and possibly boost soil organic matter. [1]

5.1.1 Soil organic matter

Soil organic matter (SOM) is a critical component of healthy soils and sustainable agricultural production. Growers understand that crops grown in healthy soils perform better and are easier to manage. Soil organic matter is '*all of the organic materials found in soils irrespective of its origin or state of decomposition*' [2] that is anything in or on the soil of biological origin, alive or dead. It is composed mainly of carbon (approximately 60%) as well as a variety of nutrients (including nitrogen, phosphorus and sulfur). It is difficult to actually measure the SOM content of soil directly so we measure the soil organic carbon (SOC) content and estimate SOM through a conversion factor:

Soil organic matter (%) = organic carbon (%) × 1.72

It is important to understand the role of plants in the SOM cycle. Photosynthesis is the process by which plants take in carbon dioxide (CO_2) from the atmosphere, combine with water taken up from the soil, and utilising the energy from the sun, form carbohydrate (organic matter) and release oxygen (O2). This is the start of the SOM cycle. When the leaves and roots (carbohydrate) die they enter the soil and become SOM. These residues are decomposed by soil organisms which provides them with the energy to grow and reproduce. The SOM cycle is a continuum of different forms (or fractions) with different time frames under which decomposition takes place. Over time SOM moves through these fractions; particulate, humic and resistant fractions. As SOM decomposes carbon is released from the system along with any nutrients that are not utilised by the microorganisms. These nutrients are then available for plants to utilise. Eventually a component of these residues will become resistant to further decomposition (resistant fraction Figure 1).

1 QDAF (2010) Nutrition management. Overview. Department of Agriculture, Fisheries and Forestry Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview

2 JA Baldock, JO Skjemstad (1999) Soil organic carbon/Soil organic matter. In KI Peverill, LA Sparrow, DJ Reuter (eds). Soil analysis: An interpretation manual. CSIRO Publishing, Collingwood Australia.

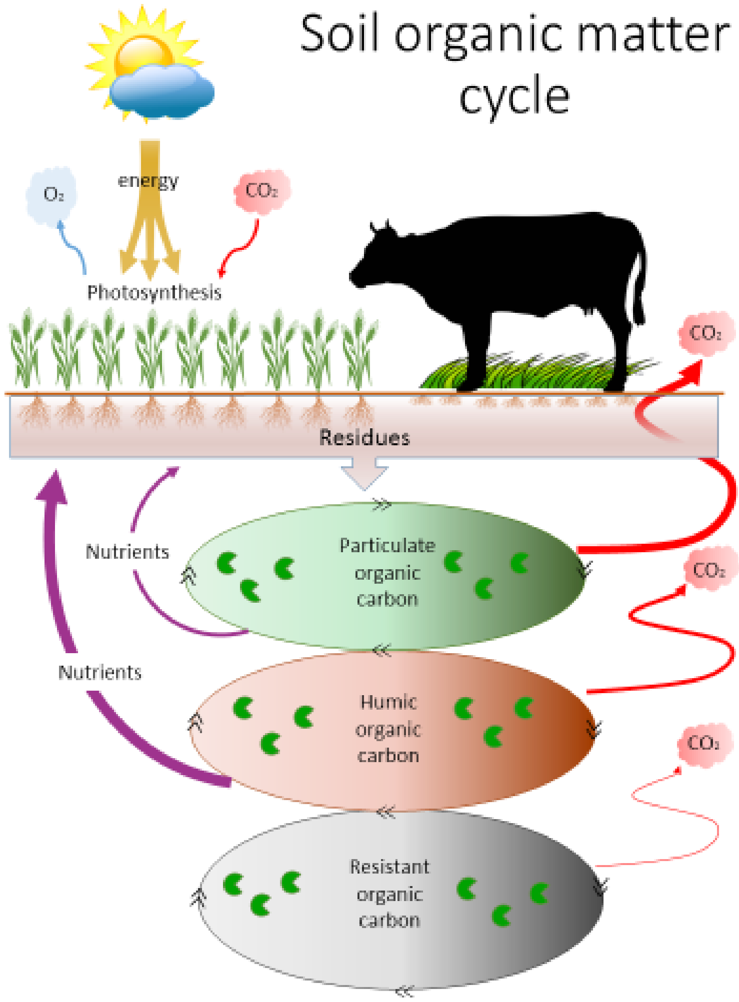

Figure 1: *Organic matter cycle.*

Source: J Gentry, QDAF

Organic matter is fundamental to several of the physical, chemical and biological functions of the soil. It helps to ameliorate or buffer the harmful effects of plant pathogens and chemical toxicities. It enhances surface and deeper soil structure, with positive effects on infiltration and exchange of water and gases, and for keeping the soil in place. It improves soil water-holding capacity and, through its high cation-exchange capacity, prevents the leaching of essential cations such as calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na). Most importantly, it is a major repository for the cycling of nitrogen and other nutrients and their delivery to crops and pastures.

Australian soils are generally low in SOM. Initial SOM levels are limited by dry matter production (and so climate) for each land type/location. SOM levels have declined under traditional cropping practices. On-farm measures (sampled 2012–15) from over 500 sites in Queensland and northern NSW confirm that soil organic matter, measured as soil organic carbon, declines dramatically when land is cleared and continuously cropped. This decline affects all soils and land types but is most dramatic for the brigalow–belah soils because their starting organic carbon levels are so high (Figure 2). [3]

3 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

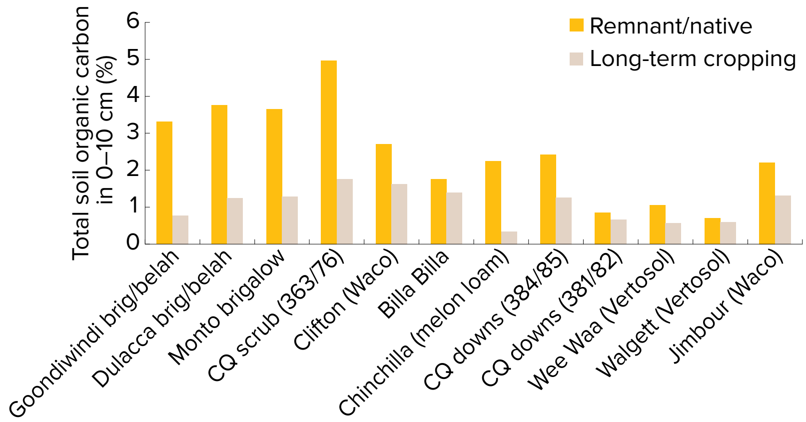

Figure 2: *The decline of soil organic carbon in long-term cropping systems.* [4]

Declining levels of SOM have implications for soil structure, soil moisture retention, nutrient delivery and microbial activity. However, probably the single most important effect is the decline in the soil's capacity to mineralise organic nitrogen (N) to plant-available N. Past research (1983) has shown that N mineralisation capacity was reduced by 39–57%, with an overall average decline of 52% (Figure 3). [5] This translated into reduced wheat yields when crops were grown without fertiliser N.

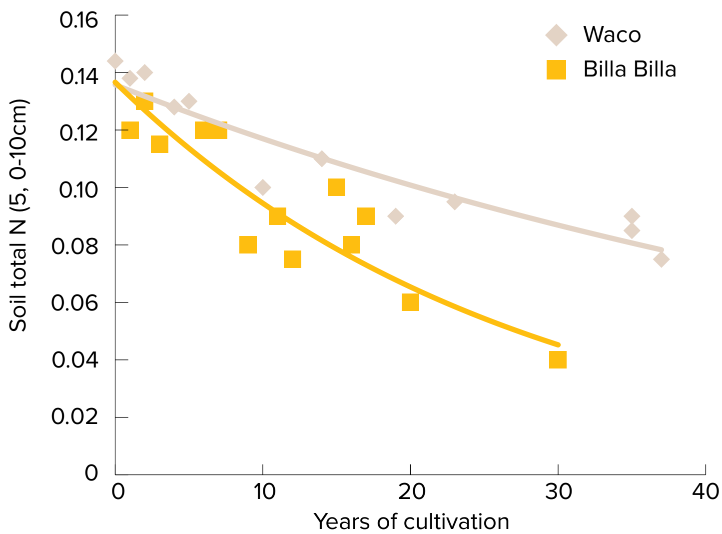

Figure 3: *Graph of decline in soil total N with years of cropping. The decline was greater for the Billa Billa soil (clay content 34%) than the Waco soil (clay content 74%).* [6]

Source: based on Dalal & Mayer (1986a,b)

4 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

5 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

6 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

5.1.2 Current situation

Soil organic carbon levels are simply a snapshot of the current balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition) constantly happening in each soil and farming system. The decline over time is overwhelmingly driven by the extent of fallowing in our farming systems. Most fallow rain in the northern region (as much as 75–80% in a summer fallow) is lost as runoff or evaporation. This wasted rain does not grow dry matter to replenish the organic matter reserves in the soil. However, increasing moisture in the fallowed soil continues to support microbial decomposition. This helps accumulate available nitrogen for the next crop, but reduces soil organic carbon. The soil organic matter and carbon levels will continue to decline until they reach a new lower level that the dry matter produced by the new farming system can sustain. Put simply,

'Crops may make more money than trees and pastures, but do not return as much dry matter to the soil.'

Total soil organic carbon levels vary within a paddock, from paddock to paddock and from region to region. Comprehensive sampling was under taken throughout the northern region, with over 900 sites sampled and analysed for total organic carbon at 0–10 cm depth. These results varied enormously across sites. The average was 1.46% however it varied from under 0.5% to over 5% (Figure 4). [7] A selection of these data from representative soil types throughout the northern grains region clearly indicates how soil carbon levels can be significantly different due to soil type (Figure 5). [8]

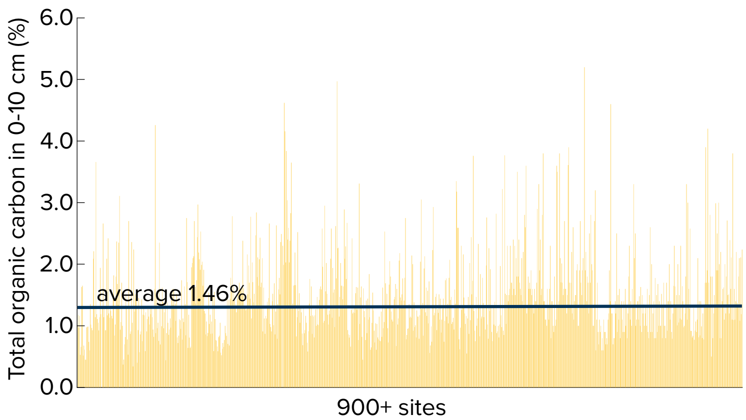

Figure 4: *Soil organic carbon levels on mixed farms within the GRDC Northern Region.* [9]

7 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

8 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

9 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

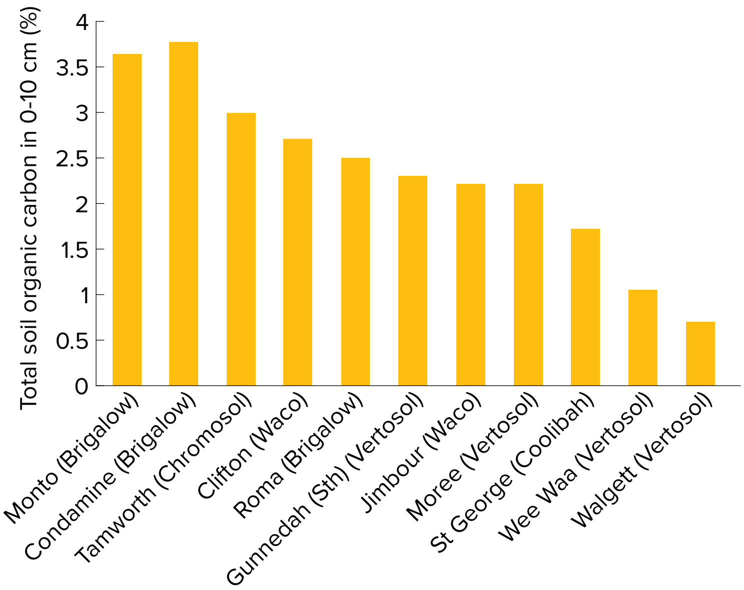

Figure 5: *Impact of land-type on total soil carbon levels (0–10 cm) across the northern region.* [10]

5.1.3 Options for reversing the decline in soil organic matter

Soil organic matter is an under-valued capital resource that needs informed management. Levels of SOC are the result of the balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition, harvested material) in each soil and farming. [11] So maximising total dry matter production will encourage higher SOC levels, and clearing native vegetation for grain cropping will typically reduce SOC and SOM levels. [12]

Modern farming practices that maximise Water Use Efficiency for extra dry matter production are integral in protecting SOM. Greater cropping frequency, crops with higher yields and associated higher stubble loads, pasture rotations and avoiding burning or baling will all help growers in the northern region to maintain SOM.

Research in the past has shown the most direct, effective means of increasing SOM levels is through the use of pastures, however these pasture have to be productive. A grass only pasture will run out of N especially in older paddocks, which is normally the reason why these paddocks are retired from cropping. As a result, a source of nitrogen is required to maximise dry matter production, this can be supplied via a legume or N fertiliser. The rotation experiments of I. Holford and colleagues at Tamworth, NSW and R. Dalal and colleagues in southeast Queensland provide good evidence of this (Table 1).

The greatest gains in soil carbon and nitrogen, relative to the wheat monoculture, were made in the 4-year grass–legume ley, with increases of 550 kg total N/ha and 4.2 t organic C/ha. The chickpea–wheat rotation fared no better than the continuous wheat system. The shorter (1–2-year) lucerne and annual medic leys resulted in marginal increases in soil organic C and N (Table 1).

10 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

11 FC Hoyle, JA Baldock, DV Murphy (2011) Soil organic carbon: Role in rainfed farming systems. In PG Tow, I Cooper, I Partridge, C Birch (eds). Rainfed farming systems. Springer, pp. 339–361.

12 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

Clearly, time and good sources of both carbon and nitrogen are required to build up SOM, which is exactly what the 4-year grass–legume ley provided. Nitrogen was supplied via N_2 fixation by the lucerne and annual medic in the pasture, with most of the carbon supplied by the grasses, purple pigeon grass and Rhodes grass. There were no inputs of fertiliser nitrogen in any of the treatments in Table 1. [13]

Table 1: *Effects of different rotations on soil total N and organic C (t/ha) to 30 cm and as gain relative to continuous wheat.*

Rotation	Wheat crops	Soil total N		Organic C	
		0–30 cm	Gain	0–30 cm	Gain
Grass/ legume ley 4 years	0	2.91	0.55	26.5	4.2
Lucerne ley (1-2 years)	2-3	2.56	0.20	23.5	1.2
Annual medic ley (1-2 years)	2-3	2.49	0.13	23.1	0.8
Chickpeas (2 years)	2	2.35	0.00	22.0	0.0
Continuous wheat 4 years	4	2.36	-	22.3	-

Further research was initiated in 2012 to identify cropping practices that have the potential to increase or maintain soil organic carbon and soil organic matter levels at the highest levels possible in a productive cropping system. Paired sampling has shown that returning cropping country to pasture will increase soil carbon levels (Figure 6). However, there were large variations in carbon level increases detected, indicating not all soil types or pastures preform the same. Soil type influences the speed by which carbon levels change, i.e. a sandy soil will lose and store carbon faster than a soil high in clay. As too does the quality and productivity of the pasture, maximising dry matter production by ensuring adequate nutrition (especially in terms of nitrogen and phosphorus) will maximise increases in soil carbon over time. Current research in Queensland being undertaken by the Department of Agriculture, Fisheries and Forestry (QDAF) is indicating that the most promising practice to date to rebuild soil carbon stocks, in the shortest time frame, is the establishment of a highly productive pasture rotation with annual applications of nitrogen fertiliser, however, adding an adapted legume is also effective. [14]

13 D Herridge (2011) Managing legume and fertiliser N for northern grains cropping. Revised 2013. GRDC, https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

14 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

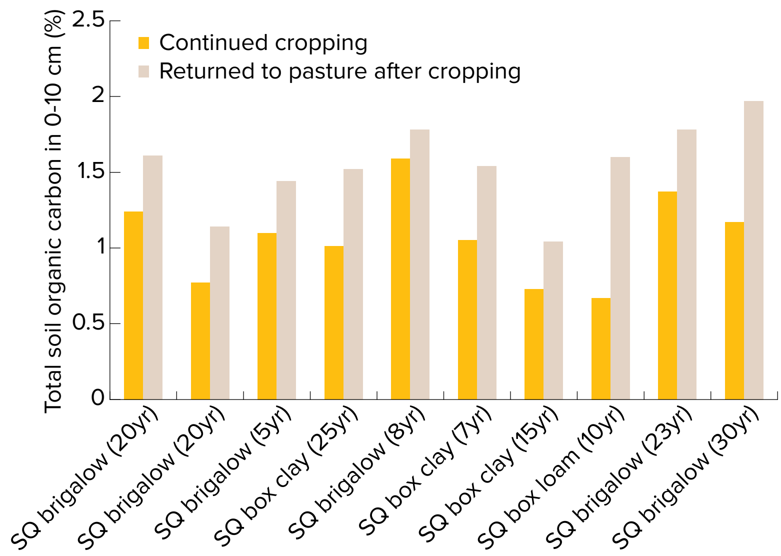

Figure 6: *Total organic carbon comparisons for croplands resown to pasture.* [15]

Impact of fertiliser N inputs on soil

If the rates of fertiliser N are sufficiently high, the effects can be positive. In the Warra experiments, both soil organic C and total N increased marginally (3–4%) over an 8-year period when no-till, continuous wheat, fertilised at a rate of 75 kg N/ha, was grown. This is in contrast with decreases of 10–12% in soil organic C and N in the non-fertilised, continuous wheat and chickpea–wheat plots. The result was much the same in NSW Department of Primary Industries experiments in northern NSW. At the Warialda site, for example, SOM increased during 5 years of cropping but only where fertiliser N had been applied to the cereals.

It is clear from the above examples that building SOM requires N. It works in two ways. First, the fertiliser or legume N produces higher crop/pasture yields and creates more residues that are returned to the soil. Then, these residues are decomposed by the soil microbes, with some eventually becoming stable organic matter or humus. The humus has a C/N ratio of about 10:1, i.e. 10 atoms of C to 1 atom of N. If there are good amounts of mineral N in the soil where the residues are decomposing, the C is efficiently locked into microbial biomass and then into humus.

If, on the other hand, the soil is deficient in mineral N, then more of the C is respired by the soil microbes and less is locked into the stable organic matter. [16]

15 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

16 D Herridge (2011) Managing legume and fertiliser N for northern grains cropping. Revised 2013. GRDC, https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

FAQ

Phosphorus (P): is the major nutrient required by field pea and rates are typically equivalent to those used on cereals, 10–40 kg P/ha. Rates should be based on soil testing, paddock cropping history and potential crop yield.

Sulfur (S) and Zinc (Zn): most pulse crops have comparable requirements for sulfur and zinc with field pea thought to be similar to chickpea, especially on alkaline soils and/or where double cropping occurs in northern regions. If soils are known to be sulfur or zinc responsive (consider soil type and cropping history), then consider using a starter fertiliser containing these nutrients when addressing the phosphorus requirements for the crop at planting. Zinc levels can also be topped up with foliar in-crop sprays of this element.

Potassium (K): as pulse crops are also significant users of potassium, it is advisable to monitor soil levels, particularly on red earth soil types and where hay is cut. Apply starter blends or specific potassium fertilisers as required. [17]

5.2 Crop removal rates

Nutrients removed by 1 tonne of field pea:

- nitrogen 38 kg
- phosphorus 3.4 kg
- potassium 9 kg
- sulfur 1.8 kg
- calcium 0.9 kg
- magnesium 1.3 kg
- copper 5 g
- zinc 35 g
- manganese 14 g [18]

5.3 Soil testing

Soil tests provide a fundamental tool which acts as the basis of deciding an appropriate fertiliser regime for your crop. Paddocks should be tested regularly as levels of nutrients can change dramatically from year to year, in particular nitrogen and sulfur.

Appropriate soil tests for measuring soil extractable or plant-available nutrients in the northern cropping region are:

- bicarbonate-extractable P (Colwell-P), to assess easily available soil P
- acid-extractable P (BSES-P), to assess slower release soil P reserves and the build-up of fertiliser residues (not required annually)
- exchangeable K
- KCl-40-extractable S or MCP-S
- 2 m KCl-extractable mineral N, to provide measurement of nitrate-N and ammonium-N. [19]

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 N, P and K, which are the primary macronutrients, with calcium (Ca), magnesium (Mg) and S considered as secondary. Higher expected yields of crops for grain or forage will place greater demand on the availability of major nutrients such

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

18 Nutrition, Grain Legume Handbook (1998). Grains Research & Development Corporation, http://www.grdc.com.au/uploads/documents/4%20Nutrition.pdf

19 GRDC (2013) Better fertiliser decisions for crop nutrition. GRDC Crop Nutrition Fact Sheet November 2013, http://grdc.com.au/Resources/Factsheets/2013/11/Better-fertiliser-decisions-for-crop-nutrition

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. Keep in mind that each pulse type is different, with different requirements for nutrients and may display different symptoms of deficiency.

A balance sheet approach to fertiliser inputs is often a good starting point when determining the amount and type (analysis) of fertiliser to apply. Other factors such as a soil test, paddock history, soil type and personal experience are useful. Tissue analysis can be helpful in identifying deficiencies once the crop is growing, and can assist in fine-tuning nutrient requirement even when deficiency symptoms are not visible.

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 Mo.

Both macro- and micronutrients are taken up by 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 lie within a certain range for nutrient uptake to occur.

5.3.1 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 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 N fixation. [20]

Recent research by Dr Mike Bell, Principal Research Fellow at the University of Queensland's Queensland Alliance for Agriculture and Food Innovation (QAAFI), shows that many farms in central Queensland have P and K concentrated in the topsoil and critically low levels in the subsoil. Plants cannot access these immobile nutrients when the topsoil is dry, and this reduces productivity. [21]

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. 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.

20 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

21 N Baxter (2013) Trials measure chickpea/rotation profit. GRDC Ground Cover Issue 107, Nov.—Dec. 2013, http://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-107-NovDec-2013/Trials-measure-chickpea-wheat-rotation-profit

Soil temperature must lie within a certain range for nutrient uptake to occur. Cold conditions can induce deficiencies of nutrients such as Zn or P.

The optimum range of temperature, pH and moisture can vary for different pulse species. Thus, nutrients may be physically present in the soil, but not available to those particular plants. Knowledge of a soil's nutrient status (soil test) pH, texture, history and moisture status can be very useful for predicting which nutrients may become deficient. Tissue tests can help to confirm the plant nutrient status. [22]

Soil types do vary in their nutrient reserves. For example, most black and red soils have sufficient reserves of K to grow many crops. However, the light, white sandy soils, which, on soil test, have <50 µg/g (ppm) (bicarbonate test) of K, will respond to applications of K fertiliser.

Other soils may have substantial nutrient reserves that vary in availability during the growing season or are unavailable due to the soil pH. This can often be the case with micronutrients. Foliar sprays can be used in these cases to correct any micronutrient deficiencies. [23]

5.4 Plant and/or tissue testing for nutrition levels

While soil tests provide a guide, the use of tissue tests is a more reliable response diagnostic tool. [24] Plant tissue testing can also be used to diagnose a deficiency or monitor the general health of the pulse crop. Plant tissue testing is most useful, because by the time noticeable symptoms appear in a crop the yield potential can be markedly reduced.

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

Although a valuable tool, tissue testing must be used as only one part of an integrated nutrition program. [25]

5.5 Nutrient toxicity

Soil pH affects the availability of most nutrients. Occasionally, some nutrients are made so available that they inhibit plant growth. For example on some acid soils, Al and Mn levels may restrict plant growth, usually by restricting the rhizobia and so the plant's ability to nodulate (Table 2).

22 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

23 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited

24 2014 GRDC New South Wales Grains Research Update for Advisers, Grain Research & Development Corporation, https://grdc.com.au/Resources/Publications/2014/02/GRDC-Grains-Research-Update-for-Advisers-NSW-2014

25 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited

Table 2: *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.

B toxicity occurs on many of the alkaline soils of the southern cropping areas. The most characteristic symptom of B toxicity in pulses is chlorosis (yellowing), and, if severe, some necrosis (death) of leaf tips or margins.

5.6 Nitrogen

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.

5.7 Phosphorus

Getting phosphorus inputs right at seeding is critical to good early plant establishment as the plant's peak demand for this element is in the early stage of its development. All plants require phosphorus (P) for root development, which then drives the plant's capacity to utilise available moisture and nutrients and achieve yield potential. Soil P levels influence the rate of nodule growth. The higher the P level, the greater is the nodule growth.

In recent years, growers have questioned whether currently grown pulse crops (e.g. chickpeas, field peas and lupins) require additional applied phosphorus in the form of fertiliser, or whether soil P reserves and pulse root exudates are adequate means to provide sufficient P to the crop. However many red (chromosol) soils in central-west NSW are either inherently low, or declining, in P levels due to original soil type source and length of cropping rotations. [26]

Recent trials conducted by NSW DPI and GRDC under the Northern Pulse Agronomy Initiative Project (DAN00171) at the Trangie Research station have shown significant responses to P fertiliser.

Figure 7 below shows the yield of field peas on a red chromosol soil with a starting Colwell P of 28 mg/kg (0–10 cm) in the 2012 trial. [27]

26 L Serafin, S Simpfendorfer, M Sissons, A Verrell, G McMullen (eds.) (2014) Northern Grains Region Trial Results Autumn 2014. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/520666/Northern-grains-region-trial-results-autumn-2014.pdf

27 L Jenkins, R Brill, A Verrell. Response of three pulse species (chickpea, field pea, lentil) to phosphorus and nitrogen rate at Trangie 2013. Leigh Jenkins NSW DPI, Trangie Rohan Brill NSW DPI, Wagga Wagga Andrew Verrell NSW DPI, Tamworth

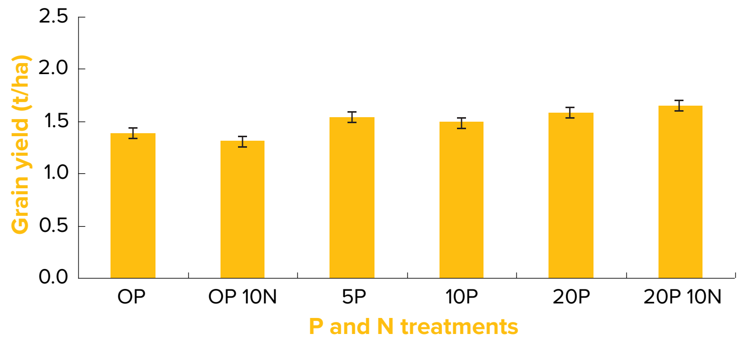

Figure 7: *Field pea yield on a red chromosol soil with a starting Colwell P of 28 mg/kg (0–10 cm) in the 2012 trial.*

5.8 Sulfur

S is important to legumes for the nodulation and nitrogen fixation process. S is required at higher rates for field peas than for cereals. If soil S levels are low, then an appropriate legume fertiliser mix should be applied. [28] Consider the application of an S–based fertiliser where the soil S level is <10 mg/kg KCL40.

5.9 Current general pre-plant nutritional levels for potassium

Responses to K are unlikely on most black earths and grey clays. Potassium fertilisers may be warranted on red earths (kraznozems) but this should be based on recent soil tests.

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

- exchangeable K of 0.25 meq/100 g (or cmol/kg) on black earths and grey clays
- exchangeable K of 0.40 meq/100 g K on red earths and sandy soils

Application of 20–40 kg K/ha banded 5 cm to the side of, and below, the seed line is recommended in situations where soil test levels are critically low. [29]

Hay and silage production result in a large removal of K off a paddock; if this practice is undertaken, K levels will need to be carefully assessed.

5.10 Current general pre-plant nutritional levels for micronutrients

Most pulse crops have comparable requirements for zinc with field pea thought to be similar to chickpeas, especially on alkaline soils and/or where double cropping occurs in the northern region.

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. [30]

28 Kaspa(): Field Pea Factsheet. AWB Seeds, http://www.seednet.com.au/documents/KaspaFactSheet.pdf

29 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

30 Kaspa(): Field Pea Factsheet. AWB Seeds, http://www.seednet.com.au/documents/KaspaFactSheet.pdf

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]

Foliar zinc sprays

A foliar spray per ha of 1.0 kg zinc sulfate heptahydrate + 1.0 kg urea + 1200 mL of non-ionic wetter (1000 g/L) in at least 100 L of water 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 or Agri Buffa if only hard water is available; zinc oxide products are highly alkaline, with a pH of 9.5–10.5. [32] [33]

Iron deficiency

Fe often appears in young plants and is related to soil type where there is high lime content under cold wet conditions. Plants often recover as conditions warm.

Deficiency shows up as chlorotic leaves and poor growth. New leaves and growth become yellow, causing smaller unfolded leaves. This deficiency then spreads to older leaves and young growth stops. Stems become slender and shortened. [34]

Zinc deficiency

Zn deficiency will be worse on alkaline soils and may be worse in cold wet weather.

Symptoms include:

- Older leaves of young plants may initially wilt.
- 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.

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31 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited

32 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited

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

34 Field peas, the ute guide pg 74 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation.

- Plants are shortened with wilting and distortion of the older leaves. [35]

Leaf tissue tests will determine the plant's zinc status at sampling and corrective foliar sprays may be applied.

Manganese deficiency

Mn deficiency is common on highly alkaline calcareous soils:

- In dun type varieties, new leaves become puckered and narrowly cupped with necrotic tipping on leaves and tendrils.
- In white seed varieties, affected leaves curl downwards along the length of the leaf. Interveinal leaf chlorosis turns into necrotic light brown spotting. Tendrils on new leaves have pale and excessively curled ends. [36]
- Deficiency late in the season may lead to discoloration, splitting and deformity of seeds called 'mash spot'. [37]

Manganese toxicity

Toxicity symptoms are worse on more acidic heavy textured parts of the paddock:

- New leaves and tendrils are first and most severely affected.
- New leaves are pale and rapidly develop light-coloured necrotic areas on leaf margins near the apex, that move in toward the midrib between the veins.
- This necrosis can appear as fine pinpoint spots on tendril leaves.
- As the toxicity increases some leaves develop severely necrotic tips and margins that shrivel, leaving the leaf cupped. [38]

Phosphorus deficiency

Symptoms include:

- Reduced early growth, stunting, and darkening in colour of the whole plant. Reddening of stems, petioles, tendrils and leaf margins can occur, particularly if the plant is stressed.
- Older growth is first and most affected.
- As deficiency progresses, older leaves develop mottled chlorosis, and leaf margins become severely chlorotic then die.

Plants have a high P requirement for phosphorus during early growth and a deficiency cannot be corrected within the growing season. [39]

Copper deficiency

Copper deficiency is worse on alkaline soils, very infertile siliceous sands and soils with a low Zn history.

- Old-to-middle leaves become mottled yellow to 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 and applying a foliar fertiliser. [40]

35 Field peas,Peas: The ute guideUte Guide (2009). Grains Research & Development Corporation.

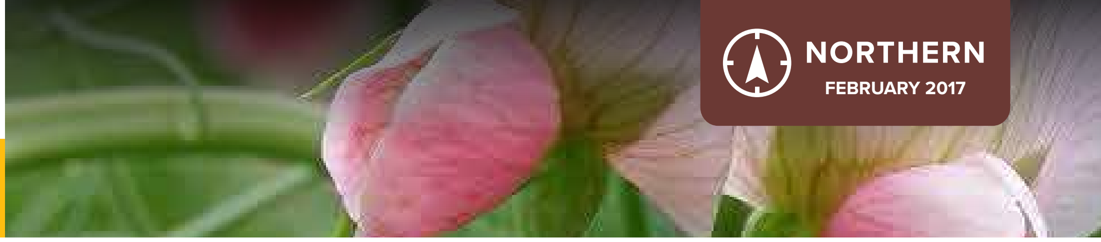
36 R Brennan (2015). Diagnosing manganese deficiency in field peas. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-manganese-deficiency-field-peas

37 Field peas, the ute guide pg 75 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation.

38 R Brennan, C Gazey (2015). Diagnosing manganese toxicity in field peas. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-manganese-toxicity-field-peas

39 C Scanlan (2015). Diagnosing phosphorus deficient in field peas. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-field-peas

40 Field peas, the ute guide pg 73 Field Peas: The Ute Guide (2009). Grains Research & Development Corporation.



5.11 Nutrition effects on following crop

One of the primary reasons field peas are grown is for their ability to fix nitrogen out of the atmosphere via rhizobia colonisation on the roots. The amount fixed varies between legumes as set out in the table below. Harvest index is the measure of the weight of a harvested product as a percentage of the total plant weight of a crop—that is, the plant's ability to effectively convert dry matter into grain (Table 3).

FAQ

Table 3: *Estimates of above-ground nitrogen fixed (kg/ha) by a pulse crop based on harvest index (HI).*

Grain yield (t/ ha)	Chickpea			Field pea, faba bean, lentil			Narrow leafed lupin			Albus lupin		
	HI 20%	HI 30%	HI 40%	HI 20%	HI 30%	HI 40%	HI 20%	HI 30%	HI 40%	HI 20%	HI 30%	HI 40%
0.40	38	21	13	35	18	10	31	15	6	28	12	3
0.60	57	32	19	52	27	14	47	22	10	42	17	5
0.80	76	42	26	69	36	19	63	30	13	56	23	6
1.00	95	53	32	87	45	24	79	37	16	71	29	8
1.20	114	64	39	104	54	29	94	44	19	85	35	10
1.40	132	74	45	121	63	34	110	52	23	99	41	11
1.60	151	85	51	139	72	39	126	59	26	113	46	13
1.80	170	95	58	156	81	43	141	66	29	127	52	15
2.00	189	106	64	173	90	48	157	74	32	141	58	16
2.20	208	116	71	191	99	53	173	81	35	155	64	18
2.40	227	127	77	208	108	58	189	89	39	169	69	19
2.60	246	138	83	225	117	63	204	96	42	184	75	21
2.80	265	148	90	242	126	67	220	103	45	198	81	23
3.00	284	159	96	260	135	72	236	111	48	212	87	24
3.20	303	169	103	277	144	77	252	118	52	226	93	26
3.40	322	180	109	294	153	82	267	126	55	240	98	28
3.60	341	191	116	312	162	87	283	133	58	254	104	29
3.80	359	201	122	329	171	92	299	140	61	268	110	31
4.00	378	212	128	346	180	96	314	148	64	282	116	32

Weed control

Weeds are estimated to cost Australian agriculture A$2.5–4.5 billion per annum. For winter cropping systems alone, the cost is $1.3 billion, equivalent to ~20% of the gross value of the Australian wheat crop. Consequently, any practice that can reduce the weed burden is likely to generate substantial economic benefits to growers and the grains industry. See more at www.grdc.com.au/weedlinks. [1]

Weed control is an essential part of growing a high yielding and effective field pea crop. Weeds not only compete for water and nutrients, but can also hinder the harvest process by blocking up machines and weed seed in the sample can downgrade the quality of the grain, resulting in a lower price for the pulse at harvest. Grass weeds can harbour diseases such as Crown rot and Yellow leaf spot and their presence in a field pea crop will decrease the effectiveness of the rotation crop as a disease break for cereal diseases.

The Grains Research and Development Corporation (GRDC) supports integrated weed management. Download the Integrated Weed Manual at https://grdc.com.au/Resources/IWMhub

Weed control is important, because weeds can:

- rob the soil of valuable stored moisture
- rob the soil of nutrients
- cause issues at sowing time, restricting access for planting rigs (especially vine-type weeds such as melons, tar vine or bindweed, which wrap around tines)
- cause problems at harvest
- increase moisture levels of the grain sample (green weeds)
- contaminate the sample
- prevent some crops being grown where in-crop herbicide options are limited (i.e. broadleaf crops)
- be toxic to stock
- carry disease
- host insects. [2]

FAQ

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 do not compete well with weeds, particularly early in the season. Despite field peas 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. [3]

Field pea provide 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;

1 GRDC (2005) Weedlinks. Integrated weed management. GRDC, www.grdc.com.au/weedlinks

2 GRDC (2005) Weedlinks. Integrated weed management. GRDC, www.grdc.com.au/weedlinks

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

- the availability of earlier maturing varieties such as Maki, PBA Oura⊕, PBA Twilight⊕ and SW Celine that enable 'crop-topping' for grass to be undertaken when the crop is close to maturity but the weeds are not.

There are a number of soil applied residual herbicides registered which 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. As residual herbicides applied to the prior cereal crop can affect the establishment and growth of field pea, refer to current pesticide labels for further information on plant-back periods. [4]

Planning your weed control strategy

1. Know your weed species. Ask your local adviser or service provider, or use the Sydney Botanic Gardens plant identification service, which is free in most cases: https://www.rbgsyd.nsw.gov.au/science/Herbarium_and_resources/plant_identification_service
2. Conduct in-crop weed audits prior to harvest to know which weeds will be problematic the following year.
3. Ensure that seed is kept from a clean paddock.
4. Have a crop-rotation plan that considers not just crop type being grown but also the weed-control options this crop system may offer, e.g. grass control with triazine-tolerant (TT) canola.

MORE INFORMATION

GRDC Update Paper: Impact of crop rotations on profit, nitrogen and ryegrass seed bank in crop sequences in southern NSW

Ground Cover Issue 124: Paraquat preferred for crop-topping pulses

6.1 Herbicide resistance

Herbicide resistance is an increasing threat across Australia's northern grain region for growers and agronomists. Already, 14 weeds have been confirmed as herbicide resistant in various parts of this region (Table 1), and more have been identified at risk of developing resistance, particularly to glyphosate (Table 2).

In northern NSW, 14 weeds are confirmed resistant to herbicides of Group A, B, C, I, M, or Z (Table 1). Barnyard grass, liverseed grass, common sow thistle and wild oat have confirmed cases of resistance to Group M (glyphosate) herbicides. Glyphosate-resistant annual ryegrass has been identified within ~80 farms in the list of confirmed resistant weeds in northern NSW (as at February 2014). [5]

4 P Matthews, 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

5 A Storrie, T Cook, P Moylan, A Maguire, S Walker, M Widderick. Managing herbicide resistance in northern NSW,. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/155148/herbicide resistance-brochure.pdf

Table 1: *List of confirmed resistant weeds in northern NSW (as at February 2014).*

Weed	Herbicide group and product/chemical (examples)	Areas with resistance in NSW	Future risk	Detrimental impact
Wild oats	A. Topik® and Wildcat® B. Atlantis® Z. Mataven®	Spread across the main wheat-growing areas. More common in western cropping areas	Areas growing predominantly winter crops	High
Paradoxa grass	A. Wildcat®	North and west of Moree	Areas growing predominantly winter crops	High
Awnless barnyard grass	C. Triazines M. Glyphosate	Mainly between Goondiwindi and Narrabri	No-till or minimum tilled farms with summer fallows	High Very high
Charlock, black bindweed, common sowthistle, Indian hedge mustard, turnip weed	B. Glean®, Ally®	Spread across the main wheat growing areas	Areas growing predominantly winter crops	Moderate
Annual ryegrass	M. Glyphosate B. Glean® A. Verdict®	Group M widespread in Liverpool Plains. Group A and B resistance in central west NSW	Areas with predominantly summer fallows. Winter cropping areas	High High
Fleabane	M. Glyphosate	Spread uniformly across the region	Cotton crops and no-till or minimum tilled systems	Moderate
Wild radish	I. 2,4-D amine	Central-west NSW	Continuous winter cereal cropping	High
Windmill grass	M. Glyphosate	Central-west NSW	Continuous winter cropping and summer fallows	High
Liverseed grass	M. Glyphosate	A few isolated cases	No-till or minimum tilled systems	Moderate
Sowthistle[A]	M. Glyphosate	Liverpool Plains	Winter cereal dominated areas with minimum tillage	High

*Testing underway to confirm glyphosate resistance. Plants are surviving label rates of glyphosate in the field and similar responses were seen under controlled environment experiments; likely to be confirmed resistant in 2014.

Table 2: *List of potential new resistant weeds in northern NSW (as at February 2014).*

Weed	Herbicide group and product/chemical	Future risk	Detrimental impact
Barnyard, liverseed and windmill grasses	A. Verdict® L. Paraquat	No-till and minimum tilled systems	Very high Very high
Common sowthistle	I. 2,4-D amine	Winter cereals	High
Paradoxa grass	B. Glean®, Atlantis®	Western wheat growing areas	High
Other brassica weeds including wild radish	B. Glean®, Ally®	Areas growing predominantly winter crops	Moderate
Annual ryegrass	L. Paraquat	Areas with predominantly summer fallows	Very high
Wireweed, black bindweed, melons and cape weed	I. 2,4-D amine, Lontrel®, Starane®	Areas growing predominantly winter crops	High
Fleabane	I. 2,4-D amine L. Paraquat	Cotton crops and no-till or minimum tilled systems	Very high Very high
Other fallow grass weeds	M. Glyphosate	No-till or minimum tilled systems	High

MORE INFORMATION

Maurie Street from Grain Orana Alliance discusses harvest weed seed management. GRDC Podcast: 096: Which weeds can be controlled at harvest

Testing services

For testing of suspected resistant samples, contact:

Charles Sturt University Herbicide Resistance Testing
School of Agricultural and Wine Sciences
Charles Sturt University
Locked Bag 588
Wagga Wagga, NSW 2678
02 6933 4001
http://www.csu.edu.au/__data/assets/pdf_file/0004/1227793/2014-report.pdf

Plant Science Consulting
22 Linley Ave Prospect,
SA 5082
0400 664 460
info@plantscienceconsulting.com.au
www.plantscienceconsulting.com.au

Be a WeedSmart farmer

The Australian grain industry stands at the crossroads with two options. Which direction will it take?

One road is for every grower to make herbicide sustainability their number one priority so that it influences decision-making and practices on all Australian grain farms. Armed with a clear 10-point plan for what to do on-farm, grain growers have the knowledge and specialist support to be WeedSmart.

On this road, growers are capturing and/or destroying weed seeds at harvest. They are rotating crops, chemicals, and modes of action. They are testing for resistance and aiming for 100% weed kill, and monitoring the effectiveness of spray events.

In addition, they are not automatically reaching for glyphosate, they do not cut on-label herbicide rates, and they carefully manage spray drift and residues. Growers are planting clean seed into clean paddocks with clean borders. They use the double-knock technique and crop competitiveness to combat weeds.

On this road, the industry stands a good chance of controlling resistant weed populations, managing difficult-to-control weeds, prolonging the life of important herbicides, protecting the no-till farming system, and maximising yields.

The other option is for growers to think resistance is someone else's problem, or an issue for next year, or something they can approach half-heartedly.

If herbicide resistance is ignored, it will not go away. Managing resistance requires an intensive but not impossible effort. Without an Australia-wide effort, herbicide resistance threatens the no-till system, land values, yields and your hip pocket. It will drive down the productivity levels of Australian farms.

Jump on board WeedSmart and take the road of least resistance. [6]

Ten ways to weed out herbicide resistance

1. Act now to stop weeds from setting seed:
- Destroy or capture weed seeds.
- Understand the biology of the weeds present.
- Remember that every successful WeedSmart practice can reduce the weed seedbank over time.
- Be strategic and committed—herbicide resistance management is not a 1-year decision.
- Research and plan your WeedSmart strategy.
- You may have to sacrifice yield in the short term to manage resistance—be proactive.

6 WeedSmart, http://www.weedsmart.org.au

- Find out what other growers are doing, and visit www.weedsmart.org.au.

2. Capture weed seeds at harvest. Options to consider are:

- Tow a chaff cart behind the header.
- Check out the new Harrington Seed Destructor.
- Create and burn narrow windrows.
- Produce hay where suitable.
- Funnel seed onto tramlines in controlled traffic farming (CTF) systems.
- Use crop-topping where suitable (field peas offer this option).
- Use a green or brown manure crop to achieve 100% weed control and build soil nitrogen levels. Field peas are perfect for this use.

Figure 1: *An example of narrow windrow burning.*

Photo: Penny Heuston

3. Rotate crops and herbicide modes of action:

- Look for opportunities within crop rotations for weed control.
- Understand that repeated application of effective herbicides with the same mode of action (MOA) is the single greatest risk factor for evolution of herbicide resistance.
- Protect the existing herbicide resource.
- Remember that the discovery of new, effective herbicides is rare.
- Acknowledge that there is no quick chemical fix on the horizon.
- Use break crops where suitable.
- Growers in high-rainfall zones should plan carefully to reduce weed populations in the pasture phase prior to returning to cropping. Use a green or brown manure crop to achieve 100% weed control and build soil nitrogen levels.

4. Test for resistance to establish a clear picture of paddock-by-paddock weed status:

- Sample weed seeds prior to harvest for resistance testing to determine effective herbicide options.
- Use the 'Quick Test' option to test emerged ryegrass plants after sowing to determine effective herbicide options before applying in-crop selective herbicides.
- Visit the WeedSmart website, www.weedsmart.org.au or www.ahri.uwa.edu.au for more information on herbicide resistance survey results.
- Collaborate with researchers by collecting weeds for surveys during the double-knock program (northern region).

5. Aim for 100% weed control and monitor every spray event:

- Stop resistant weeds from returning into the farming system.

- Focus on management of survivors in fallows (northern grains region).
- Where herbicide failures occur, do not let the weeds seed. Consider cutting for hay or silage, fallowing or brown manuring the paddock.
- Patch-spray areas of resistant weeds only if appropriate.

6. Do not automatically reach for glyphosate

- Use a diversified approach to weed management.
- Consider post-emergent herbicides where suitable.
- Consider strategic tillage.

7. Never cut the on-label herbicide rate and carefully manage spray drift and residues:

- Use best management practice in spray application. The GRDC has produced a series of Fact Sheets, available at www.grdc.com.au.
- Consider selective weed sprayers such as WeedSeeker or WeedIt.

8. Plant clean seed into clean paddocks with clean borders

- It is easier to control weeds before the crop is planted.
- Plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant weeds.
- A recent Australian Herbicide Resistance Initiative survey showed that 73% of grower-saved crop seed was contaminated with weed seed.
- The density, diversity and fecundity of weeds are generally greatest along paddock borders and areas such as roadsides, channel banks and fence lines.

9. Use the double-knock technique:

- Double-knock technique is the use of any combination of weed control that involves two sequential strategies; the second application is designed to control survivors of the first method of control used.
- Access GRDC research results at www.grdc.com.au or www.nga.org.au.

10. Employ crop competitiveness to combat weeds:

- Consider narrow row spacing and increased seeding rates.
- Consider twin-row seeding points.
- Use barley, canola, and varieties that tiller well.
- Use high-density pastures as a rotation option.
- Consider brown manure crops.
- Rethink bare fallows. [7]

MORE INFORMATION

GRDC Update Paper: Residual effects of a pulse crop phase in the farming system

Herbicides explained

Residual and non-residual

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 used in field peas include Diuron, Metrabuzin (Sencor), and Terbuthylazine (Terbyne).

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.

The persistence of herbicides will affect the crop rotation sequence. Growers must be mindful of plant-back periods on the following year's crop when applying a residual chemical in year one.

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

7 WeedSmart, http://www.weedsmart.org.au

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. [8]

Post-emergent and pre-emergent

These terms refer to the target and timing of herbicide application. Post-emergent refers to foliar application of the herbicide after both the target weeds and the crop emerged from the soil, whereas pre-emergent refers to application of the herbicide to the soil before the weeds have emerged. [9]

Examples of post-emergent sprays in field peas include Clethodim (Select), Diflufenican (Brodal), and MCPA.

Mode of action

Mode of action matters

Resistance has developed primarily because of the repeated and often uninterrupted use of herbicides with the same mode of action (MOA). Selection of resistant strains can occur in as little as 3–4 years if attention is not 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.

MOA labelling in Australia

In order to facilitate management of herbicide resistant weeds, all herbicides sold in Australia are grouped by 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 new herbicide MOA groups were created to group herbicides more accurately.

Grouping by mode of action and ranking by resistance risk

Growers and agronomists are now better assisted to understand the huge array of herbicide products in the marketplace in terms of MOA grouping and resistance risk by reference to the MOA chart. All herbicide labels now carry the MOA group clearly displayed, such as:

GROUP	**G**	**HERBICIDE**

8 T McGillion, A Storrie (Eds) (2006) Integrated weed management in Australian cropping systems—A training resource for farm advisors. Section 4: Tactics for managing weed populations. CRC for Australian Weed Management, Adelaide, http://www.grdc.com.au/~/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf

9 T McGillion, A Storrie (Eds) (2006) Integrated weed management in Australian cropping systems—A training resource for farm advisors. Section 4: Tactics for managing weed populations. CRC for Australian Weed Management, Adelaide, http://www.grdc.com.au/~/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf

Know your herbicide groups to make use of this labelling.

Not all MOA groups carry the same risk for resistance development; therefore, specific guidelines for Groups E, G, H, N, O, P, and R have not been developed because there are no recorded cases of weeds resistant to members of these groups in Australia.

Products represented in Group A (mostly targeted at annual ryegrass and wild oats) and Group B (broadleaf and grass weeds) are HIGH RESISTANCE RISK herbicides, and specific guidelines are written for use of these products in winter cropping systems.

Specific guidelines are also available for the 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 and cape weed), Group M (annual ryegrass, barnyard grass, fleabane, liverseed grass and windmill grass), Group Q (annual ryegrass), and Group Z (wild oats and winter grass).

Specific guidelines for Group K have been developed due to the reliance on this MOA to manage annual ryegrass, and the possibility of future resistance development. [10]

http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/weed-control-winter-crops

Herbicide labels refer to the node stage for the timing of spraying field peas. Figure 2 illustrates node development.

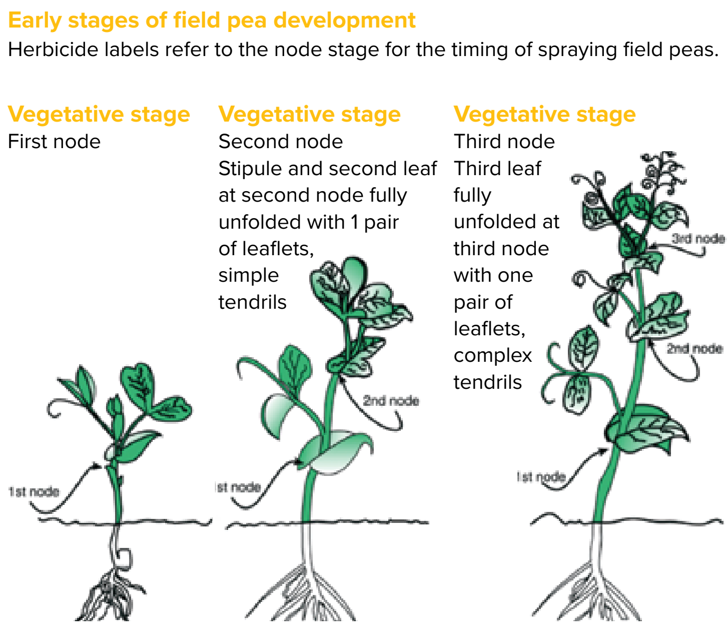


Figure 2: *Node development.*

Source: NSW DPI [11]

10 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

11 S Moore, G Cumming, L Jenkins, J Gentry (2010). Northern region field pea management guide. Pulse Australia.

6.2 Pre-emergent herbicides and post-plant pre-emergent herbicides

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 to help control herbicide resistant weeds. Examples of this chemistry include Trifluralin (Treflan), Pendimethalin (Stomp), and Triallate (Avadex).

Pre-emergent herbicides for use in field pea are generally registered for either incorporation by sowing or use as a post-sowing pre-emergent (PSPE). Most of these chemicals are very dependent on rainfall for activation; hence, 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.

See herbicide tables for field peas, NSW DPI Weed control in winter crops 2015 guide, p75–78: http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/weed-control-winter-crops

6.3 In-crop herbicides: knock downs and residuals

Field peas have a greater range of in-crop herbicide options for broadleaf weed control than other legumes (Table 3). Some of these chemicals also offer some handy residual control as well, an example being Metrabuzin offering some residual radish control.

An advantage of growing any of the pulse crops is the ability to take out grass weeds cheaply and effectively with little or no crop damage, if herbicide resistance is not an issue. Group A chemicals offer the most effective mode of control for grass weed control.

An important tool in integrated weed management is the ability to spray-top or desiccate a crop prior to harvest. Field peas are ideally suited to this as they are generally ready to desiccate before the crop weeds, in particular grasses, have set seed. The timing of this spray has to be quite specific to avoid any problems with germination of the following year's seed if the crop is being kept as a seed source. Too early a timing can also affect the quality of the seed and result in an uneven sample visually that may be penalised with a discount come marketing time.

Table 3: *Herbicide tolerance ratings.*

Herbicide		**Triflur®480® IBS Trifluralin**	**Stomp® IBS Pendimethalin**	**Terbyne® IBS Terbyne**	**Sencor750® PSPE Metribuzin**	**Spinnaker® PSPE Imazethapyr**	**Broadstrike® + Brodal® Flumetsulam + Diflufenican**	**Brodal® + MCPA Diflufenican + MCPA**	**Raptor® Imazamox**	**Aramo® Tepraloxydim**	**Broadstrike® Flumetsulam**	**Correct® Propaquizafop**	**Fusion® Fluazifop-p + Butroxydim**
Variety	Years tested	2001–13	2002–13	2010–13	1998–2013	1996–2013	2001	2005–13	2001–13	2004–08	1996–2013	1996–97	1996–2005
Bohatyr	1996–99	-	-	-	P(2)	N(2/4)	-	P(1)	-	-	P(4)	P(2)	P(3)
SW Celine	2012–13	N(1/2)	P(2)	9(1/2)	P(2)	12(1/2)	-	P(2)	N(1/2)	-	P(2)	-	-
PBA Coogeeⅆ	2012–13	14(1/2)	N(1/2)	P(2)	P(2)	13(1/2)	-	P(2)	N(1/2)	-	P(2)	-	-
CRC Walana	2012	P(1)	P(1)	P(1)	P(1)	12(1/1)	-	P(1)	P(1)	-	P(1)	-	-
Dundale	1996–2003	N(2/3)	P(2)	-	55(1/5)	P(7)	P(1)	P(2)	N(1/3)	-	P(4)	15(1/2)	P(3)
Excell	1997–2010	13–13(3/4)	9(1/2)	P(1)	11–56(4/7)	N(2/10)	P(1)	N(1/3)	N(3/6)	P(3)	19(1/4)	P(1)	P(2)
Kaspaⅆ	2004–13	N(1/4)	14(1/3)	P(5)	N(3/7)	13(1/5)	-	P(4)	N(2/5)	P(3)	N(2/4)	-	-
Maki	2008	N(1/1)	P(1)	-	P(1)	N(1/1)	-	N(1/1)	N(1/1)	P(1)	P(1)	-	-
Morgan	1996–2008	N(1/1)	P(1)	-	P(3)	N(1/5)	-	P(2)	P(1)	P(1)	P(5)	P(2)	P(3)
Parafield	1999–2008	11–11(2/3)	N(2/4)	-	9–51 (3/6)	N(2/7)	P(1)	N(1/3)	8(1/4)	P(3)	15(1/2)	-	-
PBA Gunyahⅆ	2010–12	P(1)	P(2)	P(3)	P(3)	N(1/3)	-	P(1)	P(1)	-	P(1)	-	-
PBA Ouraⅆ	2010–12	P(1)	N(1/2)	P(3)	P(3)	N(1/3)	-	P(1)	P(1)	-	P(1)	-	-
PBA Pearlⅆ	2012–13	P(2)	P(2)	P(2)	P(2)	25(1/2)	-	P(2)	N(1/2)	-	P(2)	-	-
PBA Percyⅆ	2010–13	P(2)	17(1/3)	30(1/4)	17(1/4)	14–29(2/4)	-	P(2)	P(2)	-	N(1/2)	-	-
Santi	2000	-	-	-	32(1/1)	P(1)	-	-	-	-	P(1)	-	-
Sturt	2005–13	P(4)	P(4)	18(1/3)	N(2/4)	16(1/3)	-	N(1/4)	N(1/4)	P(1)	P(4)	-	-
PBA Twilightⅆ	2010–13	P(2)	P(3)	P(3)	P(3)	N(1/3)	-	P(2)	P(2)	-	P(2)	-	-
PBA Whartonⅆ	2013	P(1)	P(1)	P(1)	P(1)	P(1)	-	12(1/1)	P(1)	-	P(1)	-	-
Yarrum	2005–13	N(1/4)	P(4)	P(3)	N(1/4)	N(2/5)	-	P(4)	N(1/4)	P(1)	P(4)	-	-
Rates (product/ha)		1.5 L	3.0 L	1.4 kg	380 g	100 g	25 g + 50 ml	150 ml + 150 ml	45 g	250 ml	50 g	300 ml	320 g
Crop stage at spraying		IBS	IBS	IBS	PSPE	PSPE	4node	4node	4node	4node	4node	4node	4node

6.4 Potential herbicide damage effect

Symptoms of crop injury from herbicides do not always mean grain yield loss will occur. The crop may change colour due to the damage but then grow away from this damage with little impact on yield. 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 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. [12]

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.

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

Herbicides have different leaching potentials, as shown by the leaching index (Table 4). For example, metribuzin, a chemical commonly used in field pea production, leaches at almost three times the rate of simazine and seven times the rate of diuron.

Table 4: *Relative leaching of some soil-active herbicides (where 1 = 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
metolachlor	Dual Gold®	6
atrazine	Atrazine	10
metribuzin	Sencor®	14

Herbicide damage effects can take a number of forms (Figures 3–6):

- Residual herbicide damage from a previous crop or fallow.
- This can be the case with Group B residues from the previous crop such as Metsulfuron (Ally) of Chlorsulfuron (Glean).
- Summer residual sprays can also result in crop damage if adequate rain fall does not fall between application and sowing, e.g. imazapic (Flame).
- Pre-emergent damage from chemical applied on the crop. Damage levels will be heightened by the following factors:
    - » Shallow sowing: seed is not separated from the chemical by the appropriate amount of soil
    - » Compacted soils, which don't allow the roots to grow away from the chemical as quickly
    - » Cloddy soils, which can result in chemical being applied directly on the seed in some cases
    - » Excessive rainfall after sowing and application: chemical gets washed into a concentrated band in the furrow
    - » Poor seedling vigour; plant cannot grow away from the chemical fast enough

12 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

» Seed dressings: some can affect the vigour of the seed. The poorer the vigour, the slower the seedling will be at growing away from the herbicide
» Insect attack, in particular soil borne insects: prune roots and plants cannot grow away from the crop quickly

Figure 3: *Spinnaker (imazethapyr) damage in Maki field peas.*

Photo: Penny Heuston

Figure 4: *Peas showing damage from Metrabuzin.*

Photo: DAFWA

- Post-emergent damage from a chemical targeted at the crop. Damage levels will be heightened by the following factors:

- » Incorrect crop growth stage. Many chemicals have a narrow safety range, so label rates should be adhered to, in particular if the crop is close to or is flowering
- » Climatic conditions—frost, waterlogging, drought
- » Incorrect rate. Many chemicals have a narrow safety range, so label rates should be adhered to.
- » Stressed: If the crop is stressed in any way, herbicide damage can be accentuated. Stress factors include poor nutrition, insect attack, soil compaction.

Figure 5: *Peas showing Group F (e.g. Brodal) damage.*

Photo: DAFWA

- Spray rig contamination: since field peas are very sensitive to certain chemical groups such as Group B and Group I, care must be taken when moving from paddock to paddock and boomsprays should be suitably decontaminated.
- Drift or off-target damage: care must be taken when spraying adjacent crops to field peas in particular if sprayed phenoxy chemicals (e.g. 2,4-D) of Group B chemicals (e.g. Ally). This can happen when those sprays are applied nearby in very windy or still conditions, especially where there is an inversion layer of air on a cool morning.

Figure 6: *Drift damage from Gramoxone.*

Photo: DAFWA

Drift and inversion

Inversion occurs when during the night the ground loses heat and the low-level air cools. This results in air temperature increasing with height and the temperature profile is said to be inverted. Unlike warm air that rises, cool air is dense and remains at the surface. When this occurs close to the ground it is called a surface temperature inversion. In a surface temperature inversion, the point where the temperature stops increasing and begins to decrease is the top of the inversion layer. When a strong surface temperature inversion has established, it can act like a barrier, isolating the inversion layer from the normal weather situation, especially the normal wind speed and direction.

Surface temperature inversion conditions are unsafe for spraying and the potential for spray drift is high as:

- the direction and distance pesticides movement is very hard to predict
- airborne droplets can remain concentrated or trapped in the inversion layer for long periods of time
- droplets or their remnants can move in different ways than indicated by the general weather pattern and move off-target. [13]

For information on cleaning and decontaminating boomsprays, see the NSW DPI publication, Weed control in winter crops 2015.

13 Surface temperature inversions and spraying fact sheet (2011) Grains Research & Development Corporation, http://www.grdc.com.au/uploads/documents/GRDC_FS_Spray%20drift%20temp%20inversions1.pdf

Insect control

Insect control is essential for field pea, not just to preserve yield but also to ensure the end product is free from damage, in particular for those peas destined for the human consumption market where visual appeal is paramount. Table 1 lists the insect pests of field peas and the susceptibility at each crop stage.

The two main insects which pose a threat to field peas are *Helicoverpa* and pea weevil. There is no varietal resistance to either pest.

Table 1: *Incidence of insect pests in field peas.* [1]

Pest	Crop stage				
	Emergence/ Seedling	Vegetative	Flowering	Podding	Grainfill
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.

1 NIPI & field pea IPM: http://ipmguidelinesforgrains.com.au/crops/winter-pulses/field-peas/

7.1 Insect control thresholds

Table 2: *Insect control thresholds.* [2]

Insect	Threshold	Crop growth stage	Crop damage	Comments	Frequency
Aphids	None established. Number of plants infected rather than numbers of aphids is important for control.	Before flowering.	Suck sap, stunt plants and transmit virus.	Direct crop damage unlikely. Check for predators. Retain cereal stubbles. Rarely seen in large numbers.	Rarely
Blue oat mites (BOM) and redlegged earth mites (RLEM)	Check seedlings for presence of mites after the autumn break. Spray if growth is retarded.	Seedling emergence to 4 nodes. Pea emergence can be suppressed.	Mottle and whiten cotyledons and leaves by rasping and suckling. May stunt and kill seedlings. RLEM more common in southern NSW.	Most feeding during cooler part of day/night. Often present under clods or underside of weeds such as capeweed/saffron thistles during day. Higher number after pasture.	Intermittent
Cutworms	Usually in large numbers in patches in crop. Treat at first sign of damage. Late afternoon preferred.	Seedling up to 4 nodes.	Eat leaves and cut stems at or below ground level. Remain in soil during the day.	Inspect crops late evening or night for presence of large dark grey-green caterpillars. Consider over-row spraying (night) or treat patches only.	Rarely
Heliothis caterpillars	Four or more 4–9 mm larvae per 10 sweeps for stockfeed. 1–2 larvae (4–9 mm) per 10 sweeps for human consumption. Larvae over 10 mm may enter pods and not be controlled.	Flowering and pod filling.	Prevent pod formation. Bore into pods, eat and damage seeds.	Observe crop for presence of moths during flowering. H. punctigera most common in spring. H. armigera in low numbers within 30 km of summer irrigation.	Annual
Loopers	Rarely a problem in field peas. Move in from edge of crop.	Early plant growth stages.	Defoliate plants.	Capeweed preferred food plant. Caterpillars have distinct looping motion.	Rarely
Lucerne fleas	Control may be necessary in southern NSW. Spray if seedling leaf area is likely to be reduced by 50%.	Seedling up to 4 nodes. Crops on heavy acidic soils most prone to damage.	Eat leaves, leaving clear membranous windows in foliage.	Eliminate weeds on headlands. Lucerne fleas hop when disturbed. Liming reduces flea numbers on acidic soils.	Intermittent
Lucerne seed web moths	At the first sign of damage. Treatments applied against heliothis caterpillars or pea weevils will give some control.	Flowering and podding.	Small caterpillars bore into seeds, leave webbing and excrement on pods.	Attack may go unnoticed until damaged has occurred. No recommended treatment.	Rarely
Pea weevils	Take 25 sweeps at each of 6 sites on crop edges. Border spray if there is average of 2 or more weevils per site.	First flowers onwards.	Larvae bore into pods, enter seeds, reduce seed weight by 25%. Reduce germination by 75%.	Fumigate all purchased seed in gas tight silo for 21 days with phosphine. Spray adults in crop before egg laying commences.	Annual
Thrips	Rarely a problem in field peas. 4–6 thrips per flower.	Budding to flowering.	Feed on young buds and flowers. Reduces pod set and distort pods.	Shake flowers into white container to dislodge thrips or open and inspect flowers.	Rarely

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

The aim of pest management is to keep pest populations below an economic threshold. Guideline thresholds (Table 2) based on research exist for some pests but most thresholds fluctuate depending on a number of factors. Monitoring and sampling of crops are essential to determine these factors and their influence on where the threshold lies. Growers who maintain a close watch on pest activity through regular crop inspections and thorough sampling are in a better position to decide if, and when, treatment is needed.

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

- environmental conditions and the health of the crop
- extent and severity of the infestation and how quickly the population increases
- prevalence of natural control agents such as parasitic wasps, predatory shield bugs, ladybirds and diseases
- type and location of pest damage and whether it affects yield indirectly or directly
- stage in the life cycle of the pest and the potential for damage
- crop stage and ability of the crop to compensate for damage
- amount of damage that has already occurred and the additional damage if the crop is not sprayed
- value of the crop (high value crops cannot sustain too much damage as a small loss in yield or quality could mean a large financial loss), the cost of the spray and its application, and the likely yield or quality benefit gained from control [3]

7.2 Integrated pest management

Integrated pest management (IPM) is a crop management approach to reduce chemical inputs and resolve 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 paddocks.

Integrated pest management is performed in three stages: prevention, observation, and intervention. It is an ecological approach aimed at significantly reducing use of pesticides while managing pest populations at an acceptable level. It therefore uses an array of complementary methods, including mechanical and physical devices, as well as genetic and biological tools, and cultural and chemical management. It is an ecological approach of prevention, observation and intervention, with a primary goal of significantly reducing the use of pesticide. Reductions in cost, contamination, residues and resistance to the pesticide are all benefits.

An IPM system is designed around five basic components:

1. Acceptable pest level

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 for another site or crop.

3 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

2. Preventive cultural practices

Using varieties best suited to local growing conditions, and maintaining healthy crops, is the first line of defence, 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 used, for example ((e.g. 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 then identification. Visual inspection, insect traps and other measuring tools are used to monitor levels of insect pests. Accurate pest identification is critical to a successful IPM program.

Monitoring of beneficial organisms and predators is important too, because they 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. *Helicoverpa*, *Etiella*). Monitor the degree-days of an environment to determine the most likely 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 focus is on promoting beneficial insects that eat target pests. In broadacre crops, the best strategy currently is to preserve those insects that are naturally occurring. Biological insecticides, derived from naturally occurring microorganisms, also fit this category (e.g. 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 aactive component may be altered to provide increased biological activity or stability. Further biology-based or ecological techniques are under evaluation.

Insecticides that are less toxic to beneficial insects should be used where possible. For example, pirimicarb for aphid control may mean fewer repeat applications compared with use of synthetic pyrethroids, because beneficial insects are preserved. [4]

4 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

MORE INFORMATION

Australian Pulse Bulletin: Managing native budworm in pulses

7.3 Native budworm (*Helicoverpa* spp.)

Heliothis is the main pest of field peas in the northern region. Insect damaged grain can lead to a downgrade from human consumption premiums to feed quality grain and can also affect the quality of sowing seed for the following year's crop.

Most crops require spraying during late flowering and pod filling and should be checked at least twice a week during this time. Growers should budget on twotwo sprays for the season.

The spray threshold for human consumption grade is 1–2 larvae per 10 sweeps, and for stockfeed, 4 or more larvae per 10 sweeps. One well timed early spray before larvae get too large (10 mm) is generally adequate. Grubs need to be control early because once they get inside the pod, they cannot be controlled till they come out again, by which stage they have eaten or damaged all the seed in that pod.

As the larvae of *Helicoverpa* are the main insect pest of field peas, it is important to be able to identify the different larval instars (very small, small, medium, large) of *Helicoverpa*. If possible, identifying which of the two species (*H. armigera* or *H. punctigera*) is present, or knowing which is predominant in your area, may help to avoid products that may not provide adequate control.

Description

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. The hind wings have a dark, broad band on the outer margin (Figure 1).

Figure 1: *Native budworm (*Helicoverpa*, previously Heliothis) moths, showing male (right) and female (left). Note the buff colouring.*

Photo: SARDI

Adult moths lay round eggs (0.5 mm in diameter) singly on the host plant. The eggs are white but turn brown just before hatching. The larvae grow to 5 cm long and vary in colour from green, yellow pink and reddish-brown to almost black (Figures 2 and 3).

Figure 2: *Left to right: fresh white, brown ring and black larval head in nearly hatching eggs.*

Figure 3: Helicoverpa *larvae occur in a range of colours.*

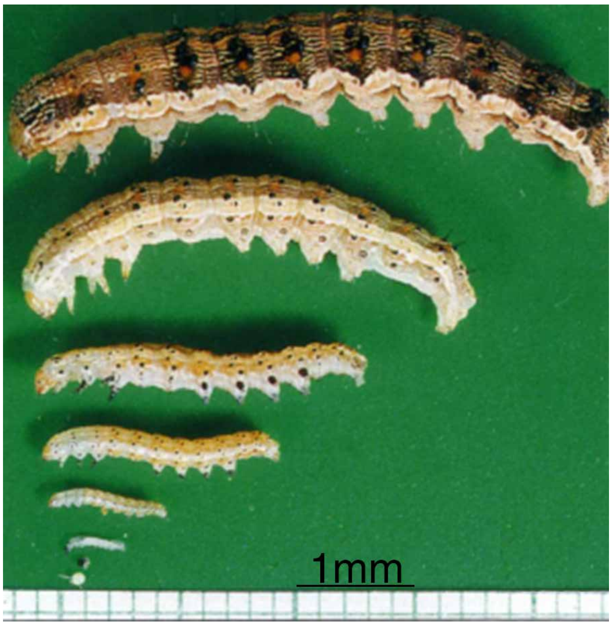


Figure 4: *In spring, eggs hatch in 1–2 weeks and larva feed for 4–6 weeks. This shows all stages from egg to fully grown larvae. Insecticides are more effective on smaller larvae.*

Photo: SARDI

Larvae can be easily identified, despite the colour variation, by a broad yellow stripe along the body (Figure 4). The young larvae (<10 mm) prefer to feed on foliage. Older larvae prefer to feed on pods.

Other larvae, which look like native budworm (*H. punctigera*), may be found in a pulse crop, such as southern armyworm and pink cutworm. These are primarily grass feeders and rarely do any damage to pulses.

Two species of *Helicoverpa*

Both *H. armigera* and *H. punctigera* are found in chickpea in Australia and attack a wide variety of crops, including chickpea.

Visual identification of the different species is sometimes possible from examination of larvae. Small *H. armigera* larvae (3rd instar) have a saddle on the fourth segment and *H. punctigera* do not. This is often difficult to see in the field and the method is not 100% reliable, but may be used as a guide.

In larger (5th and 6th instar) larvae, hair colour on the segment immediately behind the head is a good indicator of species. These hairs are white in *H. armigera* and black in *H. punctigera* (Figure 5). Moths can be differentiated by hindwing colour pattern (Figure 6).

Figure 5: *Head of 5th instar* H. armigera *larva showing the white hairs on the segment immediately behind the head. Larvae of* H. punctigera *have black hairs.*

Photo: R. Lloyd, DPI&F

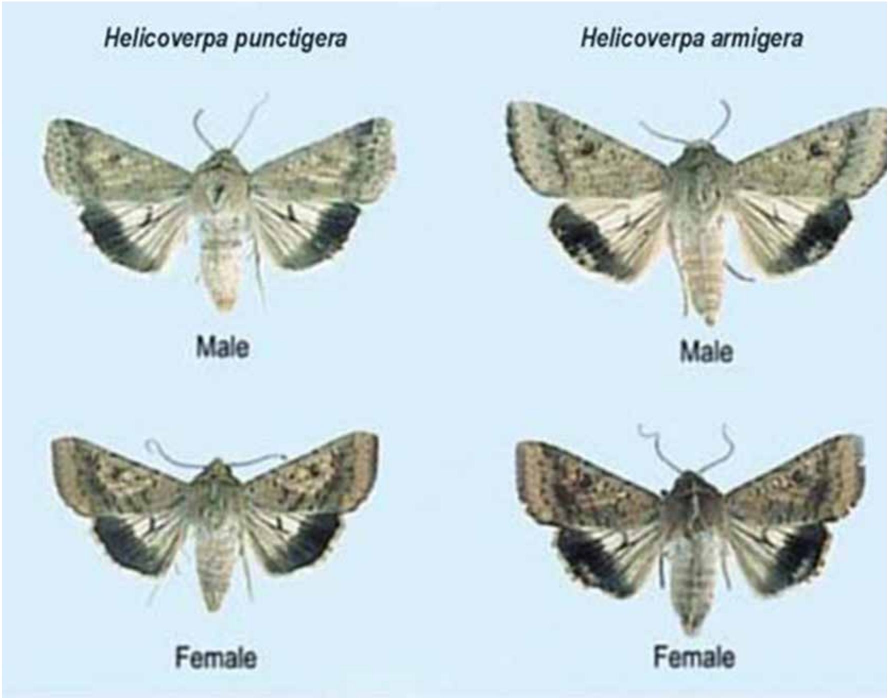


Figure 6: Helicoverpa punctigera *and* H. armigera *moths are distinguished by the presence of a pale patch in the hindwing of* H. armigera.

Species composition can vary and will affect control decisions

Species composition in the crop will be influenced by the time of year. In temperate regions (southern Queensland and further south), the majority of *H. armigera* individuals over-winter from mid-March onwards and emerge during September–October. *Helicoverpa punctigera* is usually the dominant species through September, but seasonal variation can lead to *H. armigera*-dominant early infestations in some years, particularly in more northern districts. Pheromone trap catches can be used as an indication of the species present in a region, although they are not a reliable predictor of egg lay within a crop.

If the level of *H. punctigera* infestation is high, any registered product will control the larvae. If *H. armigera* is the dominant species, spray failures with carbamates or pyrethroids may occur because of resistance. The biopesticides Helicoverpa nucleopolyhedrovirus (NPV) and Bacillus thuringiensis (Bt) currently have no known resistance problems.

Why distinguish the two species of *Helicoverpa*?

Determining which *Helicoverpa* species is present in the crop is essential, principally because of the differing susceptibility of the two species to synthetic pyrethroids and carbamates.

Visual identification of the different species is sometimes possible from examination of larvae; however, this can be difficult and unreliable with small larvae when control decisions have to be made. A hand lens, microscope or USB microscope is essential for examining small larvae.

Small *H. armigera* larvae (3rd instar) have a saddle on the fourth segment, whereas *H. punctigera* do not (Figure 7). In larger (5th and 6th instar) larvae, look at the hair colour on the segment immediately behind the head—white for *H. armigera* and black for *H. punctigera* (Figure 8).

Figure 7: *Medium* Helicoverpa armigera *(12 mm) showing the distinctive 'saddle' on 4th and 5th body segments (top), and* H. punctigera *without saddle (bottom).*

Figure 8: *Large* Helicoverpa punctigera *(left) and* H. armigera *(right) larvae showing the distinguishing dark and pale hairs, respectively, behind their heads.*

Species composition can vary between seasons and regions

Species composition in the crop will be influenced by a number of factors, such as:

- Winter rainfall in inland Australia, which drives populations of *H. punctigera*, and the occurrence and timing of wind systems that carry *H. punctigera* from inland Australia to eastern cropping regions.
- Winter rainfall in eastern cropping regions, which drives the abundance of local populations of *H. armigera* through the generation of spring hosts. In regions where field peas are grown, they may serve as a significant spring host for *H. armigera* emerging from diapause if these populations are not controlled (e.g. sub-threshold populations across large areas of chickpea, or poorly managed crops).
- Relative timing of flowering–podding (attractive and susceptible) stages and the immigration of *H. punctigera* and emergence of *H. armigera* from overwintering diapause. Note that in central Queensland, *H. armigera* does not enter winter diapause and will be the predominant species in chickpeas.
- Geographic location: In temperate regions (southern Queensland and further south), most of the *H. armigera* population overwinters from mid-March onwards and emerges during September–October. *Helicoverpa punctigera* is usually the dominant species through September when moths are migrating into eastern cropping regions. Seasonal variation can lead to *H. armigera*-dominant early infestations in some years, particularly in more northern districts. Pheromone trap catches can be used as an indication of the species present in a region. Note that pheromone traps cannot be used to predict the size of an egg-lay within a crop. [5]

Chickpeas are susceptible to significant yield loss caused by *Helicoverpa* from podset through to harvest. Although *Helicoverpa* can cause reductions in both yield and quality, the economic threshold for minimising yield loss is much lower than that which would result in a reduction in grain quality.

Seedling insect pests such as cutworm can attack chickpeas, but are rarely an economic problem. Other infrequent pests include blue oat mites, false wireworms, and aphids.

Sampling with a beat sheet is best practice for monitoring *Helicoverpa* in chickpeas. Establishment pests will be detected by visual inspection of seedlings.

Regular monitoring during the susceptible crop stages is critical, particularly for *Helicoverpa*, where you may be dealing with insecticide-resistant larvae, and good control depends on targeting of small larvae.

7.3.1 Sampling strategy and technique

The beat sheet and sweep net are accepted techniques for monitoring *Helicoverpa* larvae in chickpeas. The beat sheet is the recommended technique for crops grown on wider row spacings (>50 cm rows) (Figure 9).

5 Miles (2013) Chickpea insect pest management. Department of Agriculture, Fisheries and Forestry, Queensland, http://ipmworkshops.com.au/wp-content/uploads/Chickpea_IPM-Workshops_north-March2013.pdf

Figure 9: *The beat sheet is the recommended technique for sampling crops grown on wider spacings.*

Beat sheet v. sweep net

The sweep net and beat sheet have not been calibrated in chickpea, so it is not yet possible to use the one threshold with an adjustment for relative sampling efficiency of the sweep net.

Using a beat sheet

Check crops regularly (at least once a week) from flowering through to harvest, using a beat sheet. In addition to larval counts, visual observation of the crop growth stage, progress of flowering and podding, and the presence of eggs, diseased larvae (NPV) and moths all provide useful information for decision-making.

Each time you inspect, check at least five 1 m sections of row at a number of sites in the field. Start sampling at least 50 m into the field, and include samples from well into the field to enable a representative average field population to be calculated.

How to use a beat sheet

Place the beat sheet with one edge at the base of a row. On 1 m row spacing, spread the sheet out across the inter-row space and up against the base of the next row. Draping over the adjacent row may be useful for row spacing <1 m, or where there is canopy closure. It also minimises the chance of larvae being thrown off the far side of the sheet. With a 1 m-long stick (dowel, heavy conduit), shake the row vigorously 10 times to dislodge larvae from the plants. Measure and count larvae on the sheet.

A standard beat sheet is made from plastic or tarpaulin material with heavy dowel on each end to weigh down the sheet. The beat sheet is typically 1.3 m wide by 1.5 m long. The extra 0.15 m on each side catches insects thrown out sideways.

Using a sweep net to monitor Helicoverpa

A standard sweep net has a cloth bag and an aluminium handle. With heavy use, the aluminium handle can shear off; more robust, wooden handles are often fitted by agronomists.

Where crops are sown on narrow row spacings and it is not possible to get a beat sheet between the rows, a sweep net can be used to sample *Helicoverpa*.

Hold the sweep net handle in both hands and sweep it across in front of your body in a 180° arc. Take a step with each sweep. Keep the head of the net upright so the bottom of the hoop travels through the canopy. Use sufficient force in the sweep to pass the hoop through the canopy and dislodge larvae.

Take 10 sweeps and then stop and check the net for larvae. Record the number and size of larvae in each set of 10 sweeps. Repeat at additional sites across the field.

7.3.2 Recording of monitoring data for decision-making

Keeping records should be a routine part of insect checking. Successive records of crop inspections will show whether pest numbers are increasing or decreasing, and will help in deciding whether a control is necessary.

Records of insect checking should include as a minimum:

- date and time of day
- crop growth stage
- average number of pests detected, and their stage of development
- checking method used and number of samples taken
- management recommendation (economic threshold calculation)
- post spray counts

Figure 10: *(a) and (b).* Helicoverpa.

Photo: Gordon Cumming, Pulse Australia

Weekly trap catch data for *H. punctigera* and *H. armigera* from locations across all states can now be viewed online. The adjustable bar below the map allows selection of a time period (1 wk, 2 wks, 1 mth, etc). https://jamesmaino.shinyapps.io/MothTrapVis/

7.3.3 Control

The spraying program should aim at controlling small larvae (< 1 cm) that are normally foliage feeding and easier to control and often requiring lower insecticide rates. If using a ground or aerial contractor, then book them well in advance and keep them well informed as often spraying can clash with fungicide spraying in cereals.

Larger larvae will often burrow into pods and control becomes more difficult being shielded from the spray and more likely to survive. A single caterpillar can attack four to five pods before reaching maturity and will feed in crops for four to six weeks.

Most insecticides used for budworm control are contact chemicals and therefore it is important to have complete coverage of the target. A medium spray quality is necessary as they are light and will flow around with the airstream, particularly at low airflow rates and increase the chance of striking the target inside the canopy.

They are however more subject to off target drift when conditions are not ideal and air induction/inclusion or venturi nozzles are becoming more popular to achieve more uniform droplet size at low pressures. Most insecticide spraying should be at less than 210 microns VMD (volume mean diameter, i.e. 50% of droplets > 210 microns, and 50% of droplets < 210 microns).

This is generally finer than for most herbicides and labels will sometimes specify a droplet range along with water volumes.

In consultation with your agronomist choose a registered product that is the most suitable, and be aware of the withholding period (WHP) for harvest or windrowing/

swathing which is the same as harvest. Residue testing is routinely conducted on grain destined for export and domestic stockfeed markets. [6]

7.3.4 Economic thresholds

The economic threshold is dependent on three factors: (a) crop value ($/t) (b) cost of control, and (c) the economic loss (yield and/or quality) based on grub numbers present (Table 3).

ET = C / (K × P) C = control cost: chemical + application costs ($/ha)

K = Kg/ha eaten for every one caterpillar netted in 10 sweeps (sq mtr)

P = price of grain per kg (price per tonne × 1000)

Table 3: *Economic thresholds for* Helicoverpa punctigera. *7*

Crop	P Grain price per tonne	C Control costs chemical + application	K Loss for each grub in 10 sweeps kg/ ha/grub	ET Grubs in 10 sweeps (sq mtr)	ET Grubs in 5 lots of 10 sweeps
Field pea – trailing type e.g. Parafield, Helena	200	10	50	1.0	5
Field pea – semi-leafless e.g. Kaspa⁽ᴰ⁾, Bundi	200	10	100	0.5	2.5
Chickpeas – desi type	420	10	30	0.8	4
Faba bean	280	10	90	0.4	2
Lentil	420	10	60	0.4	2
			Grubs (>15 mm)	**Grubs/m²**	
Lupin – angustifolius	175	10	7	8.2	–

Source: Department of Agriculture and Food Western Australia

For example:

If the on-farm value of Parafield field peas is $200 per tonne and the cost of control is $12.00/ha, the calculation would be 12 / (50 × 200/100) = 1.2/10 sweeps or 6 grubs in 5 lots of sweeps.

Use of this calculation will provide each grower with a personalised and more precise measure of potential loss from native budworm damage. Growers using this table to calculate spray thresholds should substitute their own control costs and expected on-farm grain prices to provide a more accurate measure of potential loss. Premiums paid for exceeding quality standards for high value pulses (i.e. Kabuli chickpea) may necessitate lower thresholds. [8]

6 Pulse Australia (2015) Managing native budworm in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/native-budworm

7 Pulse Australia (2015) Managing native budworm in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/native-budworm

8 Pulse Australia (2015) Managing native budworm in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/native-budworm

7.4 Pea weevil (*Bruchus pisorum*)

It is one of the most damaging pests of field peas. It not only reduces yields but can also reduce germination rates of seed and grain quality to the point that it's not saleable for human consumption (Figure 11).

Figure 11: *Pea weevil.*

Photo: Grain Legume Handbook

This is a major pest in southern regions and is a sporadic pest in the central west area of NSW; as such, its presence needs to be monitored for in the northern region. Pea weevils are not in fact a weevil but rather a small, black chunky beetle about 5 mm long. They are brown with white, black, and grey patches. The white tip of the abdomen is marked with two black, oval spots. Eggs are bright yellow and cigar-shaped about 1.5 mm long, and attached individually to developing pods.

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.

Adult beetles hibernate during summer, autumn, and winter in sheltered positions (e.g. under bark of trees, 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 two weeks after arrival in the pea crop, the females lay eggs on the developing pods. Female beetle lay eggs, individually on the surface of pods.

Small larvae hatch from the eggs in about 6 to 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 larvae prepares a 2–3 mm exit hole by chewing partially through the seed coat. The larvae then pupates and after about 14 days is ready to emerge as an adult beetle (Figure 12).

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.

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 field 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. [9]

Figure 12: *Example of the holes created in field pea seed by pea weevil as they emerge from the mature field pea seed.*

Photo: QDAF

7.4.1 Monitoring and control

Control must occur during the first few weeks of flowering and before eggs are laid on the pods.

Monitoring of crops—at least weekly from flowering through to early pod set—for pea weevil should be standard practice. Monitor when average temperatures are above 20°C as this is when pea weevil are active. They are most likely to be found in parts of the paddock adjacent or close to trees, wooden fence posts or pasture. A sweep net is the most effective means of detection. Take 25 sweeps at 6–10 sites on crop edges within 1–2 m from the crop margin.

9 D Hardie, S Micic (2015) Management of pee weevil. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/pest-insects/management-pea-weevil?page=0%2C1

Control is recommended if there is >1 weevil per site (25 sweeps). Control is only effective if adult weevils are treated before they lay eggs. A border spray to 40 m into the crop will provide adequate control in most situations. [10]

7.5 Aphids

The main species affecting peas are the pea aphid (*Acyrthosiphon pisum*), green peach aphid (*Myzus persicae*), bluegreen aphid (*Acyrthosiphon kondoi*) and occasionally cowpea aphid (*Aphis craccivora*). It is unusual for aphids to colonise field peas, typically as winged aphids move through the crop they may spread viruses, [11] so if left undetected in a crop they have the potential to spread viruses relatively quickly with no curative action available.

Luteovirus are a group of viruses which are spread by aphids. These viruses are present in the northern region although their severity varies greatly between seasons. While varietal resistance is an important option, many new varieties are of unknown status. PBA Wharton⒟, Maki and Yarrum have a high level of resistance to Pea seed-borne mosaic virus (PSbMV), PBA Pearl⒟ and PBA Wharton⒟ have resistance Bean leaf roll virus (BLRV). [12]

An integrated management strategy to control aphids and viruses involves the use of both cultural and chemical measures that aim to:

- deter aphids from landing in the crop (planting a field pea crop into a standing cereal stubble can aid with this) (Figure 13)
- minimise aphid flights
- regularly monitor aphid activity and be prepared to act quickly
- identify aphid species present and beneficial species [13]
- have weed free edges and fallows that can harbour the insect. hosts include medics, volunteer cereals and marshmallow
- grow solid stands of peas on narrow spacings to prevent any bare patches in the paddock
- source clean seed and test retained seed for viruses including CMV, BYMV, Alfalfa mosaic virus (AMV) and PSbMV. Sow tested seed with <0.1% virus infection to reduce the pool of virus-infected material. Field pea seed should have <0.5% PSbMV. Where possible, choose a pulse variety that has virus resistance.

10 S Moore, G Cumming, L Jenkins, J Gentry (2010) Northern Region Field Pea Management Guide. Pulse Australia Ltd.

11 Diagnosing aphid damage in field peas (2015) Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-aphid-damage-field-peas

12 https://sydney.edu.au/agriculture/documents/pbi/pbi_region_north_field_pea_management_guide.pdf

13 Bray, T, Hawthorne, W. Virus Control & Aphid Monitoring Simplified. Australian Pulse Bulletin, Pulse Australia Ltd, http://v1.pulseaus.com.au/pdf/Virus%20Control%20and%20Aphid%20Monitoring%20Simplified.pdf

Figure 13: *Planting field peas into standing cereal stubble can disrupt the aphid flight and deter them from landing on the crop.*

Photo: Grant Thomas

Adult insects:

- The pea aphid is up to 4 mm long, and may be yellow, green, or pink in colour. They have black knees and dark joints on their antennal segments. These aphids feed primarily on pea, faba bean, and lucerne.
- The green peach aphid (GPA) tends to be shiny or waxy, and ranges from yellow, through to green and pink. They can be similar in colour to young unfurled field pea leaves. GPA has a wide host range including canola, lupins and other pulse crops, and can also be found on weeds including wild radish, doublegee and blackberry nightshade.
- The bluegreen aphid (BGA) is up to 3 mm long, and matt bluish-green. Large numbers of winged BGA fly from pastures to crops later in the growing season.
- The cowpea aphid (CPA) has a black body and black and white legs; it is not typically found on field pea, but often colonises lupin and faba bean 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. [14]

7.6 Lucerne flea

Broadleaf seedlings—including canola, lupins, faba beans, field peas, clovers and lucerne—are most susceptible to the lucerne flea. It requires cool, moist conditions to hatch and will produce up to five generations in most years with the final generation of females each season laying eggs that over-summer in the soil and ingest soil particles to help form the protective mass that protects the eggs.

Insecticides provide the most effective means of control.

14 Diagnosing aphid damage in field peas (2015) Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-aphid-damage-field-peas

In southern regions, the standard recommendation for autumn control is to spray four weeks after the first significant rain of the season. Lucerne flea control is not easy. Effective control depends on understanding its biology, knowledge of the property on a paddock-by-paddock basis, and monitoring to ensure the right timing.

Lucerne flea is an agile member of the springtail family that moves by jumping instead of flying. It does not move quickly between or across paddocks. It can be found in pastures and crops from autumn to spring, depending on temperature and moisture levels. It requires cool, moist conditions and will produce up to five generations in most years with the final generation of females each season laying eggs that over-summer in the soil.

Over-summering eggs hatch the following autumn when the right combination of temperature and moisture occurs. In southern areas, hatching conditions usually follow the first significant autumn rain. In northern summer-rainfall areas where autumn tends to be dry, the moisture is more likely to be provided by irrigation

Lucerne flea prefers to feed on lucerne and most clovers but is also found on a range of annual winter crops. These include canola, pulses, wheat, triticale, barley, and oats.

The pest works up the plants from ground level, eating tissue from the underside of the foliage, leaving 'windows' of transparent leaf membrane. Lucerne flea also feeds on weeds including shepherd's purse, chickweed, common sow thistle, and wild radish. Keeping fallows free of these weeds can help prevent build-up of the pest. The females lay their eggs in the soil.

In northern areas where there is no 'autumn break', the timing of early-season sprays is based on monitoring, with the appearance of increasing numbers of larger nymphs the trigger for spraying. Late-season spraying (in spring) can reduce the number of insects in the following autumn by preventing the last generation of females from laying aestivating (over-summering) eggs.

Timing based on effective monitoring is the key to success with spring spraying. A planned out program of timely spring and autumn sprays with effective chemicals over two to three years can reduce populations to very low levels.

Crops and pastures on farms where lucerne flea is a problem should be monitored for damage levels and the number of insects present. Crops, particularly canola and pulses, should be inspected frequently at and immediately following emergence, when they are most susceptible to damage. (Monitoring usually involves working on hands and knees.)

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

Monitor crops by checking plants in 50 cm of row at five to 10 sites across the paddock. Examine foliage for damage and check the soil surface where insects may be sheltering. If it is necessary to check for the insects at later growth stages in field crops, 'sweeping' the more open and upright vegetation with a dark-coloured 'sweep' net is preferred over the 'icecream container' method suited to pastures. [15]

7.7 Snails

Snails are a significant problem in field pea crops across the southern region of Australia however rarely a problem in all but the very southern parts of the northern region. Grain contamination by round and conical snails poses a serious threat to grain exports. Snails also cause damage to emerging crops and can clog machinery at harvest resulting in delays and frustration.

It is highly recommended to avoid sowing field pea crops where snails are evident. Bash'Em, Burn'Em and Bait'Em are the only recommendation for snail control in pulse crops.

15 GRDC (2002) Knowledge, timing, key to Lucerne Flea Control—Grains Research Advice. Grains Research & Development Corporation, http://www.grdc.com.au/uploads/documents/lucerneflea_nov02.pdf

A rule of thumb is if snail numbers are above 20/m^2 in cereals and 5/m^2 in pulses and oilseeds, and be prepared to deal with grain contamination at harvest.

- Use header modifications and grain cleaning to eliminate snail contamination of grain.
- Snails appear to build up most rapidly in canola, field peas and beans. However, they can feed and multiply in all crops and pastures.
- Baiting before egg laying is vital. Timing and choice of controls will depend on the season. Understand the factors that determine control effectiveness.
- Stop baiting eight weeks before harvest to avoid bait contamination in grain.

For more information on snail control go to the GRDC publication Bash ‘Em Burn ‘Em Bait ‘Em https://www.grdc.com.au/uploads/documents/Snails%20BBB.pdf

7.8 Mites

Mites are among the most diverse and successful of all invertebrate groups. They are small in size and often go unnoticed; however, mites are one of the most important pest groups attacking Australian grain crops. Some species have become more problematic over the last decade as farming practices have changed, and others are proving difficult to control due to tolerance and chemical resistance issues. The two main species that can pose a problem in the northern region are Redlegged earth mites (RLEM) and Blue oat mite (BOM), with the BOM the more predominant pest in central and northern NSW, whilst the RLEM the more dominant species in southern NSW.

Monitor these pests closely from emergence up to the 4-node stage. If crop damage becomes apparent, undertake appropriate control measures. [16]

7.8.1 Redlegged earth mites

Description

- RLEM grow to about 1 mm in length.
- Adults have a velvety black body and eight red legs.
- Newly hatched mites are pinkish-orange with six legs and are 0.2 mm long
- Nymphs develop into mature adults in approximately 4–6 weeks.

In autumn, over-summering eggs hatch when there is significant rainfall and the mean daily temperatures fall below approximately 21°C.

RLEM can have three generations per season.

Crops attacked

- Canola, pulses, and other legume seedlings are the most susceptible.
- Red legged earth mites feed on broadleaf weeds, particularly capeweed. They also attack cereals and grasses especially when selective herbicides eliminate preferred hosts.

RLEM are often found in feeding aggregations, of up to 30 individuals. Feeding causes silvering or white discoloration of leaves and distortion or shrivelling in severe infestations (Figure 14). [17]

16 P Matthews, 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/agriculture/broadacre-crops/guides/winter-crop-variety-sowing-guide

17 Crop Mites Back Pocket Guide (2012) Grains Research & Development Corporation, http://www.grdc.com.au/Resources/Publications/2012/06/GRDC-Crop-Mites-Back-Pocket-Guide

Figure 14: *Redlegged earth mites (RLEM).*

Photo: GRDC Crop Mites – the back pocket guide

7.8.2 Blue oat mites

Description

- Blue oat mites (BOM) are 1 mm in length when adults.
- Adults have a blue-black body with a distinctive red mark on their back and eight red-orange legs.
- Nymphs are pinkish-orange in colour with six legs on hatching, but soon become greenish and then blue-black.

BOM usually have three generations per season, with each generation lasting 8–10 weeks.

Over-summering diapause eggs hatch in autumn, stimulated by cold temperatures and adequate moisture.

There are three BOM species that are pests of grain crops in Australia. A microscope is required to distinguish between species.

Crops attacked

- All crops and pastures are vulnerable to attack and are most susceptible at the seedling stage.
- BOM feed on cereals, grasses, canola, field peas, legumes, and various weeds.

Feeding causes silvering or white discoloration of leaves and distortion or shrivelling in severe infestations (Figure 15). [18]

18 Crop Mites Back Pocket Guide (2012) Grains Research & Development Corporation, http://www.grdc.com.au/Resources/Publications/2012/06/GRDC-Crop-Mites-Back-Pocket-Guide

Figure 15: *Blue oat mites (BOM).*

Photo: GRDC Crop Mites – the back pocket guide

7.9 Etiella or Lucerne seed web moth (*Etiella behrii)*

Description

- The moths are small (12 mm long at rest, with a 20–22 mm wingspan) and distinctively coloured.
- They are grey-brown with a distinctive stripe along the leading edge of each forewing and an orange band on each forewing (about one quarter of the distance along each forewing from its base).
- Hindwings are pale grey.
- The wings are folded back along the body when resting.

Moths have a prominent 'snout' (formed by the labial palps) that is typical of pyralids. The eggs are small (0.6 mm diameter), cream, and flattened. Small larvae may be cream or pale green, with no stripes and a dark head. Mid-sized larvae may be pale green or cream, with pale brown or reddish stripes. Larger larvae are characteristically green with pink or reddish stripes and a brown head. Larvae in the pre-pupal stage can be aqua-blue or dark pink with no stripes.

Eggs are laid on pods and flowers or under bracts and are very hard to detect. In most legumes with above-ground pods, newly-hatched etiella larvae bore straight into pods leaving a near-invisible entry hole.

Crops attacked: lentil, field pea, lupin, soybean (WA, SA, VIC, NSW), and peanuts (QLD)

Damage

- Incidence and abundance varies by season. Severe infestations can result in a loss of yield and quality.
- Etiella flights commonly occur in mid to late September and often coincide with early pod development in pulses.
- Larvae burrow into pods within 24 hours of hatching. They feed on pods and seeds, remaining in pods until entire content has been eaten. Frass is left in the pod, and adjacent pods may be webbed together as larvae move between pods.

- Seeds usually only partially eaten out, often with characteristic pin-hole damage.
- Damage is difficult to grade out and unattractive appearance reduces seed quality.

Control:

- 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 monitoring for oneone week after chemical applications. [19]

MORE INFORMATION

QDAF, Biosecurity Queensland: Locusts

Australian Plague Locust Commission

7.10 Locusts (sporadic)

The major difference between locusts and grasshoppers is that locusts have the ability to swarm; grasshoppers do not (Figures 16 and 17). There are some 500 grasshopper species in Australia, some of which can develop large localised infestations without the risk of swarming. [20]

Key points

- Locusts pose more than just a physical threat to pulse crop yields and quality.
- Controlling locusts before harvest is imperative to ensure marketable quality grain and to ensure successful delivery.
- Pulse growers need to make contact with their receival agent well in advance of harvest to discuss probable industry attitudes to high locust inclusion in the grain sample.
- Both receival agents and marketers may reject grain with high locust inclusion despite the sample technically meeting the receival standard for field insects.
- Grain staining, slimes and objectionable odours may arise from squashing live locusts during harvest. This material is difficult, if not impossible to remove.
- Objectionable material and odours in the sample will result in the product being rejected at the receival point.
- Only permitted chemicals are to be used for control of locusts.
- Maximum residue limits apply and grain samples may be collected and analysed for compliance with regulatory and market requirements.
- Locusts can potentially affect pulse crops in all Australian grain production regions. Locusts have the potential to damage green crops and can have significant impact on yield and delivery quality of pulse grain. [21]

19 http://ipmguidelinesforgrains.com.au/pests/etiella/

20 QDAF (2016) Locusts. QDAF, Biosecurity Queensland, https://www.daf.qld.gov.au/__data/assets/pdf_file/0009/55593/IPA-Identification-Locusts-PA22.pdf

21 Pulse Australia (2015) Impact of locusts on pulse crops and grain quality. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/locust-control

Figure 16: *Locust hatchlings cause the most damage when they form feeding bands that move across the land eating anything that is green.* [22]

Figure 17: *Locust swarms can travel long distances on the wind. Landholders are required to report locust activity.* [23]

7.10.1 Effect on growing crops

While it is well known that cereals are particularly vulnerable to locusts, the susceptibility of the various pulses is uncertain, but it is assumed that they could be attacked while they remain green. It is important to note that:

- Established green crops are susceptible to damage by adult locusts but tend to be avoided by hoppers (immature locusts), although crop edges can be damaged and may warrant a perimeter spray.
- Locusts cause little damage to crops that have dried off, but crops that are beginning to dry down when locusts begin to fly are still susceptible to attack.
- Even slight damage to pulse crops that have a high grain value or are destined for specific export markets could justify the cost of control.
- As a general rule, hopper and adult numbers should be closely monitored, and if any damage is seen, then spraying should be commenced immediately.
- Comply with label directions for the chosen insecticide and pay particular attention to withholding periods (WHP) for harvest/windrowing or swathing, and for grazing/fodder. [24]

22 Pulse Australia (2015) Impact of locusts on pulse crops and grain quality. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/locust-control

23 Pulse Australia (2015) Impact of locusts on pulse crops and grain quality. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/locust-control

24 Pulse Australia (2015) Impact of locusts on pulse crops and grain quality. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/locust-control

7.10.2 Impact on pulse deliveries

The receival and export farmer dressed standards for most pulses have a tolerance for a maximum of 0–2 grasshoppers or locusts in a 200 g sample (or max. 4 in 400 g), dead or alive. For grasshoppers and/or locusts, six legs, three body parts or two wings or part thereof, constitutes one entire insect respectively. More than one of the same body part constitutes greater than one insect.

Storage and handling companies and marketers may refuse to receive grain into current market grades if they find unacceptable levels of locusts present, despite the sample technically meeting the standard for field insects.

In years of high grasshopper and locust density at harvest, discuss the potential of contamination with your prospective storage agent or marketer before harvest.

Apart from the issue of physical presence of locusts in grain samples, there is an added quality concern, similar to snail contamination. Slime and intestine contents from live locusts squashed during harvest are major concern. Seed staining is likely, and there is added potential for objectionable odours to occur. Any slime or odour associated with the grain will deem the grain unacceptable to market as there is a nil tolerance of odour and contamination with slime material.

The potential contamination of the grain will usually warrant the implementation of control measures from crop emergence, through spring growth and up to harvest. Only a few chemicals are registered for control of locusts in pulse crops. These must be used according to product labels and the required withholding periods to ensure that maximum residue limits are complied with. Using chemicals off-label is an offence and places the marketing of affected pulses in jeopardy. [25]

7.10.3 Reporting infestations

Landholders and land managers are expected to report hatchings and to control infestations on their own property, unless control of the density is beyond their means or it is public land where activities may need to be taken by specific government agencies. Reports are to be made to the biosecurity agency in your state or to the Australian Plague Locust Commission. [26]

7.10.4 Management options

The decision on how locusts in crops are best managed is affected by a range of factors including:

- Growth stage of the crop, i.e. is there any green plant material or has the crop completely dried off?
- Ability to harvest early—desiccation may be an option to advance harvest.
- Delivery standards required for the specific pulse—discuss requirements with potential buyers.
- Risk to market from pesticide residues—WHP for windrowing/swathing is the same as harvest.
- Ability to clean physical locust contamination from harvested grain. [27]

7.10.5 Control

The most effective and easiest way for landholders to control locusts is by ground spraying the hoppers when they have formed into dense aggregations called bands. This normally occurs from 1–2 weeks after hatching. The time available for controlling an outbreak is short with hoppers taking about 5 weeks to develop into swarming

25 Pulse Australia (2015) Impact of locusts on pulse crops and grain quality. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/locust-control

26 Pulse Australia (2015) Impact of locusts on pulse crops and grain quality. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/locust-control

27 Pulse Australia (2015) Impact of locusts on pulse crops and grain quality. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/locust-control

adults. Hoppers are most likely to hatch in pasture paddocks and along roadsides, fence lines and non-cultivated ground around the crop perimeter, but some hoppers may hatch from egg beds laid within crops particularly bare areas such as wheel tracks where tram lining is practiced.

It is critical in these situations that the correct insecticide is used to avoid residue issues. Australian grain produce must meet minimum residue levels (MRLs). Individual deliveries of grain will be tested for chemical residues, to detect the use of unapproved pesticides and to ensure that withholding periods have been followed.

- Only use an insecticide that is registered or has a permit for locust control in the specific pulse crop.
- Users must obtain, read and adhere to the conditions of APVMA permits prior to use.
- Follow label directions and pay attention to the WHP (withholding period). Following pesticide application, the relevant withholding period MUST expire BEFORE cutting for hay, windrowing, harvest or undertaking of any similar operation.
- Plan well ahead in choosing the most appropriate product(s) to suit your situation as availability may become an issue as the season progresses.
- Be aware of the receival standards that apply to insect contamination (alive or dead) and grain damage from locust feeding.
- Be aware of nil tolerance for odour and taints that could arise from crushing locusts during harvest, handling or while in storage.
- Avoid inadvertent contamination of grain with other chemicals not used in pulses. [28]

For information on insecticides registered or permitted for control of locusts in pulse crops, see http://www.pulseaus.com.au/growing-pulses/publications/locust-control

7.10.6 Australian plague locust (*Chortoicetes terminifera*)

Most locust plagues originate in south-west Queensland and adjacent areas of South Australia, NSW and the Northern Territory. Locust 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 eggs, which produce the spring outbreak.

Description

Adults of the Australian plague locust can be identified by their characteristic black spot on the tip of the hind wing (Figure 18). Nymphs or hoppers are more difficult to identify. If they are in a large band, then it is likely to be the plague locust.

28 Pulse Australia (2015) Impact of locusts on pulse crops and grain quality. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/locust-control

Figure 18: *Adult Australian plague locust.* [29]

Life-cycle

Adults are sexually mature within 2 weeks of developing wings. Females select suitable laying sites in the barest ground available (e.g. roadsides, tracks).

Eggs are laid in pods at a depth of 20–50 mm. Each pod contains 30–50 pale-yellow eggs shaped like a banana, 5–6 mm long. Females lay up to four pods each before dying.

Eggs develop according to temperature and moisture. Eggs laid in autumn are usually dormant over winter and hatch in spring with soil temperature increases. Eggs laid in summer under ideal conditions may hatch within 14–16 days. After hatching, nymphs or hoppers grow through five growth stages.

Wing buds become progressively more notable through each stage.

Nymphs move away from egg beds and tend to concentrate into dense marching bands of size from a few square metres to several hectares. Bands may merge to increase to several kilometres with a distinct front. Older hoppers can travel up to 500 m in a single day. Hoppers complete their development in 4–6 weeks.

After their final moult, young adults emerge with fully-developed wings. Milling flights increase over the band until the majority of hoppers have fledged. Adults concentrate into groups called swarms, which make low drifting flights up to 50 m high, and they can cover 10–20 km per day. Flight behaviour depends on the age of the adult, wind speed, and temperature. Long-distance migration will occur at night if green feed has been available to enable fat accumulation.

Damage

Crops can be physically damaged, particularly seedlings. Rejection at grain delivery can occur if adult locusts, or parts of them, are present in the sample, or if objectionable stains and odour exist.

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 areas.

In the event of a plague, local government may undertake some spraying operations (e.g. roadsides) within their own area. Where significant problems are expected, government agencies may undertake large-scale control in pastoral and adjacent agricultural areas.

29 QDAF (2016) Locusts. QDAF, Biosecurity Queensland, https://www.daf.qld.gov.au/__data/assets/pdf_file/0009/55593/IPA-Identification-Locusts-PA22.pdf

Effective suppression of locusts can only be achieved by cooperation between landowners, local governments and government agencies, combined with ongoing APLC activities.

Cultivation of 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 APVMA permits are required for chemical use. [30]

7.10.7 Spur-throated locust (*Austracris guttulosa*)

Spur-throated locust (Figures 19–21) is a pest of pastures, crops and some tree species. It is a tropical species of northern Australia, but extends its habitat into areas experiencing wet summer seasons.

It is often noticed in northern NSW, and in northern grain areas in Western Australia, but it rarely reaches damaging numbers. It is a declared pest insect in NSW.

Figure 19: *Adult-spur throated locust.*

Photo: Australian Plague Locust Commission)

30 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Figure 20: *Adult spur-throated locust in a near mature lupin crop—note the pods.*

Photo: K. Roberts NSW DPI

Figure 21: *Spur-throated locust showing the spur between the first pair of legs.* [31]

Damage

Spur-throated locusts can cause damage to crops when they migrate in from neighbouring pastures and vegetation.

Life-cycle

After hatching, nymphs or hoppers grow through six growth stages. Nymphs take 10 weeks to reach maturity. Nymphs do not form into large bands, so cannot be identified in the air, unlike the Australian plague locust.

31 QDAF (2016) Locusts. QDAF, Biosecurity Queensland, https://www.daf.qld.gov.au/__data/assets/pdf_file/0009/55593/IPA-Identification-Locusts-PA22.pdf

Control

Control measures may be economic only in high-value crops or with high densities. Nymphs do not band and are generally quite scattered. Effective control will only be achieved if nymphs are also controlled in adjoining pastures and vegetation to prevent re-invasion.

Ensure that product registration or a current APVMA permit exists before using any insecticide. [32]

32 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Nematode control

Pratylenchus thornei (Pt) (Figure 1) appears to be one of the key 'issues' for winter cereal production in the northern region. Pt is a major constraint due to: the large impact on yield and economics when intolerant varieties are grown; broad geographic distribution with Pt populations frequently at above threshold levels; and the susceptibility (Pt hosting) of key rotation crops such as chickpeas.

Successful Pt management will involve a range of practices including on-farm hygiene and soil testing to identify problem paddocks. However crop and variety choice are likely to be the major tools used for management. Wheat varieties are well-characterised in terms of tolerance (yield impact suffered during the year of crop production) and resistance (impact from variety on the multiplication or build-up of Pt). Both characteristics are important for long term management. [1]

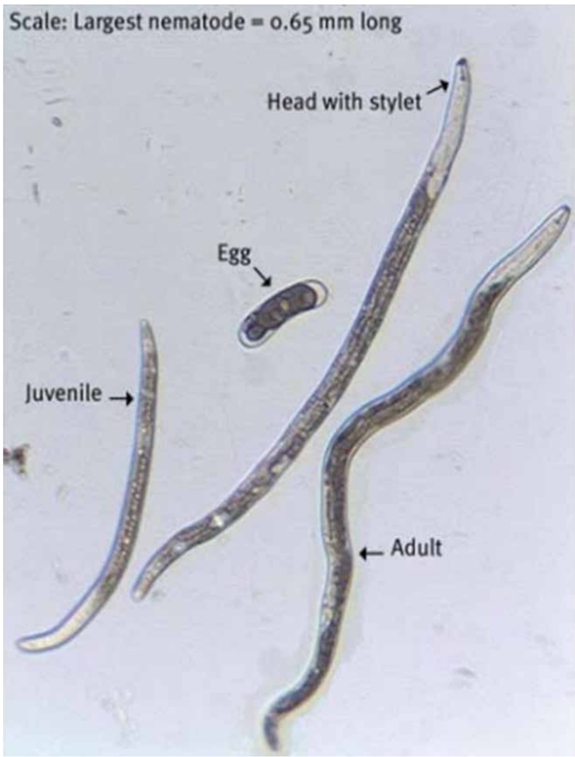


Figure 1: *Root-lesion nematodes and egg viewed under a microscope. The stylet in the nematode's mouth is used to break plant cell walls for feeding.*

Photo: DAF

1 Daniel, R, Northern Growers Alliance. Impact from Pratylenctus thornei. Grains Research & Development Corporation, http://www.nga.org.au/module/documents/download/135

8.1 Symptoms and detection

In the field, symptoms include stunted growth, uneven patches, or waviness across the paddock.

Root-lesion nematodes invade the root tissue resulting in light browning of the roots or localised deep brown lesions. 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. [2]

To determine nematode numbers, consider a PreDicta B test. PreDicta B (B = broadacre) is a DNA-based soil testing service that identifies soil-borne pathogens, including root lesion nematode, that pose a significant risk to broadacre crops prior to seeding.

PreDicta B is a DNA based soil test which detects levels of a range of cereal pathogens that is commercially available to growers through the South Australian Research and Development Institute (SARDI). The main pathogens of interest in the northern grains region detected by PreDicta B are *Fusarium* spp. (crown rot), *Bipolaris sorokiniana* (common root rot), *Pythium* (damping off) and both *Pratylenchus thornei* and *P. neglectus* (root lesion nematodes, RLNs). Over recent years, PreDicta B has been shown to be a reliable method for assessing RLN populations. [3]

For tips on improving the accuracy of PreDicta B soil testing, see the GRDC Update paper, Improving the accuracy of PreDicta B soil testing.

8.2 Varietal resistance or tolerance

Unlike chickpeas who can endure yield losses of 20–30% in intolerant varieties, field peas are resistant to *P. thornei* and *P. neglectus*. Resistant lines minimise nematode multiplication for following crops. [4]

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

It is generally believed that field peas are resistant to nematodes. Some recent trial work by the GRDC-funded Northern Growers Alliance (NGA) has challenged this. In 2011 and 2012, a trial was designed to improve the understanding of the differences in tolerance between a range of winter crops and varieties, followed by an assessment of the impact of these options on subsequent Pt densities. An approach was used to create alternating strips of 'low' and 'high' Pt population where the impact of increased Pt numbers on each variety could be evaluated. For the chosen paddock, tests indicated a Pt population close to the 2000/kg soil threshold widely used in the industry. Generally, a population density of 2000 RLN/kg soil anywhere in the soil profile has the potential to reduce the grain yield of intolerant varieties.

Three varieties of field peas were grown in the crop mix with both NDVI and yield measurements taken. The trial showed there was a significant reduction in NDVI score from the 'low' to the 'high' Pt strips and an average 8% reduction in yield (~280 kg/ha) in the field peas strips (Figures 2 and 3). [5]

2 Root-lesion nematodes: management of root-lesion nematodes in the northern grain region (2009). Grains Research & Development Corporation and Queensland Government, https://www.daf.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

3 S Simpendorfer, A McKay, S Rowe (2015). Grains Research & Development Corporation,http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Improving-the-accuracy-of-PreDicta-B-soil-testing

4 Root Lesion Nematode (2002). Department of Environment and Primary Industries, Victoria, http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/root-lesion-nematode

5 Daniel, R, Northern Growers Alliance. Impact from Pratylenctus thornei. Grains Research & Development Corporation, http://www.nga.org.au/module/documents/download/135

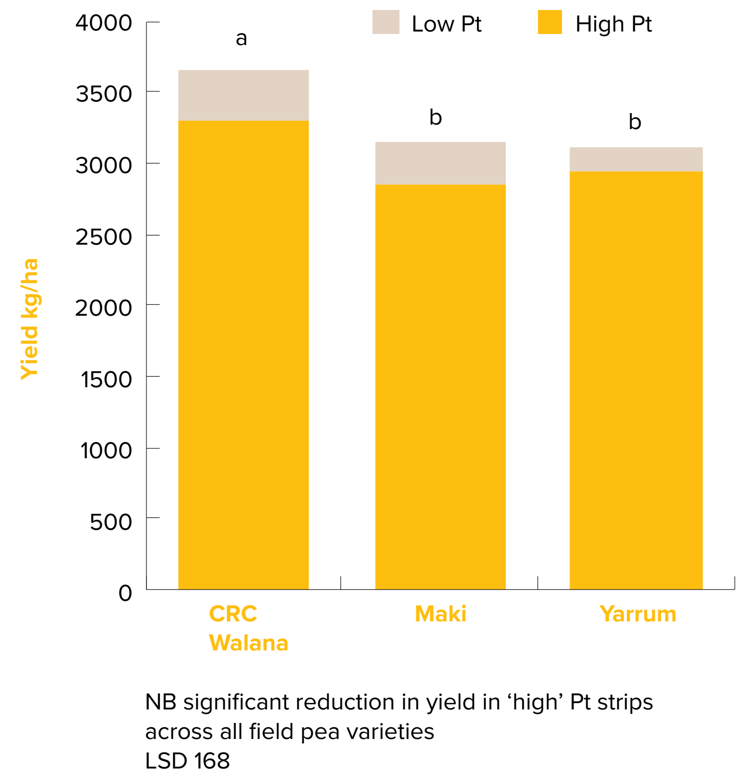


Figure 2: *Field peas are a 'resistant crop' to nematodes; that is, they do not allow numbers to build up for the following year's crop. The NGA trial showed this to be the case below.* [6]

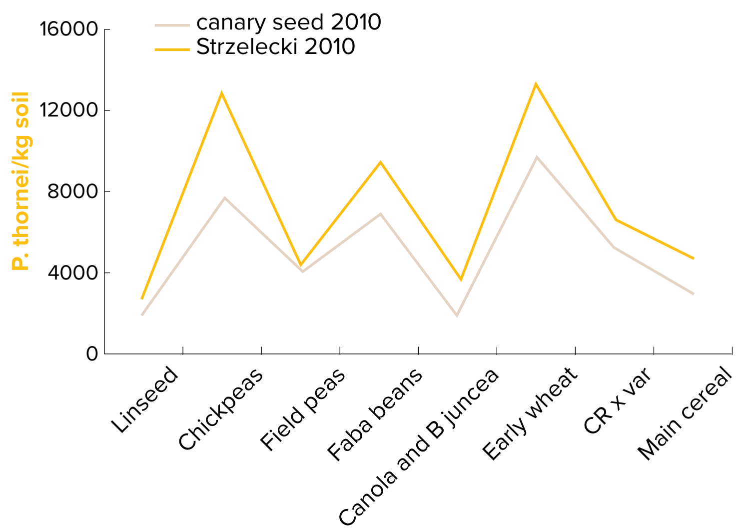


Figure 3: *Overall Pt populations in strips sown to canary seed or Strzelecki in 2010. Even 18 months after the canary seed and Strzelecki were sprayed out (September 2010) there was still a clear trend to increased Pt populations in strips where Strzelecki had been grown.*

6 Crop or variety impact on Pratylenchus thornei populations. Northern Grower Alliance and Grains Research & Development Corporation http://www.nga.org.au/module/documents/download/139

Diseases

The current loss from diseases in the Australian pulse industry averages $74 million per year, or 14.8% of the gross value of pulse production. These losses are due to diseases caused by fungi, nematodes, bacteria, viruses, and phytoplasmas (Table 1). Losses would be far higher without the current range of controls, which includes the use of resistant varieties, rotation, paddock management, and the use of pesticides. [1]

The major diseases considered important in the region include powdery mildew, downy mildew and viruses (including pea seed-borne mosaic virus and a number of the luteoviruses). [2] Black spot or ascochyta blight is the major disease of the south and west, and growers in the north need to be mindful of this disease as the area and frequency of growing field peas in the north expands.

In the northern region, three diseases had a potential average annual yield loss of >10%. The highest average annual potential yield loss was 70.0% from powdery mildew, followed by bean leafroll and pea seed-borne mosaic. With current disease controls, bean leafroll was the highest with 9.4% present average annual loss and almost no loss from any other disease. [3]

Effective disease management relies on the combined use of the correct selection of the variety with the best profile of disease resistance, the most suitable paddock, clean seed, agronomic practices and canopy management, as well as the use of fungicides. [4]

Recommended strategies to minimise disease in field include:

- 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 situation.
- Sowing and rainfall: use 'Black spot manager' computer model to assist with sowing date decisions. Do not sow within two weeks of the first rains of the season unless in low rainfall/short season areas and black spot risk is low.
- Sowing date: sow within the optimum 'sowing window' for your district, using Black spot 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 black spot. Know 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.

1 G Murray, J Brennan (2012) The Current and Potential Costs from Diseases of Oilseed Crops in Australia. Grains Research & Development Corporation, https://www.grdc.com.au/Resources/Publications/2012/06/The-Current-and-Potential-Costs-from-Diseases-of-Oilseed-Crops-in-Australia

2 S Moore (2010) Field Peas—Field Performance and Role in Northern Farming Systems. Grains Research & Development Corporation, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/05/Field-Peas-Field-Performance-and-Role-in-Northern-Farming-Systems#sthash.97QzfomV.dpuf

3 G Murray, J Brennan (2012) The Current and Potential Costs from Diseases of Oilseed Crops in Australia. Grains Research & Development Corporation, https://www.grdc.com.au/Resources/Publications/2012/06/The-Current-and-Potential-Costs-from-Diseases-of-Oilseed-Crops-in-Australia

4 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation.

- Foliar fungicide application: Foliar fungicide can effectively control powdery mildew. A fungicide program for controlling black spot 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. [5]

The impact of disease on field pea production can be minimised by sowing disease- and virus-free seed, by planning sensible crop rotations (not growing field pea in the same paddock more than once every four years), eliminating volunteer field pea plants, and not sowing near or immediately downwind of the previous season's field pea paddock. [6]

The GRDC pulse germplasm enhancement program is pursuing resistance genetics for a range of pulse diseases. Field peas with improved resistance to two bacterial blight strains have been identified and new knowledge gained about the diversity and virulence of bacterial blight strains. A new seedling screening method for the disease has been readily adopted by PBA and will help speed the development of field pea varieties with resistance to bacterial blight. [7]

MORE INFORMATION

Winter crop variety sowing guide

Table 1: *Occurrence of field pea diseases and pests, including nematodes, by GRDC region.* [8]

Pathogen	Disease	Northern	Southern	Western	Australia
Necrotrophic leaf fungi					
Ascochyta pisi	leaf and pod spot	Y	Y	P	Y
Botrytis cinerea	grey mould	Y	Y	P	Y
Leptosphaerulina trifolii	pepper spot	U	Y	U	Y
Phoma medicaginis var. pinodella	Phoma black spot	Y	Y	P	Y
Phoma koolunga	Koolunga black spot	U	Y	N	Y
Mycosphaerella pinodes	Mycosphaerella black spot	Y	Y	P	Y
Septoria pisi	Septoria blotch	Y	Y	Y	Y
Mp, Ap, Pm	black spot complex	U	U	Y	Y
Biotrophic leaf fungi					
Erysiphe pisi	powdery mildew	Y	Y	Y	Y
Peronospora viciae	downy mildew	Y	Y	Y	Y
Root and crown fungi					
Aphanomyces euteiches	Aphanomyces root rot	P	N	N	P
Botrytis cinerea	Botrytis damping off/root rot	P	Y	N	Y
Fusarium oxysporum f.sp. pisi	Fusarium wilt	U	Y	U	Y
Macrophomina phaseolina	charcoal rot	U	U	N	N

5 W Hawthorne, J Davidson, L McMurray, E Armstrong, B Macleod, H Richardson (2012) Field pea Disease Management Strategy. Australian Pulse Bulletin, Pulse Australia Ltd, http://www.pulseaus.com.au/storage/app/media/crops/2012_APB-Fieldpea-disease-management-South-West.pdf

6 P Matthews, 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/agriculture/broadacre-crops/guides/winter-crop-variety-sowing-guide

7 T Slater (2015) Diseases pursued in multi-pronged breeding program. Grains Research & Development Corporation, http://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-116-Foliar-fungal-diseases-of-pulses-and-oilseeds/Diseases-pursued-in-multipronged-breeding-program

8 G Murray, J Brennan (2012) The Current and Potential Costs from Diseases of Oilseed Crops in Australia. Grains Research & Development Corporation, https://www.grdc.com.au/Resources/Publications/2012/06/The-Current-and-Potential-Costs-from-Diseases-of-Oilseed-Crops-in-Australia

Pathogen	Disease	Northern	Southern	Western	Australia
Mycosphaerella pinodes	Mycosphaerella foot rot	U	Y	N	Y
Phoma medicaginis var. pinodella	Phoma foot rot	U	Y	N	Y
Pythium spp.	Pythium damping off/root rot	U	Y	Y	Y
Rhizoctonia solani	Rhizoctonia seed and stem rot	Y	Y	U	Y
Rhizoctonia solani	bare patch	U	U	Y	Y
Rhizoctonia solani AG11	epicotyl rot	U	U	Y	Y
Sclerotinia sclerotiorum	Sclerotinia stem rot	Y	Y	Y	Y
Nematodes					
Ditylenchus dipsaci	stem nematode	U	N	N	N
Meloidogyne incognita	root knot nematode	U	N	U	N
Pratylenchus neglectus	root lesion nematode neglectus	U	U	U	U
Pratylenchus penetrans	root lesion nematode penetrans	U	N	Y	Y
Pratylenchus teres	root lesion nematode teres	U	U	P	P
Pratylenchus thornei	root lesion nematode thornei	U	N	Y	Y
Radopholus sp.		U	U	P	P
Bacteria					
Pseudomonas syringae pv. pisi	pisi bacterial blight	Y	Y	Y	Y
Ps. syringae pv. syringae	syringae bacterial blight	Y	Y	U	Y
Viruses					
Alfalfa mosaic virus (AMV)	alfalfa mosaic	Y	Y	U	Y
Bean common mosaic potyvirus (PCMV)	bean common mosaic	U	U	U	U
Bean leafroll virus (BLRV)	bean leafroll	Y	Y	U	Y
Bean yellow mosaic virus (BYMV)	bean yellow mosaic	Y	Y	P	Y
Beet western yellows virus (BWYV)	beet western yellows	Y	Y	P	Y
Clover yellow vein virus (CYVV)	clover yellow vein	U	U	U	U
Cucumber mosaic virus (CMV)	cucumber mosaic	Y	Y	U	Y
Pea seed-borne mosaic virus (PsBMV)	pea seed-borne mosaic	Y	Y	Y	Y
Soybean dwarf virus (SbDV)	soybean dwarf	Y	U	U	Y
Subterranean clover stunt virus (SCSV)	subterranean clover stunt	Y	P	U	Y
Tomato spotted wilt virus (TSWV)	tomato spotted wilt	Y	U	U	Y

Y= present in region
P = present in region but no or incomplete data on incidence and severity
N = not recorded in region
U = unknown status

9.1 Powdery mildew (*Erysiphe polygoni*)

Powdery mildew is the major disease threat to field pea production in the northern region, north of and including the Macquarie Valley (Figures 1–2). [9]

This disease can cause yield losses and occurs more frequently in the drier areas of the central and northern wheat belt, generally towards the end of the season. Mild day temperatures and cool nights with dew formation favour the disease.

It is more likely to occur when the season is protracted, sowing is late, or later maturing varieties are grown. Powdery mildew develops quickly in warm (15–25°C), humid conditions (over 70%) for 4–5 days, particularly at flowering and after canopy closure. As with downy mildew, rainfall will wash spores off the plants. Free moisture on plants will also restrict germination of the spores and does not promote the epidemic. If infection occurs earlier than four weeks from maturity, yield losses due to powdery mildew arise from the infection covering stems, leaves and pods, which will lead to shrivelled seeds. [10]

The fungus over-summers on infected pea trash and produces spores which are blown by wind into new crops. The disease may also be seed-borne, but this source of infection is less important.

Figure 1: *Powdery mildew.*

Photo: Joop van Leur, NSW DPI

Symptoms:

- Infected plants are covered with a white powdery film, and severely infected foliage is blue-white in colour; tissue below these infected areas may turn purple.
- All aerial parts of the plant may become infected resulting in withering of the whole plant.
- Severe pod infection can cause a grey-brown seed discoloration that lowers the quality of the grain. [11]

Control measures:

9 S Moore, G Cumming, L Jenkins, J Gentry (2010). Northern region field pea management guide. Pulse Australia.

10 W Hawthorne, J Davidson, L McMurray, E Armstrong, B Macleod, H Richardson (2012) Field pea Disease Management Strategy. Australian Pulse Bulletin, Pulse Australia Ltd, http://v1.pulseaus.com.au/pdf/Field%20pea%20Disease%20Management%20Strategy%20Southern%20&%20Western%20Region.pdf

11 Diagnosing powdery mildew in field peas (2015). Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-powdery-mildew-field-peas

- Leaving 4 years between field pea crops.
- Separating crops from previous field pea crops.
- Burning or incorporating infected field pea trash soon after harvest.
- Using fungicidal control when disease symptoms first appear.
- Growing a resistant variety

Control is only economical and effective if disease is detected early when disease levels are low. It is essential to use a proper paddock sampling procedure to estimate disease levels and to have the disease correctly identified. [12]

Foliar fungicides can be used to manage the disease in more susceptible varieties. These are generally inexpensive and can be applied at the same time as an insecticide.

Varietal resistance is the best method of control. All three newer varieties–PBA Coogee⒫, PBA Hayman⒫ and PBA Wharton⒫–as well as the older varieties (CRC Walana, Maki and Yarrum) carry a powdery mildew resistance gene that provides complete protection against this disease. Other currently commercially available varieties are susceptible to varying degrees.

Figure 2: *Powdery mildew.*

Photo: SARDI

9.2 Bacterial blight

This disease is very sporadic and often unpredictable. It is caused by the bacterium *Pseudomonas syringae*. There are two pathovars (pv) of *P. syringae* found in NSW, *P. syringae* pv *pisi* and *P. syringae* pv *syringae*. *Pseudomonas syringae* pv. *pisi* is largely restricted to field pea. *Pseudomonas syringae* pv. *syringae* however has a wide host range including clover, common bean, faba beans, lentil, chickpea and vetch. [13]

Frost damage followed by wind and frequent rain encourages the development and spread of the disease. This highly infectious disease can be easily spread by movement of machinery, people and animals through the crop. [14]

12 P Matthews, A Nikandrow (2003) Powdery mildew in field peas: A growers guide to management. Pulse Point 14th edition, Grains Research & Development Corporation and NSW Agriculture, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/157349/pulse-point-14.pdf

13 W Hawthorne, J Davidson, L McMurray, E Armstrong, B Macleod, H Richardson (2012) Field pea Disease Management Strategy. Australian Pulse Bulletin, Pulse Australia Ltd, http://v1.pulseaus.com.au/pdf/Field%20pea%20Disease%20Management%20Strategy%20Southern%20&%20Western%20Region.pdf

14 P Matthews, 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/agriculture/broadacre-crops/guides/winter-crop-variety-sowing-guide

9.2.1 Symptoms

Plants can be affected at all growth stages but the disease first becomes evident as small, dark-green, water-soaked lesions on leaves and stipules. The lesions may enlarge and coalesce, but are always delimited by the veins and develop a characteristic fan shape (Figure 3). The lesions on the leaflets turn yellowish and later brown and papery, lesions on the pods are sunken and turn olive-brown.

Figure 3: *(left): Water soaked lesion, caused by bacterial blight, spreading into the leaf from the base. (right): Leaf lesions caused by bacterial blight.*

Photos: DAF

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 *Pseudomonas syringae* pv. *pisi* or *Pseudomonas syringae* pv. *syringae* are indistinguishable from each other on the pea plant. [15]

9.2.2 Management

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.

- Eliminate sources most likely for blight infection (seed, pea stubble, weeds).
- Select paddocks in less frost prone areas, and avoid the poorly drained heavier soil types. Heavy cereal stubbles can increase disease spread, and risk of crop damage from frost.
- 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 the plant tissue. Minimise the use of post emergence sprays as the severity of bacterial blight can increase if plant tissue is damaged. Avoid paddocks where sulfonylurea residues may be present and paddocks which are more prone to frost. [16]
- Variety choice is very important in high incidence areas and high-risk situations. Resistance ratings have been established for the bacterial blight strain (*P. syringae* pv. *syringae*), the more common strain.
- Delay sowing as greater exposure to frost events followed by prolonged wet conditions could increase the incidence and spread of the disease. [17]

15 H Richardson, G Hollaway (2007) Bacterial blight of field peas. Department of Environment and Primary Industries, Victoria, http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bacterial-blight-of-field-peas

16 H Richardson, G Hollaway (2007) Bacterial blight of field peas. Department of Environment and Primary Industries, Victoria, http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bacterial-blight-of-field-peas

17 T Bray (2010) Minimising bacterial blight in field peas. Southern Pulse Bulletin, Pulse Australia Ltd, http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Fieldpea-bacterial-blight.pdf

9.2.3 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 peas 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 two years.

9.2.4 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 that are registered for use in field peas against bacterial blight, but evidence for their effectiveness in Australian field pea crops is limited and inconclusive.

Field peas with improved resistance to two bacterial blight strains have been identified and new knowledge gained about the diversity and virulence of bacterial blight strains. A new seedling screening method for the disease has been readily adopted by PBA and will help speed the development of field pea varieties with resistance to bacterial blight. [18]

MORE INFORMATION

Virus resistance of Australian pea (*Pisum sativum*) varieties

Ground Cover Radio 114: Pilot online tool extends itself

Australian Pulse Bulletin: Managing viruses in pulses

9.3 Viruses

Field pea crops can be affected by a number of virus diseases. Some are seed-borne, but all require aphids to move between plants. Most require a 'green bridge' to survive between seasons.

PSbMV, AMV, BYMV, CMV and CYVV are non-persistent in aphids. The aphids soon lose infection after feeding on infected plants, spreading virus only over short distances.

BLRV, BWYV, SbDV, and SCSV (yellowing or luteoviruses) are persistent in aphids. The aphid remains infected for life and can spread the virus over a long time and distance. Spread of the virus can be controlled through aphicide applications.

Symptoms

Virus symptoms can include yellowing, leaf mottles or mosaics, stunting, and tip distortion. Symptoms can easily be mistaken for herbicide damage, nutrient deficiencies, salinity effects, or other abiotic factors. It is difficult to diagnose a virus just on field symptoms and growers are advised to seek expert advice. [19]

Virus management

Control strategies for virus diseases can only be preventative, as infected plants cannot be cured. Virus management aims at prevention through integrated management practice that involves controlling the virus source, aphid populations, and virus transmission into pulse crops:

- Rotate legume crops with cereals to reduce virus and vector sources and where possible avoid close proximity to perennial pastures (e.g. lucerne) or other crops that host viruses and aphid vectors.
- Eliminate summer weeds and self-sown pulses 'green bridge' that are a host for viruses and a refuge for aphids.
- Aphid activity is influenced by seasonal conditions and will require early monitoring in nearby crops and pastures and possible use an aphicide or cultural controls to reduce numbers.

18 T Slater (2015) Diseases pursued in multi-pronged breeding program. Grains Research & Development Corporation, http://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-116-Foliar-fungal-diseases-of-pulses-and-oilseeds/Diseases-pursued-in-multipronged-breeding-program

19 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation.

- Sow directly into cereal stubbles (preferably standing), and encourage rapid canopy cover through early planting, high planting density as bare soil is more attractive to some aphid species.
- Purchase virus-tested seed or have farmer seed virus tested as PSbMV, CMV, BYMV, and AMV depend largely on seed transmissions for survival.
- Imidacloprid (Gaucho® 350SD) is now registered and when applied as seed treatment will help protect faba beans, field pea, and lentil seedlings from early season aphid attack and reduce virus spread.
- Sow varieties with some resistance. Recent studies indicate that both Maki and Yarrum have a high level of resistance to PSbMV and useful levels of resistance to BLRV.

Several virus species cause disease in field peas.

9.3.1 Pea seed-borne mosaic virus (PSbMV)

This is the only virus of importance in Australia that survives between seasons in infected seed. The virus is found wherever susceptible pea varieties are grown and infected seed has been sown. Crops sown with infected seed often reach 100% infection but, as leaf symptoms are difficult to see, the effect on crop growth and yield is often missed. Uneven canopy is an important indicator of widespread crop infection with PSbMV. [20]

Figure 4: *Pea seed-borne mosaic virus. The most widespread pea virus in all pea growing regions. Symptoms are mild (note curling of the leaf edges), but causes significant yield losses after early infection. Seed-infested seed has poor vigour. Varieties with complete resistance are available.*

Photo: Joop van Leur, NSW DPI

Symptoms

Affected plants are generally stunted and mature later than uninfected plants (Figure 4). Margins of leaves are rolled downwards, there is mild chlorosis, mosaic, veins are clear. Terminal leaves are often reduced in size and tendrils excessively curled. Infection in later stages results in top leaves turning yellow. [21]

20 B Coutts (2015) Pea seed-borne mosaic virus in field peas. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/pea-seed-borne-mosaic-virus-field-peas

21 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation.

PSbMV reduces yields and can, depending on the growing environment of the plant, cause tennis-ball markings on the seed (Figure 5).

PSbMV is spread by many aphid species including the green peach (*Myzus persicae*), cowpea (*Aphis craccivora*), and pea (*Acyrthosiphon pisum*) aphids. PSbMV is transmitted non-persistently. This means an aphid picks up the virus within 1–2 seconds while probing an infected plant and then transmits the virus within 1–2 seconds to healthy plants. However after the aphid has probed 1–2 healthy plants it loses the virus from its system and will not transmit it again until it picks up another virus from an infected plant. [22]

Figure 5: *The 'tennis-ball' marking on field pea seed caused by PSbMV.*

Photo: SARDI

9.3.2 Bean leafroll virus (BLRV)

BLRV (Figure 6) is the most common virus of field peas in the north. This virus infection results in yellowing and stiffening of the leaves. BLRV can cause severe yield losses and, with early infection, stunting and plant death. The virus survives between seasons on pasture legumes and lucerne. Higher levels of infection are generally found in the higher rainfall cropping zones or in the vicinity of irrigated lucerne paddocks. [23]

The natural host range of BLRV is limited to the *Fabaceae* family. BLRV is transmitted by several aphid species in a persistent manner; it is not transmitted mechanically and not through seed. Pea aphid (*Acyrthosiphon pisum*) is the principal vector of BLRV. [24]

22 B Coutts (2015) Pea seed-borne mosaic virus in field peas. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/pea-seed-borne-mosaic-virus-field-peas

23 P Matthews, 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/agriculture/broadacre-crops/guides/winter-crop-variety-sowing-guide

24 M Aftab, A Freeman (2005) Temperate Pulse Viruses: Bean Leafroll Virus (BLRV). Department of Primary Industries, Victoria http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/temperate-pulse-viruses-bean-leafroll-virus-blrv

Figure 6: *Bean leafroll virus, the most important and devastating virus on field pea in the north. Center plot is OZP805, now PBA Wharton⦶, which has good BLRV resistance. Right plot is the highly susceptible variety, Kaspa⦶, left plot the moderately resistant variety Yarrum.*

Photo: Joop van Leur, NSW DPI

Symptoms

Virus-infected legume plants show general yellowing, stunting, yellowing of young leaf tips, and sometimes downward leaf rolling.

MORE INFORMATION

Ground Cover Radio 121: The high risk of back to back chickpeas

9.4 Black spot or Ascochyta blight (*Mycosphaerella pinodes*, *Phoma medicaginis* var. *pinodella* and *Phoma koolunga*)

Black spot is the number one disease of field peas in southern farming areas with losses up to 40% recorded. It is not as prevalent in the north. It is sometimes referred to as Aschochyta blight but is not related to the disease of the same name in chickpeas, *Ascochyta rabiei*. Ascochyta blight is a disease complex caused by the pathogens *Mycosphaerella pinodes*, *Phoma medicaginis* var. *pinodella*, *Phoma koolunga* and *Ascochyta pisi*. [25] Summer and autumn rainfall events drive spore development and release of the black spot fungus. As a result, the timing of spore release can vary widely even at the same site.

Severity of black spot depends on the level of inoculum (from stubble, soil and seed) and the duration of prolonged wet, cool conditions particularly before flowering. Rainfall or heavy dews on pea stubble releases spore 'showers' provided the temperature is not too high (average daily temperatures over 15°C). These spore 'showers' generally last 3–4 weeks after the opening rains, but in WA may continue well into the growing season, and infect emerged plants. [26]

The relationship between summer/autumn rain and spore release underpins the 'Black spot Manager' model developed by the Department of Agriculture and Food, WA, and now used widely across southern Australia to guide the field pea sowing date. The Field Pea Black spot Management Guide is a weekly location- and season-

25 T Bretag (2007) Ascochyta blight of field peas. Department of Environment and Primary Industries, Victoria, http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ascochyta-blight-of-field-peas

26 W Hawthorne, J Davidson, L McMurray, E Armstrong, B Macleod, H Richardson (2012) Field pea disease management strategy. Australian Pulse Bulletin, Pulse Australia Ltd, http://www.pulseaus.com.au/storage/app/media/crops/2012_APB-Fieldpea-disease-management-South-West.pdf

specific forecast. It accounts for varietal resistance and chemical options, agronomic yield potentials, agronomic constraints (frost and terminal drought), risks of spores showers, disease severity, disease related yield loss, and it weighs agronomic yield loss and disease yield loss. Then it suggests a window of sowing dates. [27]

The link to this site is https://www.agric.wa.gov.au/field-peas/field-pea-blackspot-management-guide-victoria-updated-15-april-2016

Black spot in field pea can be managed by manipulating sowing date to avoid the autumn/winter spore release and by applying foliar fungicides before the spring spore release, provided crop yields are high enough (>2 t/ha) to justify this economically. [28]

Early sown field pea crops are more prone to developing black spot if conditions are wet in winter or developing bacterial blight if conditions are dry and frosty.

Early epidemics of the disease can result in significant yield loss, but most crops in southern NSW develop the disease later in the season and suffer very little, if any, yield loss. [29]

Bacterial blight was not widespread in 2015, with few reports of the disease in southern NSW. Reports of bacterial blight outbreaks were received from central and northern NSW where frost events in July and August caused damage to more advanced field pea crops compared to the southern districts. Slower developing crops and fewer frost events in southern NSW did not cause crop injury, and hence, outbreaks of the disease. [30]

9.4.1 Symptoms

- Symptoms include purplish-black discoloration 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.
- Infected seeds may be discoloured and appear purplish-brown. Discoloration 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. [31]

9.4.2 Control measures

The fungi that cause black spot may either be seed-borne, soil-borne, or survive in pea trash; as such, effective black spot disease management options are varied and include:

- Use of a fungicidal seed dressing: to reduce seed transmission of the disease and provide early seedling protection (products such as P-Pickle-T).
- Crop rotation: a break of at least four years to ensure adequate time between field pea crops for soil-borne spore populations to decease.
- Paddock selection: do not sow this year's field pea crop adjacent to last year's field pea stubble which will release air-borne spores onto new season's crops. Leave a distance of at least 500m between last year's stubble and this year's field pea crop.

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27 K Salam (2015) Field pea black spot management guide for South Australia—updated 18 June 2015. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/field-pea-blackspot-management-guide-south-australia-updated-11-april-2016

28 Ground Cover Supplement Issue 16: Foliar fungal diseases of pulses and oilseeds (May-June 2015). Grains Research & Development Corporation, http://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-116-Foliar-fungal-diseases-of-pulses-and-oilseeds#sthash.Jfql5tic.dpuf

29 K Lindbeck (2016) Pulse diseases 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

30 K Lindbeck (2016) Pulse diseases 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

31 T Bretag (2007) Ascochyta Blight of Field Peas. Department of Environment and Primary Industries, Victoria, http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ascochyta-blight-of-field-peas

- Time of sowing: do not be tempted to sow crops too early outside the recommended sowing window for your district. Early sowing will expose crops to early season spore showers and allow crops to develop a dense canopy by mid–late winter, which further favours disease development. Early sown crops are also more prone to bacterial blight by increasing exposure to frost events. [32]
- Soil testing: Predicta B is a management tool to reduce yield losses associated with disease. It is a DNA-based test which determines which soil borne pathogens pose a significant risk before crops are sown. The test is relevant to field peas measure soil inoculum levels of rhizoctonia bare patch, stem nematode and black spot. The black spot test is best used in conjunction with the 'Black spot Manager' model.

9.5 Downy mildew (*Perenospora viciae*)

This disease can develop quickly when conditions are cool (5–15°C) and wet for 4–5 days, often when field pea crops are emerging and in the early vegetative stage. Heavy dews will promote the production of spores and rain splash is the main means of disease dispersal within a crop. The disease is caused by the fungus *Peronospora viciae*, which can survive in soil, on old field pea trash, and also on seed.

9.5.1 Symptoms

The most notable symptom of downy mildew is the appearance of stunted, yellowish/pale green seedlings with pale yellow-green blotches on the upper surface of leaves, with fluffy mouse-grey spore masses in equivalent positions on the leaf underside. The blotches turn greenish-brown and shrivel and the leaf dies.

The fungus usually affects the lowest leaves and then progresses up the plant, if conditions permit, infecting flowers and pods. Infected pods are deformed and covered with yellow to brownish areas and superficial blistering. [33]

Heavy infection can stunt plants early and kill seedlings if favourable conditions continue. Warm, dry weather is unfavourable for disease development. [34]

Downy mildew makes plants more vulnerable to herbicide damage by affecting the protective wax coating on leaves.

The downy mildew fungus survives in the soil for 10–15 years, and also on plant residues. Infection from these sources can lead to systemic and leaf infections in volunteer pea seedlings. These seedlings act as a source of infection from which the disease spreads by wind to adjacent plants and crops.

Variety Kaspa⫽ is resistant to the common Parafield strain of the fungus, but susceptible to the new Kaspa⫽ strain. [35]

9.5.2 Control measures

- Sow disease free seed
- Treat seed with fungicide, e.g. Mefenoxam (Apron XL)
- Use a resistant variety

32 K Lindbeck, S Marcroft, A Van de Wouw, V Elliott, B Howlett (2014) Canola and pulse disease management; maintaining the vigilance. Grains Research & Development Corporation, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Canola-and-pulse-disease-management-maintaining-the-vigilance

33 Diagnosing downy mildew in field peas (2015). Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-downy-mildew-field-peas

34 P Matthews, 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/agriculture/broadacre-crops/guides/winter-crop-variety-sowing-guide

35 Diagnosing downy mildew in field peas (2015). Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-downy-mildew-field-peas

9.6 Sclerotinia (*Sclerotinia sclerotiorum*)

This is a minor disease in field peas which is found in wetter seasons and often in association with botrytis grey mould. It appears mainly on older plants where the biomass is high. The disease is more common in canola and in chickpeas with the same strain attacking a wide host range, including many weeds and most broadleaf crop.

9.6.1 Symptoms

Water-soaked patches on stems and leaves (Figures 7–8).

9.6.2 Control measures

- Only sow field peas once every four years in a paddock.
- Do not sow field peas in paddocks adjacent to canola stubble.
- Eliminate infected stubbles.
- Control green bridges.

Figure 7: *Stem dissection showing 'sclerites'.*

Photo DAFWA

Figure 8: *Chickpeas showing white fungal growth on the lower stems.*

Photo DAFWA.

9.7 Grey mould (*Botrytis cinerea*)

The *Botrytis* grey mould (BGM) pathogen (*Botrytis cinerea*) can survive and spread in infected seed and stubble, and some strains produce dark, hard sclerotia, which also aid survival and spread. However, the BGM pathogen has a very wide host range, and is able to colonise dead and dying tissue of virtually any plant. Huge numbers of spores are produced on BGM lesions and are spread on air currents. BGM can also cycle in 5–7 days. White-seeded varieties are more susceptible to attack.

9.7.1 Symptoms

The disease develops firstly on dead tissue (particularly old flowers) and then spreads to other plant parts under moist conditions.

Leaves, flowers, and stems become covered in fluffy blue-grey mould and die. Stem, leaf and pod rot occur under humid conditions.

Seed infection can affect crop establishment.

9.7.2 Control measures

- Sow disease free seed.
- Wider row spacings can limit canopy density.
- Only sow field peas once every four years in a paddock.
- Do not sow field peas in paddocks adjacent to pulse stubbles.
- Control green bridges. [36]

36 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation.

9.8 Seedling diseases

Root rots caused by *Fusarium* spp, *Pythium* spp and *Phytophthora* spp are major problems in some regions of the eastern states, in particular in the south. Areas or scattered seedlings that fail to emerge or wilt and die, or survive but lack vigour.

Symptoms are worse where plants are stressed, such as cold wet areas of a paddock.

9.8.1 Symptoms

Sudden death or yellowing and death of older leaves that progresses up the plant

Poorly developed and rotting root systems. Symptoms include root-browning, pruning, soft watery lesions.

Roots on Fusarium wilt-affected plants appear normal, but the interior of the tap root and often the stem is light orange to brick red. [37]

9.8.2 Control measures

- Grow good, vigorous seed which can grow away from the disease.
- Have an adequate fertiliser regime to ensure the plant optimises its early growth and can grow away from the disease.
- Apply seed dressings such as Apron (Metalaxyl) or P Pickle T (Thiram + Thiabedazole).

9.9 Further information

As a result of the extreme weather conditions experienced in much of the pulse growing areas in spring 2016, in particular in NSW, timely fungicide application is now more important than ever.

Pulse Australia has issued revised fungicide guides for chickpea, faba bean and lentil crops. These guides provide a consolidated list of chemicals and approved usage patterns, for both on-label and permit, http://www.pulseaus.com.au/blog/post/2016-fungicide-guides.

Growers are reminded that only fungicides registered for specific crops are permitted, (including those permitted under the listed Emergency Use Permits), and that in the lead up to harvest, withholding periods must be observed.

37 Diagnosing seedling rot in field peas (2015). Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-seedling-root-rot-field-peas

Plant growth regulators and canopy management

Not applicable for this crop.

MORE INFORMATION

Ground Cover Issue 124: Paraquat preferred for crop-topping pulses

Crop desiccation/spray out

11.1 Desiccation and 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. Windrowing may be considered as an alternative to desiccation. The timing of windrowing is similar to desiccation. [1]

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 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. [2]

Withholding periods must be observed when desiccation sprays are undertaken.

11.1.1 Purpose

Desiccation and crop-topping are used to achieve different objectives.

Desiccation

- prepares the pulse crop for harvesting by removing moisture from plants and late maturing areas of the paddock
- is an aid to a timely harvest, particularly where uneven ripening occurs across a paddock, and is now a common practice in lentil and chickpea
- enables a timely harvest to avoid weather damage. Application timing is based on the crop when the grain is 75–90% mature, to avoid reducing the quality of the harvested grain. Windrowing can be considered similar to desiccation in timing and benefits to harvest.

Crop-topping

- aims to stop the seed set in surviving weeds without substantially affecting crop yield and grain quality
- is timed for the weed growth stage to control weed seed set from survivors of normal in-crop weed control
- cannot be used in all pulses
- is effective in early maturing species like field pea and common vetch and early maturing varieties of narrow leafed lupins, e.g. Mandelup. It is also effective in drying off late maturing weeds to reduce high moisture or contamination of harvested grain.

1 Pulse Australia (2015) Desiccation and croptopping in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping#controlling-annual-ryegrass

2 S Moore, G Cumming, 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

- is part of an integrated weed management (IWM) strategy and should not be used as a sole strategy. [3]

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.
- Herbicide rates for desiccation are higher than that required for crop-topping.
- Crop-topping will advance the harvest timing in some pulse crops.
- Neither desiccation nor crop-topping can be used effectively in all pulses.
- Both will cause reduced grain quality and yield if applied at the wrong maturity stage of the crop. [4]

11.1.2 Timing

Field pea is ideally suited to desiccation and crop-topping (Figure 1). They mature early, usually in advance of weed survivors, with a very low risk of damage to grain quality from the herbicide application. With correct timing, desiccation and crop-topping can improve profitability in pulses.

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. Timing is aimed at the soft dough stage of the target grass weed species, typically annual ryegrass, to stop seed set. If radish is the target, the herbicide should be applied at the pre-embryo stage. In most crops, targeting radish exposes the crop to a heightened risk of crop damage. [5]

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 close crop monitoring as maturity approaches.

- 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.
- 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. [6]

3 Pulse Australia (2015) Desiccation and croptopping in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping - controlling-annual-ryegrass

4 Pulse Australia (2015) Desiccation and croptopping in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping - controlling-annual-ryegrass

5 Pulse Australia (2015) Desiccation and croptopping in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping - controlling-annual-ryegrass

6 S Moore, G Cumming, 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

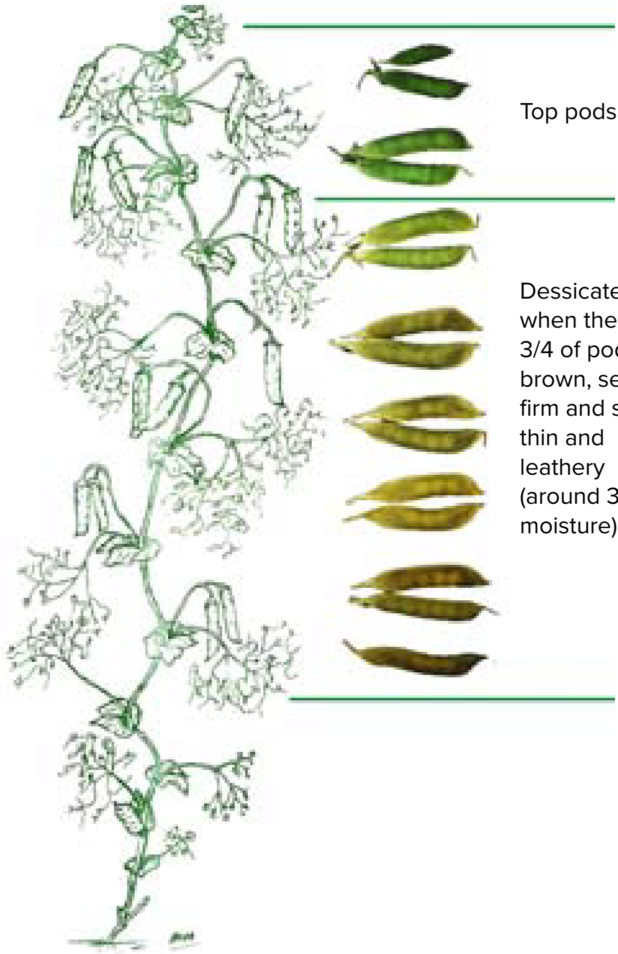


Figure 1: *Desiccation and harvest of field peas.*

Source: NSW DPI

11.1.3 Seed crops

Desiccation and crop-topping can affect seed viability if applied incorrectly. To avoid damaging seed viability, it is advisable not to desiccate or crop-top a pulse seed crop. *Field peas destined for the sprouting market, should not be desiccated or crop-topped.* [7]

11.1.4 Treating crops

Pulse species differ in their time to maturity, making some unsuitable for crop-topping. Crop-topping is conducted before the target weed species mature, later maturing pulse species will be adversely affected.

Early maturing species such as field pea, lupin and vetch are well suited to crop-topping. They will be close to maturity at the time of herbicide application, minimising the risk to yield and grain quality.

Chickpea and broad bean are late maturing species. Crop-topping these will usually lead to unacceptable yield and quality problems as the grain will be too immature at the correct weed maturity stage.

7 Pulse Australia (2015) Desiccation and croptopping in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping - controlling-annual-ryegrass

With care, yield and quality losses can be minimised with crop-topping, while desiccating at the correct maturity stage of the pulse will minimise any risk. [8]

Details on registered herbicides for use when crop-topping or desiccating pulses can be found at http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping

11.1.5 Controlling annual ryegrass

Getting the best result from crop-topping for the control of ryegrass is a race between the maturity of the crop to avoid yield and quality losses, and the latest possible time before the ryegrass seeds mature to ensure that all have emerged. A typical result is about 80% control of ryegrass seedset with little damage to the pulse. Consider all aspects of integrated weed management, such as seed capture at harvest, to maximise the effectiveness of crop-topping.

The correct timing for applying herbicide is when the last ryegrass seed heads have emerged from the plant and the majority is at or just past flowering. The latest time to apply paraquat is at the soft dough stage. Glyphosate must be applied after the crop has physiologically matured or significant yield losses may occur. For this reason, paraquat is the preferred herbicide for most situations. [9] Choosing paraquat rather than glyphosate for crop-topping pulse crops will also minimise resistance development. [10]

11.1.6 Products

Both glyphosate 540 g/L (e.g. Roundup PowerMAX®) and diquat 200 g/L (e.g. Reglone®) are registered for desiccation of field peas. 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. [11]

8 Pulse Australia (2015) Desiccation and croptopping in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping - controlling-annual-ryegrass

9 Pulse Australia (2015) Desiccation and croptopping in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping - controlling-annual-ryegrass

10 GRDC (2016) Paraquat preferred for crop-topping pulses. Ground Cover Issue 124, September-October 2016, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-124-SeptemberOctober-2016/Paraquat-preferred-for-croptopping-pulses

11 S Moore, G Cumming, 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

Harvest

The most important part about growing field peas is an on-time and effective harvest. When peas are ready to go, they need to be stripped, at the expense of other cereal or oilseed crops, which have inherently better standability in the paddock. They may be 14% moisture one day and then under 10% and very brittle the next day. Harvesting at the higher moisture levels will result in fewer split grains in the sample and less losses from shatter at the knife on the header. Low splits are important if human consumption is the target market. Higher moisture peas will cope with handling (augering) better over the coming summer into autumn months and will make for a better planting seed in the following season. They can be delivered at the higher moisture level of 14%, which can be an advantage in itself that the cereal crops mat have too high a moisture level, especially at night time or after rainfall, but field peas can still be stripped and delivered. Harvesting at night or early in the morning is advantageous, when humidity is higher, temperatures are cooler and a dew may aid the process and lead to less split grain.

Delayed harvest leads to:

- seed quality loss
- harvest clashes with other crops
- greater soil contamination
- increased pod shattering
- emergence of pea weevil in the field
- problems with late weed growth
- more severe crop lodging
- increased crop vulnerability to damage by rain and hail.

Planting crops into standing stubble can considerably reduce soil contamination of the seed.

Seed to be kept for planting should be harvested first when moisture content is higher and damage caused by the header is least. Grain damage can be minimised by adjusting header settings, in particular low drum speeds should be used. It is recommended that harvester speeds be reduced from normal cereal harvest speeds. Attention to the correct plant population and row spacing at planting will greatly help to minimise the potential for crop lodging and help the crop to feed into the header front (Figure 1). [1]

Western Australian research has found field peas can be safely harvested at 16% moisture and the grain will naturally dry out in an open stack or shed floor without any need for specialist aeration equipment prior to delivery.

Varieties with the sugar-pod trait, however, may be harder to thresh and chop than other varieties in cool weather. [2]

1 S Moore, G Cumming, L Jenkins, J Gentry (2010). Northern region field pea management guide. Pulse Australia.

2 Machinery used for swathing semi-leafless field peas (2014). Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/machinery-used-swathing-semi-leafless-field-peas

Figure 1: *Maki field pea harvest, Nyngan 2014.*

Photo: Penny Heuston, NSW DPI

12.1 Header setup

12.1.1 Conventional headers

Conventional headers with table auger fronts and lifters work well in semi-leafless crops yielding 1.0–1.3 t/ha. The make of the crop lifter is a personal choice and may depend on what is readily available or type of header in question. In general, heavier lifters tend to disturb more soil than lighter lifters, which may contribute to soil in the grain sample. [3]

Grain damage can be minimised by adjusting header settings, in particular low drum speeds should be used.

Table 1: *Suggested harvester settings for field peas (*Rotary machines only).*

Reel speed	Medium
Spiral clearance	Standard
Thresher speed	400–600 rpm
Concave clearance	10–30 mm
Fan speed	High
Top sieve	32 mm
Botton sieve	16 mm
Rotor speed*	700–900 rpm

3 I Pritchard (2003) Modifying harvesters for semi-leafless field peas crops. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/modifying-harvesters-semi-leafless-field-peas-crops

12.1.2 Conventional headers with a plucker front

Conventional headers with table auger fronts either with barrel or cylinder-type pluckers (Smale) or belt-type pluckers (Knuckey) are able to harvest semi-leafless field peas; however, blockages and losses can be high when growers attempt to harvest at speeds greater than 6 km/h. Pluckers perform best as the temperature increases during the day because the peas are more easily plucked from the ground.

Header set-up and modifications appear to determine harvest speed. For example:

- Sund plucker without reel: 4–5 km/h
- Smale-type plucker, lupin breakers fitted to table auger: 6 km/h (the crop could not be harvested without lupin breakers)
- Smale-type plucker with a 380 mm (15 inch) diameter raised cross auger above table auger: 9–11 km/hr [4]

12.1.3 Draper fronts

Headers with draper–belt fronts appear to have the greatest difficulty in successfully harvesting semi–leafless peas due to the large volume-to-weight ratio resulting in the harvested material sitting on top of the belts and not feeding across into the broad elevator.

Draper fronts do a very average job as the peas tend to be 'fluffy', ror billow over the top of the comb resulting to what can be substantial losses in the paddock

This is especially so with fronts which rely on gravity to feed material into the broad elevator (the feeder house auger set well back and low). Harvested material needs to be aggressively pulled into the broad elevator, for example, the feeder house auger set well forward, fitting retractable fingers on the broad elevator auger which is extended, fit the auger with lupin breakers, fit paddles on the cross auger, etc.

As a general comment any modification which creates downward pressure on the harvested material or uses force to move the harvested material will help material feed into the broad elevator. [5]

12.1.4 Cross-augers

Harvesting is slow and expensive, with header speed commonly one-third that of when cereals are being stripped. In the central-west of NSW, seasoned field pea growers have purchased cross-augers to aid in field pea harvest. Not only has this header attachment nearly doubled the harvest speed from 3 km/hr to 5 km/hr, but has enabled more of the crop to be dragged in the front of the header than billowing around the comb being lost.

4 Machinery used for swathing semi-leafless field peas (2014). Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/machinery-used-swathing-semi-leafless-field-peas

5 S Moore, G Cumming, L Jenkins, J Gentry (2010). Northern region field pea management guide. Pulse Australia.

See this Youtube video showing a cross-auger in action:

12.2 Windrowing

The biggest challenge for windrowing crops across all regions is losing the swath to wind. This can especially be the case in lower yielding crops. The problem can be further accentuated if the paddock was not sown into a standing cereal stubble, if the crop was thin, and if row spacings are wide.

Growers in the Esperance region of WA have undertaken this practice with the following observations:

- Swathing semi-leafless field peas presents similar problems harvesting with a draper front harvester but it is not quite as bad due to slightly heavier plants at swathing.
- Grower remedies subsequently were also the same—that is, cross-top augers, cross-top augers with paddles and one suggestion yet to be tried; a top belt near the exit hole of the draper.
- All field pea swaths must be rolled with a cotton reel or canola roller. Field pea swaths can be very bulky so adjust swath width and weight of roller to produce a stable swath.
- Semi-leafless field peas make an excellent swath—much better than conventional trailing varieties. There is less risk of blowing. [6]

12.3 Hostile harvesting

Damage to pea seed during harvest or by grain-handling equipment both on the farm and after it leaves can be greatly reduced if seed moisture content is 14% rather than 8%. [7]

Hostile harvesting in field peas occurs when:

- The crop was too dry: that is, under the recommended moisture level of 14%, resulting in too high a split percentage in a sample, with a maximum of only 3% defectives allowed within the Field pea Grade one receival specifications
- Harvesting in the heat of the day: will lead to an increased percentage of splits and losses at the knife with peas being brittle and smashing instead of feeding into the header

6 I Pritchard (2003) Modifying harvesters for semi-leafless field peas crops. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/field-peas/modifying-harvesters-semi-leafless-field-peas-crops

7 Desiccate field peas for best harvest and seed (2010). NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/archive/news-releases/agriculture/2010/desiccate-field-peas

- Travelling too fast at harvest and hence losing too much crop with it either going over the reel or being knocked by the knife, shattering and not entering the header
- Harvesting too high, with the lowest pods not being picked up by the header. This can be an issue in paddocks where sticks, stones or clods are a problem or where gilgais or other uneven surfaces are a problem
- Too high a drum speed, leading to splits.

12.4 Wet harvest issues and management

Field pea handle a wet harvest better than cereals and do not germinate or shoot as easily as cereal or oilseed crops. Farmers will often wait for a small shower before commencing harvest if the peas have dried down too quickly prior to harvest and moisture levels have dropped to a point where split grain would be an issue. The other advantage after rainfall is that field peas can be stripped at up to 14% moisture compared with pulse cousins at 12%, so harvest can often start in the field peas while the cereal crops are still drying down.

Problems with a wet harvest would include:

- Weathered pods becoming more difficult to thresh, resulting in grain loss in unthreshed pods discarded out of the back of the header or in the sample, cracked grain and a slower harvest
- Increased likelihood of crop lodging
- Grain quality deterioration. This is an issue if the peas are destined for the human consumption market. Excell, a variety of blue/green peas, has issues with the seed being bleached through the pod and subsequent quality downgrading resulting
- Machines getting bogged and truck access restricted.

If harvest is delayed a long time and weeds emerge, consider desiccation to dry the paddock down, prevent contamination in the sample and commence the fallow for the following year.

12.5 Dry harvest issues and management

Dry harvests can be a real issue with field peas. If the peas are stripped at a low moisture value (i.e. <10%), splits will be greatly increased and the product potentially downgraded, especially if it is destined for the human consumption market.

To avoid this problem:

- Desiccate crops for a more uniform crop (i.e. so you are not waiting for small areas of green to come in at the expense of the whole crop).
- Aim to harvest peas before the cereals, which would have a greater standability in dry times than pulse crops.
- Harvest at night time when conditions are cooler and humidity higher.
- Minimise handling post the header to reduce other potentially splitting operations. Try to avoid the use of screw augers—belt augers will result in less split grain.

12.6 Fire prevention

On average, fire destroys about 12 harvesters a year in Australia, but studies show the risk can be greatly reduced if growers or contractors adopt a few basic precautions. [8]

For more information on how to avoid header fires see http://www.grdc.com.au/Media-Centre/Media-News/South/2014/11/Take-simple-steps-to-reduce-harvester-fire-risk

8 N Baxter (2012) A few steps to preventing header fires. Grains Research & Development Corporation, https://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-101/A-few-steps-to-preventing-header-fires

12.7 Receival standards

Table 2: *Field pea trading standards 2014–2015.* [9]

Test Code	Binned Grade	PEAF
Physical Characteristics – The peas shall be hard and well filled.		
VARP	**Purity minimum (% by weight)** Includes whole field peas, defective field peas and seed coats	97
MOGR	**Moisture max (%)**	14
Defective Grains – maximum % by weight per 200 g sample.		
DEFG	**Defective max (% by weight)** Field Peas not of the specified variety. Field Peas that are bin burnt, broken, caked, chipped, diseased, frost damaged, heat damaged, insect damaged, sappy, shrivelled, split, sprouted, weather damaged, wrinkled. Includes pods that contain Field Peas, whether broken or unbroken, loose seed coat and all Field Pea seed material falling through the 3.75m slotted screen.	3
PCOL	**OF WHICH** **Poor Colour max (% by weight)** Seed coat or kernel is distinctly blemished and/or off colour from the characteristic colour of the predominating class	1
MLD	**Affected by mould (field or storage) maximum (per 200 g)**	1
Foreign Seeds – Tolerances apply to whole seeds or their equivalent in pieces and refer to the maximum total of all seeds named in each type per 200 g. Except TYPE(1) in which the maximum applies on an individual seed basis per 200 g.		
WS1	**TYPE(1):** Colocynth, Doublegees, Spiny Emex or Three Cornered Jack, Jute, Long Head Poppy, Mexican Poppy, New Zealand Spinach, Parthenium Weed**, Poppy (Field), Poppy (Horned), Wild Poppy	4*
WS2	**TYPE(2):** Castor Oil Plant, Coriander, Crow Garlic or Wild Garlic, Darling Pea, Opium Poppy, Ragweed, Rattlepods, Starburr, St. Johns Wort	NIL
WS3A	**TYPE(3a):** Bathurst Burr, Bulls Head or Caltrop or Cats Head, Cape Tulip, Cottonseed, Dodder, Noogoora Burr, Thornapple	1
WS3B	**TYPE(3b):** Vetch (Tare), Vetch (Commercial)	2
WS3C	**TYPE(3c):** Heliotrope (Blue)***, Heliotrope (Common)*** Note included in this Type are tolerances for seeds or pods	1pods/ 4 seeds
WS4	**TYPE(4):** Bindweed (Field), Cutleaf Mignonette, Darnel (Drake Seed), Hexham Scent or Melilot (King Island), Hoary Cress, Mintweed, Nightshades, Paddy Melon, Skeleton Weed, Variegated Thistle	10
WS5	**TYPE(5):** Knapweed (Creeping) or Knapweed (Russian), Sesbania Pea, Patterson's Curse or Salvation Jane	20
WS6	**TYPE(6):** Colombus Grass, Johnson Grass, Saffron Thistle, Clover (Pods), Lucerne (Pods), Marshmallow (Pods), Medic (Pods), Muskweed (Pods), Wild Radish (Pods), Trefoil (Pods)	5
WS7A	**TYPE(7a):** - Chickpeas, Corn, Cowpea, Faba Beans, Lentils, Lupin, Maize, Soybean	10
WS7B	**TYPE(7b):** Barley (2 row), Barley (6 row), Bindweed (Australian), Bindweed (Black), Durum, Oats (Black or Wild), Oats (Sand), Oats (Common), Rice, Rye (Cereal), Sorghum (Grain), Triticale, Turnip Weed, Wheat	10
WS7C	**TYPE(7c):** Safflower, Sunflower includes Clover Burr	1
WS8	**TYPE(8):** Bellvine	100
SFS	Small Foreign Seeds max (% by weight)	0.6%

9 Graincorp/Pulse Australia Field Peas Standards 2014–2015: https://www.graintrade.org.au/sites/default/files/file/Commodity%20Standards/Pulse%20Standards%20201415%20Final.pdf

Test Code	Binned Grade	PEAF
*Individual seed basis **Parthenium Weed is a **NIL** tolerance in NSW/VIC/SA ***Heliotrope pods must be opened and the seeds counted ****Hexham Scent is only acceptable if no tainting odour is present		
Other Contaminants – Maximum per 200 g sample unless otherwise stated.		
FMAT	**Foreign Material max (% by weight)** Includes unmillable material and all vegetable matter other than field pea seed material	3
UNML	**OF WHICH** **Unmillable Material max (% by weight)** Includes soil, stones, metals and non-vegetable matter	0.5
SOIL	**OF WHICH** **Soil max (% by weight)**	0.3
SNAL	**Snails Live or Dead max (by count)**	1
GWBL	**Field Insects Live or Dead max (by count)** Includes hairy fungus beetle, ladybirds, minute mould beetles, pea weevil (dead only), sitona weevil, desiantha weevil, wood bugs, other field insects (Excludes Grasshoppers & Locusts, Max 2)	15
OBJM	**Objectionable Material max (entire load)** Includes animal excreta, rodents, crushed insect bodies or parts that adhere to the grain, live insect pests, pickling compounds, tainting agents, odours, sticks, stones (>1 mm)	NIL
ERGR	**Ryegrass Ergot max (length in cm when pieces are laid end to end per 200 g sample)**	2 cm
CHEM	**Non Approved Treatment Chemicals or Treatment Levels above Legal Tolerances (entire load)**	NIL

12.8 Harvest weed seed management

Weeds that 'escape' herbicide control can quickly contribute vast quantities of seed to a paddock's soil seedbank Destroying or capturing weed seeds at harvest is the number one strategy for combating herbicide resistance and driving down the weed seed bank.

For field peas as per any other crop, an audit of the paddock should be conducted prior to harvest to assess whether the paddock is clean from weeds, has had any escapes from an in-crop herbicide spray or has had a late germination of non-sprayed weeds. Weed seeds should be collected and sent away for herbicide resistance (HR) testing to ascertain if HR is an issue in that paddock and how subsequent management plans can be developed for that crop in the following years.

Harvest weed seed management can take a number of forms:

- narrow windrow burning
- use of a Harrington weed destructor
- chaff carts.

12.8.1 Windrow burning

A windrow will burn at a higher temperature for longer than spread stubble, thereby improving weed kill. Burning a narrow windrow also reduces the percentage of the paddock that is burnt, thereby reducing the area prone to wind erosion.

It has been identified that a temperature of 400°C for 10 seconds is required to kill annual ryegrass seed (Chitty and Walsh 2003) and that wild radish pods will be destroyed by 400°C for 20–30 seconds or 500°C for 10 seconds (Walsh et al 2005). Walsh et al (2005) also demonstrated that it was possible to achieve temperatures above 500°C for over three minutes in a lupin trash windrow, where dry matter in the windrow was estimated at 15 t/ha. [10]

Field peas, and other pulse crops, have been successfully windrow burnt in the central-west of NSW for the past 3–4 years due in part to the extensive work conducted by the GRDC-funded group, Grain Orana Alliance (GOA). YouTube videos on this practice can be accessed below:

10 Integrated Weed Management Manual (2014) Grains Research & Development Corporation, http://www.weedsmart.org.au/bulletin-board/integrated-weed-management-manual/

Storage

Storing pulses successfully requires a balance between ideal harvest and storage conditions. Harvesting at 14% moisture content captures grain quality and reduces mechanical damage to the seed but requires careful management to avoid deterioration during storage.

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 chickpeas.

Pulses exposed to weathering before harvest deteriorate more quickly in storage.

To minimise damage to field pea grain, augers should be run full and at a slower speed than for cereals. Belt shifters are preferred for handling pulses. Field peas can be stored in sheds, bunkers and silos. Where pea weevil infestation of the grain is detected on farm, fumigate with phosphine tablets in a sealed silo. [1]

Pulses are one of the riskier grains to store in grain bags. Carefully assess the use of grain bags for pulses against the option of using other forms of storages for them and using the bags for another grain that is more appropriate. If pulses are to be stored in grain bags, it should be considered as temporary only, and all precautions must be taken in terms of site selection, moisture content at filling, bag sealing, monitoring and maintenance. Consider using grain bags for treatment of a pulse grain sample that requires attention for it to make grade. [2]

13.1 How to store pulses on-farm

Cleaning silos and storages thoroughly and removing spilt and leftover grain removes the feed source and harbour for insect pests. Clean the following areas thoroughly:

- empty silos and grain storages
- augers and conveyers
- harvesters
- field and chaser bins
- spilt grain around grain storages.

Chemicals used for structural treatments do not list the specific use before storing pulses on their labels and MRLs in pulses for those products are either extremely low or nil.

Using chemicals even as structural treatments risks exceeding the MRL, so is not recommended.

Using diatomaceous earth (DE) as a structural treatment is possible but wash and dry the storage and equipment before using for pulses. This will ensure the DE doesn't discolour the grain surface. [3]

If unsure, check with the grain buyer before using any product that will come in contact with the stored grain.

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

2 Pulse Australia (2015) Grain bags for pulse storage. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/grain-storage-bags

3 Grain Storage Fact Sheet: Storing Pulses (2014), Grains Research & Development Corporation, http://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

Because field peas are susceptible to splitting at the ideal storage MC of ≤12%, cone-based rather than flat-based silos are recommended for easy out-loading with minimal seed damage. Always fill and empty silos from the centre holes. This is especially important with pulses because most have a high bulk density. Loading or out-loading off-centre will put uneven weight on the structure and could cause it to collapse. [4]

Use of a belt conveyor instead of an auger is advisable when handling chickpeas. If movement via auger cannot be avoided, minimise the number of times that augers shift grain and adjust auger settings to ensure the chickpeas are handled as gently as possible. Follow these rules to minimise auger damage to chickpeas:

- Ensure augers are full of grain and operated at slow speeds.
- Check auger flight clearance—optimum clearance between flight and tube, in order to minimise lodging and damage, should be half the grain size.
- Operate augers as close as possible to their optimal efficiency—usually an angle of 30°.

At industry level, it is within growers' best interests to house grain in aerated, sealable storages to help curtail the rise of insect resistance to phosphine. This resistance has come about because of the prevalence of silos that are poorly sealed or unsealed during fumigation. [5]

13.2 Stored grain pests

Stored grain insects are not common in field peas. The biggest exception to this is the pea weevil (*Bruchus pisorum*) which is one of the most damaging pests of field peas. It not only reduces yields but can also reduce germination rates of seed and grain quality to the point that it's not saleable for human consumption The pea weevil will not reproduce in stored grain but the larvae can emerge from the seed ewhile in storage leading to both live insects in the sample and pin holes in the grain that will detract from quality.

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 field pea weevil.

Weevil development ceases at temperatures below 20°C. This is a strong incentive for aeration cooling, especially if gas-tight storage is not available. [6]

If insects are found in stored field peas, the only treatment options are controlled atmospheres (CO_2, N_2), or phosphine fumigation. When using phosphine, it is important that gas concentrations are held at high levels for the full fumigation exposure time. Immature stages of the insects and resistant strains that are being found more frequently will be controlled by phosphine only in a sealed, gas-tight storage. Phosphine is toxic to people as well as insects, so do not handle treated grain before the 7–10-day exposure period plus the required airing or venting period to remove the gas.

13.3 Grain protectants for storage

Protectants are not registered for use on field peas. These grains must be protected by residue-free methods such as fumigation or aeration. [7]

4 P Burrill, P Botta, C Newman, C Warrick (2012) Storing pulses. GRDC Fact Sheet, March 2012, http://www.grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

5 C Warrick (2012) Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once. GRDC Grains Industry Guide, January 2011. Reprinted Aug. 2012, http://www.grdc.com.au/~/media/5EC5D830E7BF4976AD591D2C03797906.pdf

6 Grain Storage Fact Sheet: Storing Pulses (2014), Grains Research & Development Corporation, http://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

7 P Matthews, D McCaffery, L Jenkins (2015) Winter crop sowing variety guide 2015—NSW DPI Management Guide. NSW Government Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

13.4 Aeration during storage

Research has shown that harvesting pulses at higher moisture content (up to 14%) reduces field mould, mechanical damage to the seed, splitting and preserves seed viability. The challenge is to maintain this quality during storage as there is an increased risk of deterioration at these moisture levels. As a result, pulses stored above 12% moisture content require aeration cooling to maintain quality.

13.4.1 Aeration cooling

- Creates uniform conditions throughout the grain bulk
- Prevents moisture migration
- Maintains seed viability (germination and vigour)
- Lengthens (and in some instances stops) insect reproduction cycles
- Reduces mould growth
- Slows seed coat darkening and quality loss.

Aeration cooling allows for longer-term storage of low-moisture grain by creating desirable conditions for the grain and undesirable conditions for mould and pests. Unlike aeration drying, aeration cooling can be achieved with air-flow rates of as little as 2–3 litres per second per tonne (L/s/t) of grain.

High-moisture grain can also be safely held for a short time with aeration cooling before blending or drying. Run fans continuously to prevent self-heating and quality damage. [8]

13.4.2 Aeration drying

Pulses stored for longer than three months at high moisture content (>14%%) will require drying or blending to maintain seed quality. Aeration drying has a lower risk of cracking and damaging pulses, which can occur with hot-air dryers.

Unlike aeration cooling, drying requires high airflow rates of at least 15–25 L/s/t and careful management.

For more information on aeration drying refer to the GRDC booklet, Aerating stored grain, cooling or drying for quality control at http://www.grdc.com.au/uploads/documents/GRDC-Aeration-Book-2011v2.pdf [9]

8 Grain Storage Fact Sheet: Storing Pulses (2014), Grains Research & Development Corporation, http://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

9 Grain Storage Fact Sheet: Storing Pulses (2014), Grains Research & Development Corporation, http://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

Environmental issues

14.1 Frost

Field peas are considered to be one of the more sensitive pulses to frost damage.

Pod set and grain fill is 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 total loss to frost with their extended flowering (e.g. Parafield). Other late flowering varieties may escape early frost periods. Some varieties can occasionally be extremely vulnerable if they flower over a very short period.

Conventional, trailing type peas in the field appear less frost sensitive than many of the shorter, erect semi-leafless types. Physical damage from traffic or herbicides on frosted peas during the pre-flowering stages can leave the peas more vulnerable to the spread of the disease bacterial blight, an additional complication with frost damage in peas. [1]

Symptoms of frost damage in field peas:

- flowers are killed by frost
- developing seeds in the pod are shrivelled or absent
- white/green mottling & blistering of pods
- affected pods feel 'spongy' and the seeds inside turn brown/ black.

14.1.1 Minimising frost damage in pulses

Frost risk is difficult to manage in pulses; however, some key management strategies may reduce the risk or extent of damage. These strategies include:

- Know the topography, and map areas of greatest risk so that they can be managed to minimise frost damage.
- Choose the right crop type, crop variety and sowing time to help reduce exposure or impact at vulnerable growth stages.
- Carefully assess the soil type, condition and soil moisture levels, along with stubble and canopy management.
- Correct crop nutrition and minimised crop stress can influence the degree of frost damage.

Modifications to conditions over large areas are required to reduce frost risk. Small changes in management can have a big impact because frost damage occurs at specific 'trigger' temperatures. Keeping the air temperature even 0.1°C above the critical 'trigger' point will avoid frost damage. Air flow through the canopy can also have a positive impact towards avoiding frost damage. If the frost is severe, below the 'trigger temperature', damage occurs regardless of management, so then avoidance becomes important.

MORE INFORMATION

Australian Pulse Bulletin: Using pulses for forage

1 W Hawthorne (2007) Managing pulses to minimise frost damage. Australian Pulse Bulletin PA 2007 #01, Pulse Australia Ltd, http://www.pulseaus.com.au/storage/app/media/crops/2007_APB-Pulses-frost.pdf

The soil is the heat bank, and it is desirable to have warm soil so that warm air can rise at night to minimize frost risk. The crop canopy will trap cold air on top, so a dense canopy is not necessarily desirable. [2]

Problem areas and timings

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 risk occurs is also important for crop management.

Crop and sowing time

Strategies to minimise frost damage in pulses work in combinations of either: 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; or ensuring that most grain is sufficiently filled to avoid damage when frost occurs (see table). Targeting flowering and early podding to periods of least frost risk (lowest probability) is achieved through combinations of sowing date and variety choice based on flowering time and flowering duration. Local experience will indicate the best choices.

Late flowering targets avoidance of early frosts, but in the absence of frost may also reduce yield potential due to moisture deficiency or 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. [3]

Variety and crop choice

Pulse species and varieties differ in their frost susceptibility and risk exposure times (Table 1), so choose wisely for the situation.

Table 1: *Frost susceptibility and risk exposure times for a range of pulses.* [4]

Crop type	Frost tolerance of pods & seeds	Commencement of flowering	Length of flowering (duration)	Example variety	Frost tolerance or avoidance 'mechanism'
Beans[A]	medium	early	long	PBA Zahra, PBA Samira, Farah, Nura	Grain tolerance, early podding and seed fill
Chickpeas	low	medium	medium	Genesis 090	Avoidance (escape early frosts), flower in heat
		late	short–medium	Almaz, Nafice	Avoidance (escape early frosts), flower in heat
Lupins[A]	low–medium	very early–early	long	Mandelup, Wonga	Compensation with later podding
		late	short–medium	PBA Jurien, Jindalee, PBA Barlock	Avoidance (early frosts), some late podding compensation
Lentils	low	medium	medium	PBA Hurricane, PBA Jumbo2	Some avoidance (early frosts), sowing date, short crop height a disadvantage
Peas[B]	very low[B]	early[C]	long	PBA Hayman⟑, Parafield, Sturt	Extended flowering, early podding, lodging
		late[C]	short	Kaspa⟑B, PBA Wharton⟑	Possible avoidance (early frosts), quick flowering
		early[C]	short	ExcelB, PBA Twlight, PBA Percy⟑	Possible avoidance (late frosts), early podding

2 Pulse Australia (2015) Minimising frost damage in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/minimise-frost-damage

3 Pulse Australia (2015) Minimising frost damage in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/minimise-frost-damage

4 Pulse Australia (2015) Minimising frost damage in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/minimise-frost-damage

Crop type	Frost tolerance of pods & seeds	Commencement of flowering	Length of flowering (duration)	Example variety	Frost tolerance or avoidance 'mechanism'
		late[C]	medium	Morgan, Mukta	Avoidance (early frosts), lodging
Vetch[D]	very low	early	long	Rasina, Languedoc	Extended flowering, some later compensation, possible avoidance (late frosts), lodging
		late	short	Morava, Blanchfleur	Possible avoidance (early frosts), lodging

A Beans, lupins are usually sown early.

B Erect, semi-leafless peas may be more frost susceptible in the field than conventional, lodging types.

C Damage from traffic or herbicides on frosted peas during pre-flowering stages can leave the peas more vulnerable to spread of the disease bacterial blight, particularly on some semi-leafless, erect types.

D Vetch is a multi-purpose forage and grain crop that enables flexibility of use.

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 optional use for the pulse in high frost-risk paddocks provides flexibility.
- **Mixing two pulse varieties** (long and short season, tall and short etc) balances frost risk with the risk of end of season 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 peas, narrow leafed lupins, kabuli chickpeas, and perhaps desi chickpeas. Flowering time differences are minimal in lentils and beans.
- **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 frost events can occur that may damage both crops. Pulses grown in a mix will be suitable for feed markets only unless 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. [5]

Reduce frost damage

- **Minimise input costs** to reduce financial risk exposure in frost-prone paddocks. Bear in mind though, that reducing inputs may reduce financial exposure and assist grain gross margins when crops are hit by frost, but can lessen the chance of a successful hay cut or jeopardize the crop if no frost occurs.
- **Manage nodulation and nutrition**. Ensure pulse crops are adequately nodulated and fixing nitrogen. Ensure pulses have an adequate supply of trace elements and macro-nutrients – (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.
- **Canopy management**. A bulky crop canopy, and exposure of the upper pods may increase frost damage. The pulse canopy can be managed. 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

5 Pulse Australia (2015) Minimising frost damage in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/minimise-frost-damage

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.

- **Channel cold air flow** away from the susceptible crop by using wide rows aligned up and down the hill or slope. A sacrifice area may be required where the cold air settles.
- **Cereal stubble presence** provides a cooler soil and 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.
- **Rolling** can help keep soils warm by preventing soil moisture loss, but not necessarily on self-mulching or cracking soils. Note that press wheels roll only in the seed row, but 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** increase the ability of the soil to absorb and hold heat by making the soil colour darker, and retaining moisture nearer the surface.
- **Higher carbohydrate level** in the plant during frost leads to is less leakage during thawing. Biological farmers measure sugars in the plant sap ('Brix' reading). 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 plant to increase plant carbohydrates is unknown.
- **Better varieties coming**. The GRDC is investing through Pulse Breeding Australia in germplasm enhancement and pulse variety breeding for frost tolerance, including 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. [6]

14.2 Waterlogging/flooding issues

Field peas have very low tolerance of waterlogging. Crops sown into hardsetting soils can suffer from water logging as these soils tend to be poor draining. Waterlogging causes the most damage if it occurs shortly after sowing when the seed can burst or get attacked by moulds etc. and become unviable.

Plants can show symptoms of iron and/or nitrogen deficiency (Figure 1). Roots systems are shallow and blackened with root rots.

Plants can seem to survive waterlogging but die quickly after the soil dries. [7]

6 Pulse Australia (2015) Minimising frost damage in pulses. Australian Pulse Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/minimise-frost-damage

7 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation.

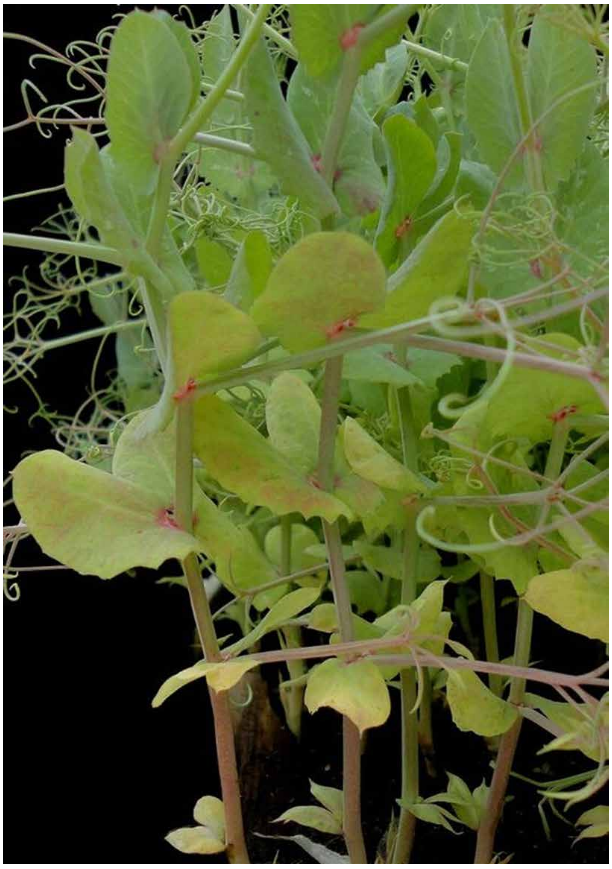


Figure 1: *Waterlogged pea plant.*

Photo DAFWA

14.3 Drought tolerance

Field peas are one of the better legumes at tolerating drought or water limiting conditions.

Low soil moisture can lead to poor germination, growth and short crops which can prove challenging come harvest time. Hot windy weather at flowering time, common in the nnorthern region, can result in reduced flower set, poor grain fill, and smaller grain. [8]

In field pea, grain number is mostly determined and the crop has the highest sensitivity to stress in the period between the beginning of flowering and the beginning of seed fill for the last seedbearing phytomer. [9]

Researchers in South Australia are identifying and selecting field pea germplasm that has superior yield and yield stability under water deficit as well as favourable conditions.

Field peas are better suited to drier climates than chickpeas.

MORE INFORMATION

GRDC Update paper: Improving yield and reliability of field peas under water deficient

Liebe Group: Growing field peas and chickpeas in low rainfall zones

8 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation.

9 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, http://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

MORE INFORMATION

GRDC Update Paper: Viable growth in the pulse industry

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 shows a grain selling flow chart that summarises:

- decisions to be made
- drivers behind the decisions
- guiding principles for each decision point.

The grower will run through a decision-making process each season, because growing and harvesting conditions, and prices for grains, change all the time. For example, in the seven years to and including 2015, Port Adelaide field pea values have varied A$60–$370/t, a variability of 30–60% (Figure 2). For a property producing 200 tonnes of field peas this means $12,000–$74,000 difference in income, depending on timing of sales.

The reference column refers to the section of the GrowNote where you will find the details to help in making decisions.

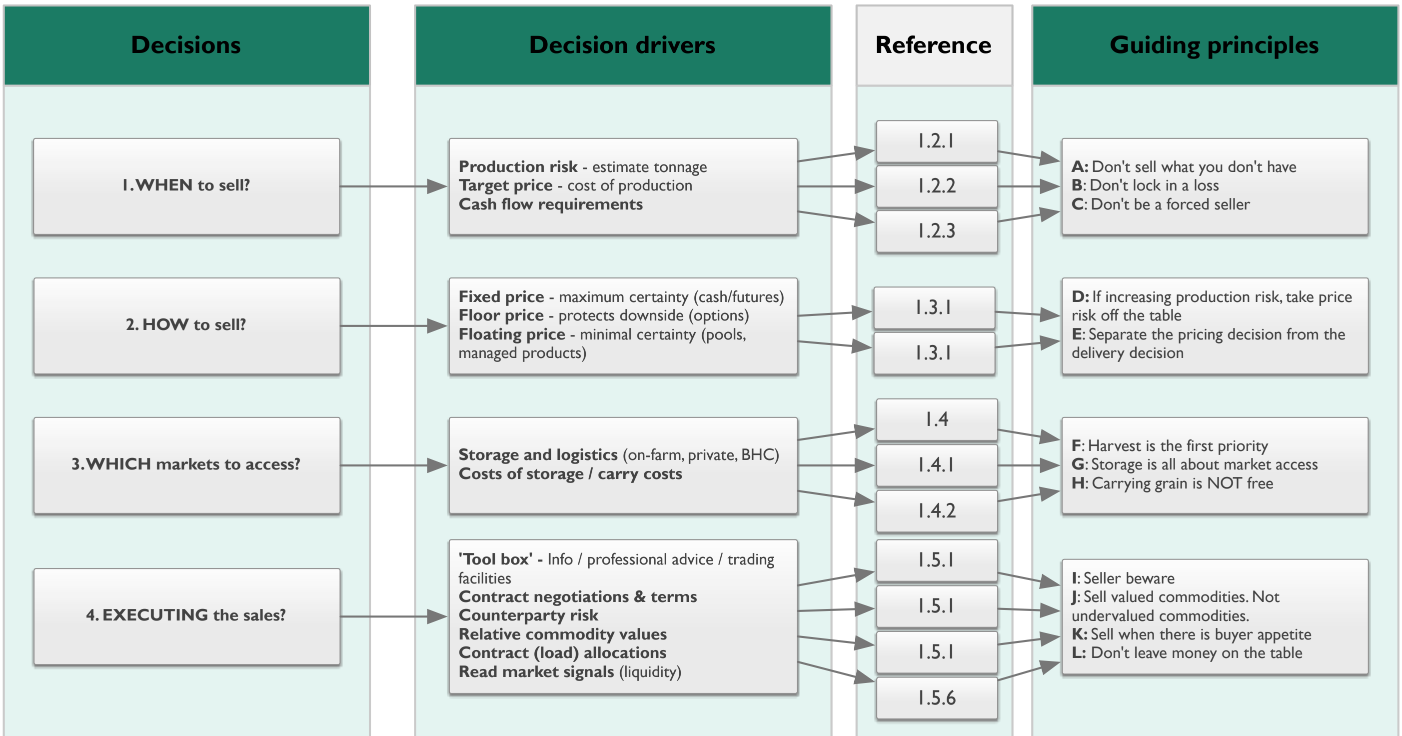


Figure 1: *Grain selling flowchart.*

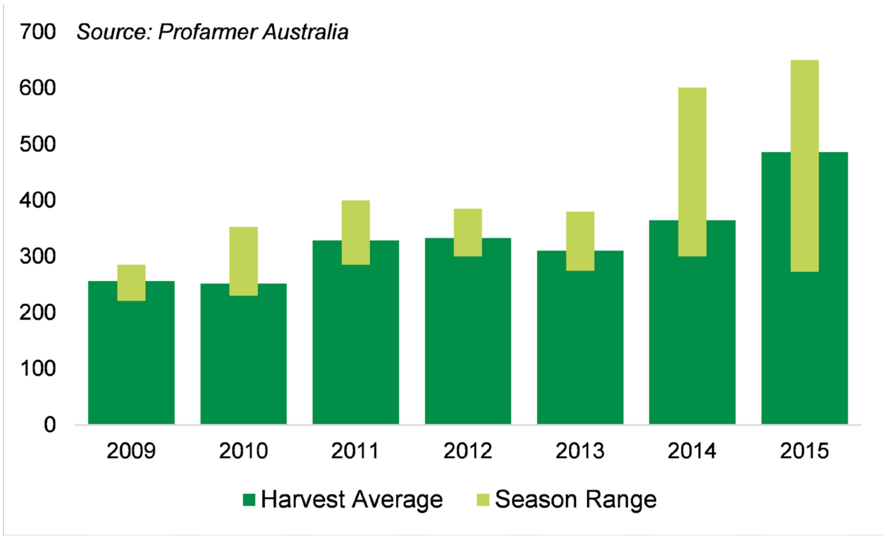


Figure 2: *Intraseasonal variance of Port Adelaide field pea values.*

Source: Profarmer Australia

15.1 Selling principles

The aim of a selling program is to achieve a profitable average price (the target price) across the entire business. This requires managing several unknowns to establish a target price and then work towards achieving the target price.

Unknowns include the amount of grain available to sell (production variability), the final cost of producing the grain, and the future prices that may result. Australian farm-gate prices are subject to volatility caused by a range of global factors that are beyond our control and are difficult to predict.

The skills growers have developed to manage production unknowns can also be used to manage pricing unknowns. This guide will help growers manage and overcome price uncertainty.

15.1.1 Be prepared

Being prepared by having a selling plan is essential for managing uncertainty. The steps involved are forming a selling strategy, and forming a plan for effectively executing sales. The selling strategy consists of when and how to sell.

When to sell

Knowing when to sell requires an understanding of the farm's internal business factors, including:

- production risk
- a target price based on the cost of production and the desired profit margin
- business cashflow requirements

How to sell

Working out how to sell your grain is more dependent on external market factors, including:

- the time of year—determines the pricing method
- market access—determines where to sell
- relative value—determines what to sell

The following diagram (Figure 3) lists the key principles to employ when considering sales during the growing season. Exactly when each principle comes into play is indicated in the discussion of marketing, planning and timing in the rest of section 15.

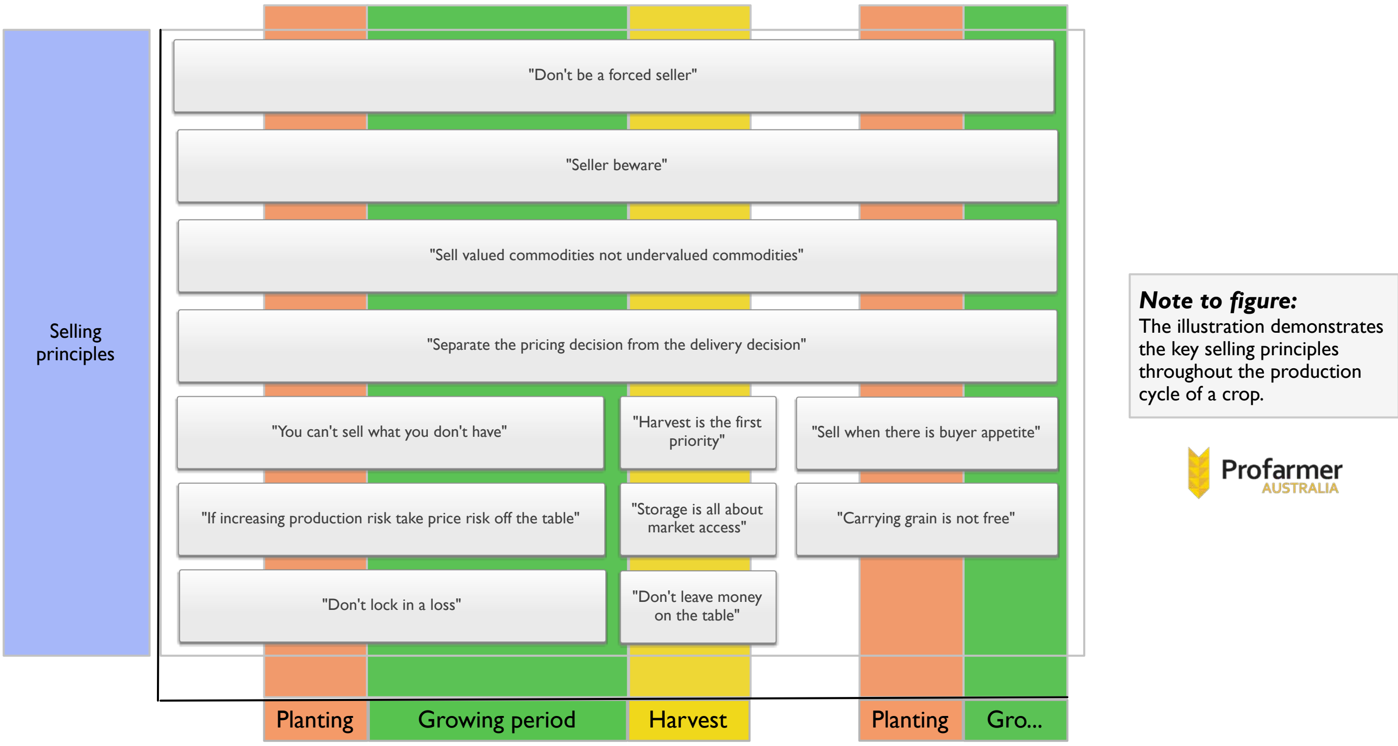


Figure 3: *Timeline of grower commodity selling principles.*

Source: Profarmer Australia

15.1.2 Establish the business risk profile

Establishing your business risk profile helps you determine when to sell: it allows you to develop target price ranges for each commodity, and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify the risks during the production cycle are described below (Figure 4).

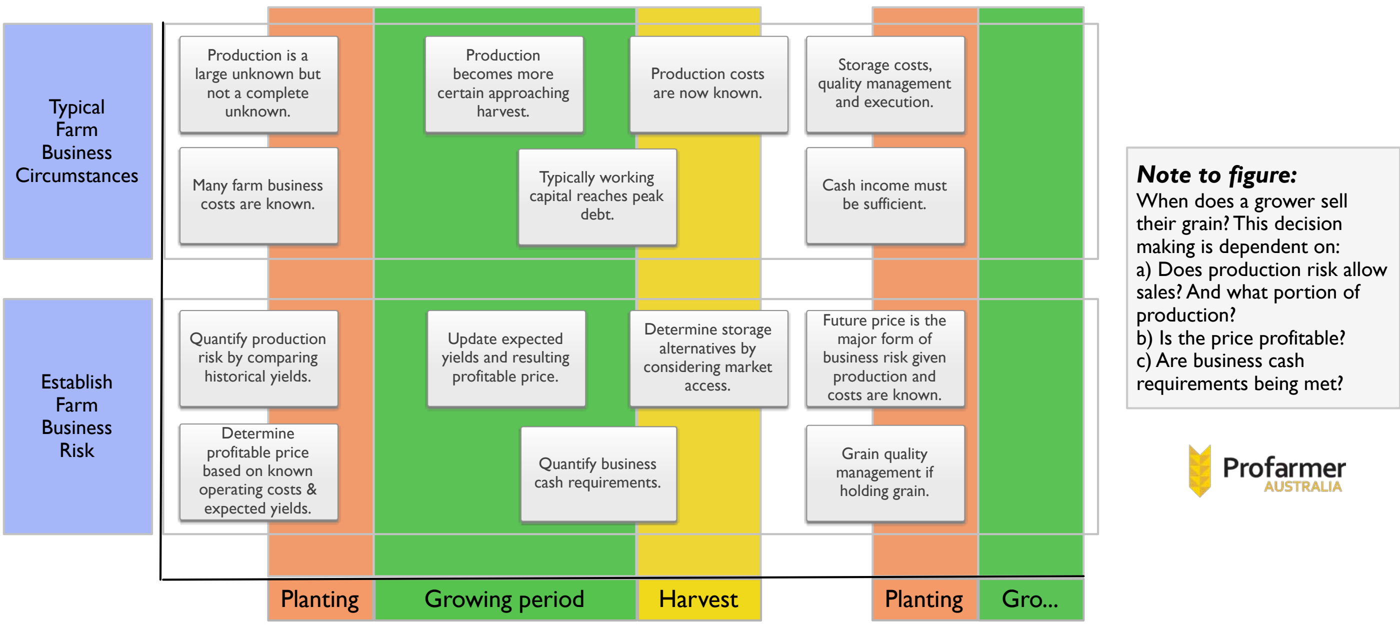


Figure 4: *Typical farm business circumstances and risk.*

Source: Profarmer Australia

Production risk profile of the farm

Production risk is the level of certainty around producing a crop and is influenced by location (climate, season and soil type), crop type, crop management, and the time of the year.

Principle: You can't sell what you don't have.

Therefore, don't increase business risk by over committing production. Establish a production risk profile (Figure 5) by:

1. Collating historical average yields for each crop type and a below-average and above-average range.
2. Assessing the likelihood of achieving the average, based on recent seasonal conditions and the seasonal outlook.
3. Revising production outlooks as the season progresses.

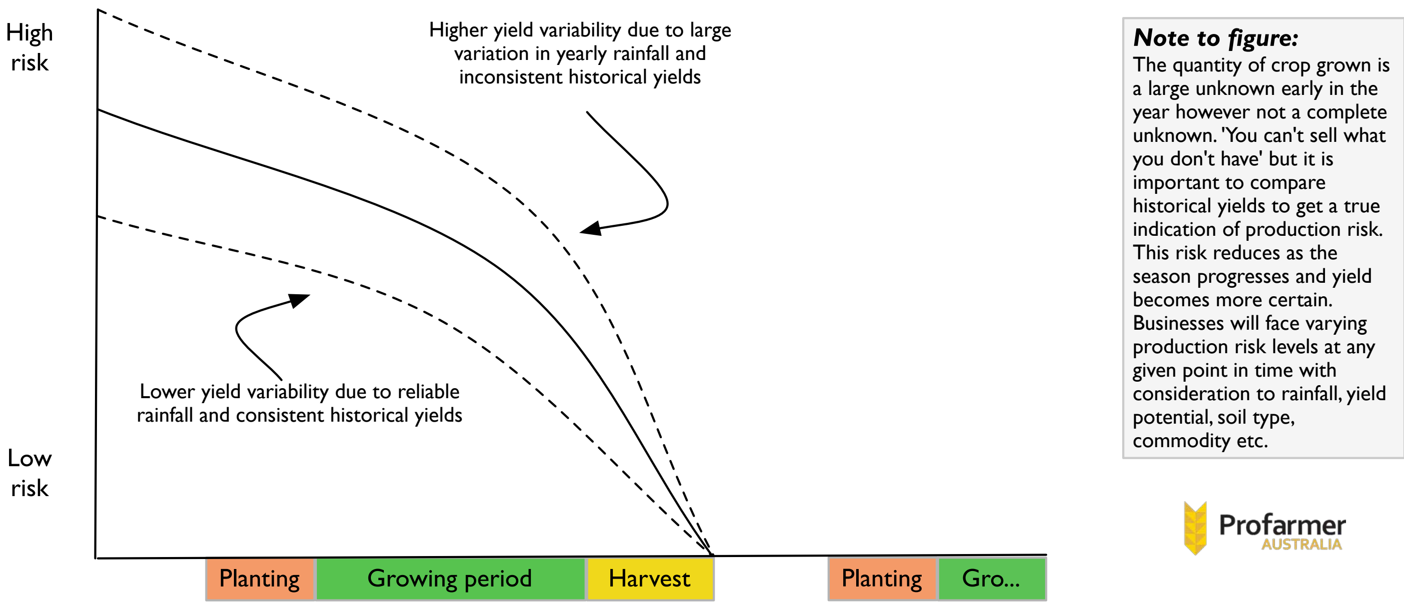


Figure 5: *Typical risk profile of a farm operation.*

Source: Profarmer Australia

Establishing a target price

A profitable commodity target price is the cost of production per tonne plus a desired profit margin. It is essential to know the cost of production per tonne for the farm business, which means knowing all farming costs, both variable and fixed.

Principle: Don't lock in a loss.

If committing production ahead of harvest, ensure the price will be profitable. The steps needed to calculate an estimated profitable price is based on the total cost of production and a range of yield scenarios, as provided below (Figure 6).

Estimating cost of production - Wheat	
Planted area	1,200 ha
Estimate yield	2.85 t/ha
Estimated production	3,420 t
Fixed costs	
Insurance and general expenses	$100,000
Finance	$80,000
Depreciation/Capital replacement	$70,000
Drawings	$60,000
Other	$30,000
Variable costs	
Seed and sowing	$48,000
Fertiliser and application	$156,000
Herbicide and application	$78,000
Insect/fungicide and application	$36,000
Harvest costs	$48,000
Crop insurance	$18,000
Total fixed and variable costs	$724,000
Per tonne equivalent (total costs + estimated production)	$212 /t
Per tonne costs	
Levies	$3 /t
Cartage	$12 /t
Receival fee	$11 /t
Freight to port	$22 /t
Total per tonne costs	$48 /t
Cost of production port FIS equiv	$259.20
Target profit (ie 20%)	$52.00
Target price (port FIS equiv)	**$311.20**

Step 1: Estimate your production potential. The more uncertain your production is, the more conservative the yield estimate should be. As yield falls, your cost of production per tonne will rise.

Step 2: Attribute your fixed farm business costs. In this instance if 1,200 ha reflects 1/3 of the farm enterprise, we have attributed 1/3 fixed costs. There are a number of methods for doing this (see M Krause "Farming your Business") but the most important thing is that in the end all costs are accounted for.

Step 3: Calculate all the variable costs attributed to producing that crop. This can also be expressed as $ per ha x planted area.

Step 4: Add together fixed and variable costs and divide by estimated production

Step 5: Add on the 'Per tonne' costs like levies and freight.

Step 6: Add the 'Per tonne' costs to the fixed and variable per tonne costs calculated at step 4.

Step 7: Add a desired profit margin to arrive at the port equivalent target profitable price.

Figure 6: *An example of how to estimate the costs of production.*

Source: Profarmer Australia

GRDC's manual Farming the Business also provides a cost-of-production template and tips on grain selling *v.* grain marketing.

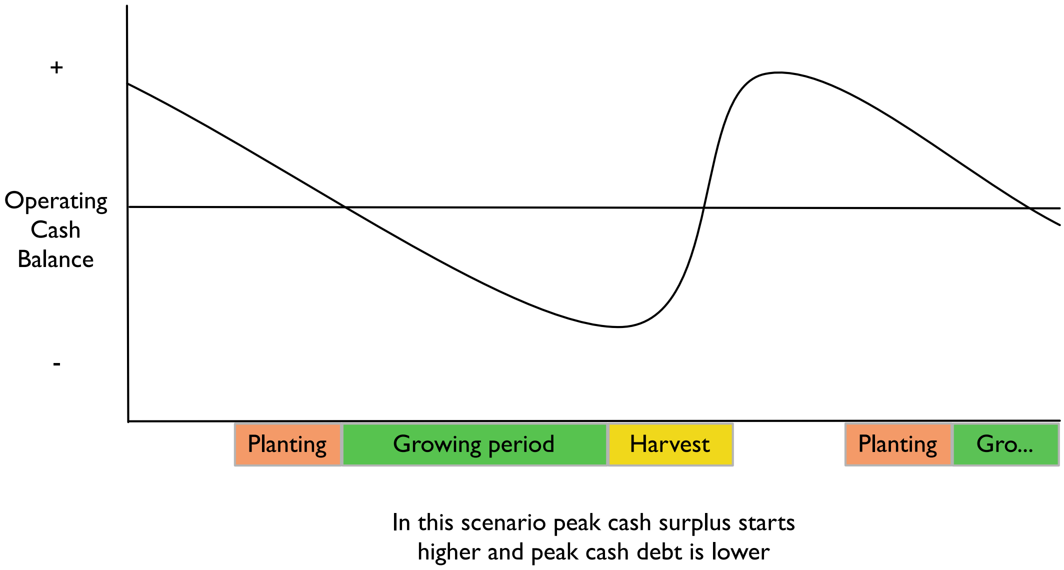
Income requirements

Understanding farm business cash flow requirements and peak cash debt enables growers to time grain sales so that cash is available when required. This prevents having to sell grain below the target price to satisfy a need for cash.

Principle: Don't be a forced seller.

Be ahead of cash requirements to avoid selling in unfavourable markets.

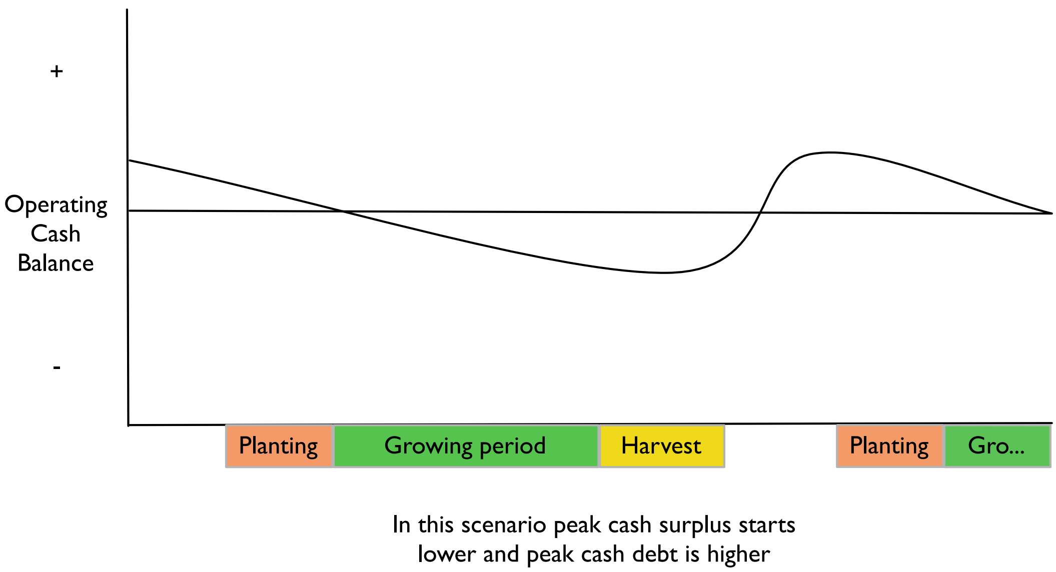
Typical cash flow to grow a crop are illustrated below (Figures 7 and 8). Costs are incurred up front and during the growing season, with peak working capital debt incurred at or before harvest. Patterns will vary depending on circumstance and enterprise mix. Figure 8 demonstrates how managing sales can change the farm's cash balance.



Note to figure:
The chart illustrates the operating cash flow of a typical farm assuming a heavy reliance on cash sales at harvest. 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.

Figure 7: *A typical operating cash balance when relying on cash sales at harvest.*

Source: Profarmer Australia



Note to figure:
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.

Figure 8: *Typical operating cash balance when crop sales are spread over the year.*

Source: Profarmer Australia

The 'when to sell' steps above result in an estimated production tonnage and the risk associated with producing that tonnage, a target price range for each commodity, and the time of year when cash is most needed.

15.1.3 Managing your price

The first part of the selling strategy answers the question about when to sell and establishes comfort around selling a portion of the harvest.

The second part of the strategy, managing your price, addresses how to sell your crop.

Methods of price management

Pricing products provide varying levels of price risk coverage, but not all products are available for all crops (Table 1).

Table 1: *Pricing methods and how they are used for different crops.*

	Description	Wheat	Barley	Canola	Oats	Lupins	Field peas	Chick peas
Fixed price products	Provides the most price certainty	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash	Cash	Cash	Cash
Floor price products	Limits price downside but provides exposure to future price upside	Options on futures, floor price pools	Options on futures	Options on futures	none	none	none	none
Floating price products	Subject to both price upside and downside	Pools	Pools	Pools	Pools	Pools	Pools	Pools

Figure 9 summarises how the different methods of price management are suited to the majority of farm businesses.

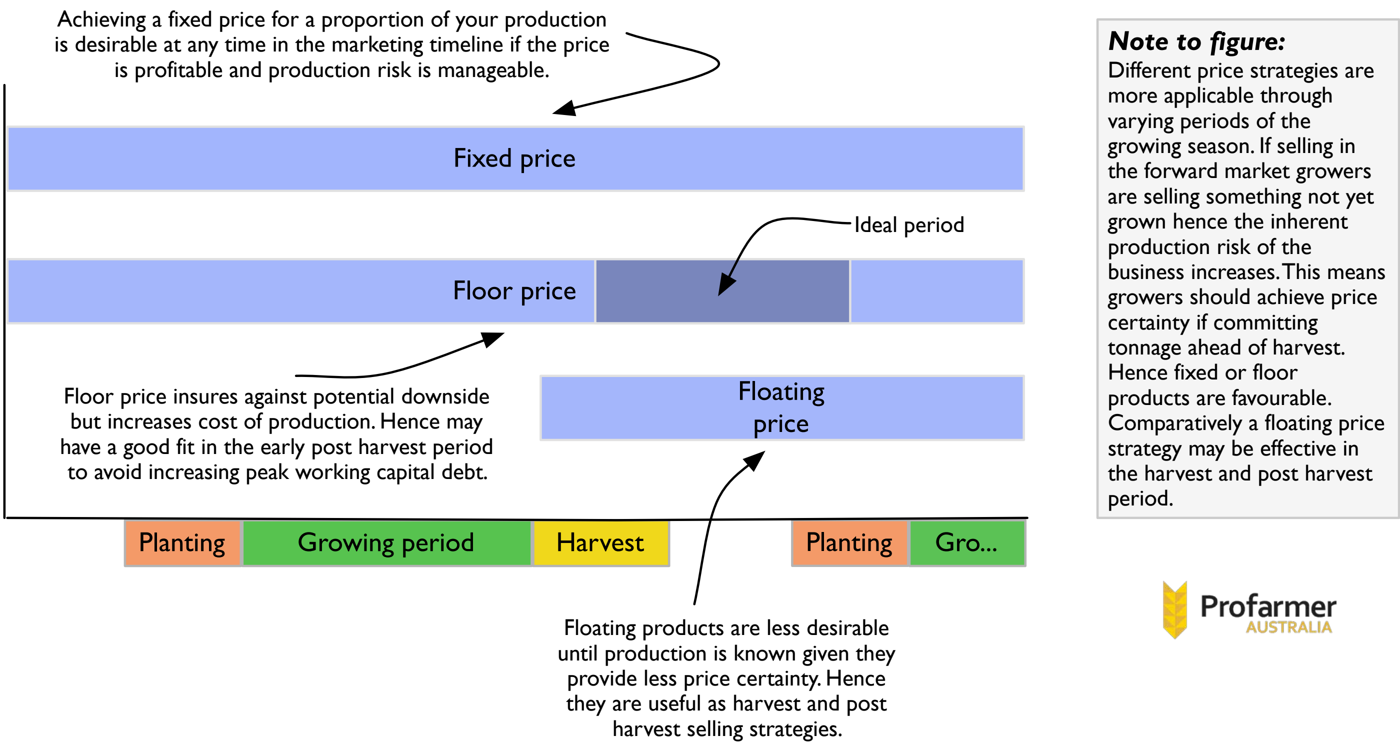


Figure 9: *Price strategy timeline, summarising the suitability for most farm businesses of different methods of price management for different phases of production.*

Source: Profarmer Australia

Principle: If increasing production risk, take price risk off the table.

When committing to unknown production, price certainty should be achieved to avoid increasing overall business risk.

Principle: Separate the pricing decision from the delivery decision.

Most commodities can be sold at any time with delivery timeframes being negotiable, hence price management is not determined by delivery.

Fixed price

A fixed price is achieved via cash sales and/or selling a futures position (swaps) (Figure 10). It provides some certainty around expected revenue from a sale as the price is largely a known factor, except when there is a floating component in the price, e.g. a multi-grade cash contract with floating spreads or a floating-basis component on futures positions.

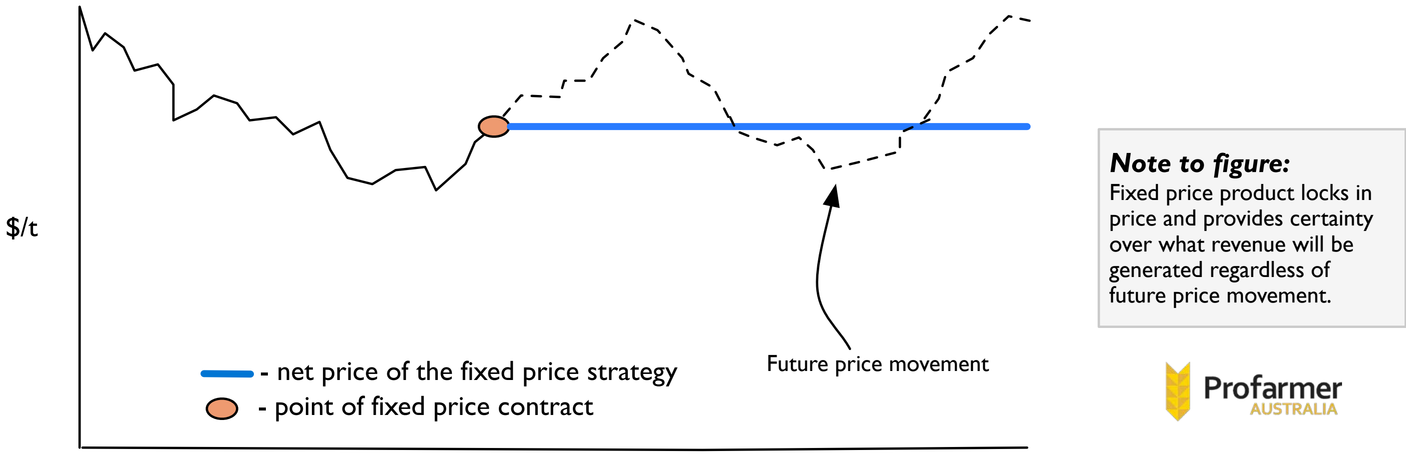


Figure 10: *Fixed price strategy.*

Source: Profarmer Australia

Floor price

Floor price strategies (Figure 11) can be achieved by utilising options on a relevant futures exchange (if one exists), or via a managed-sales program (i.e. a pool with a defined floor price strategy) offered by a third party. This pricing method protects against potential future price decrease while capturing any price increase. The disadvantage is that this kind of price 'insurance' has a cost, which adds to the farm's cost of production.

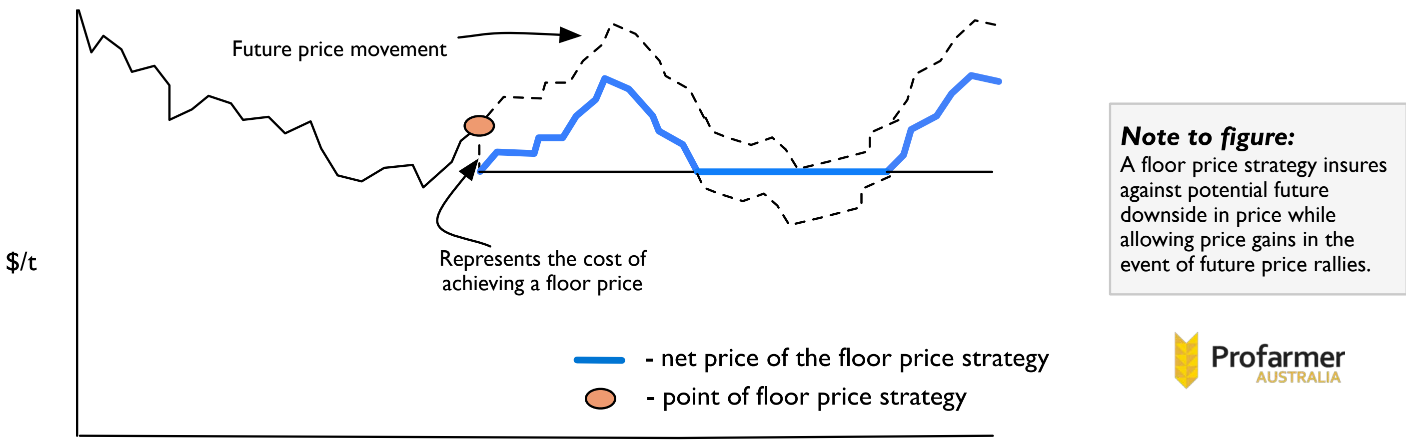
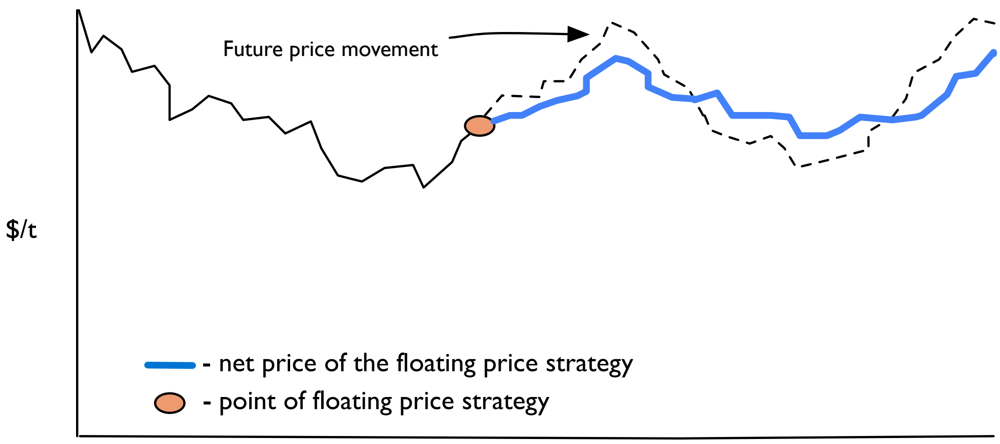


Figure 11: *Floor price strategy.*

Source: Profarmer Australia

3. Floating price

Many of the pools or managed-sales programs are a floating price, where the net price received will move up and down with the future movement in price (Figure 12). Floating-price products provide the least price certainty and are best suited for use at or after harvest rather than before harvest.



Note to figure:
A floating price will move to some extent with future price movements.

Figure 12: *Floating price strategy.*

Source: Profarmer Australia

Having considered the variables of production for the crop to be sold, and how these fit against the different pricing mechanisms, the farmer may revise their selling strategy, taking the risks associated with each mechanism into account.

Fixed price strategies include physical cash sales or futures products, and provide the most price certainty, but production risk must be considered.

Floor price strategies include options or floor-price pools. They provide a minimum price with upside potential and rely less on production certainty, but cost more.

Floating price strategies provide minimal price certainty, and so are best used after harvest.

15.1.4 Ensuring access to markets

Once the questions of when and how to sell are sorted out, planning moves to the storage and delivery of commodities to ensure timely access to markets and execution of sales. Planning where to store the commodity is an important component of ensuring the type of access to the market that is likely to yield the highest return (Figure 13).

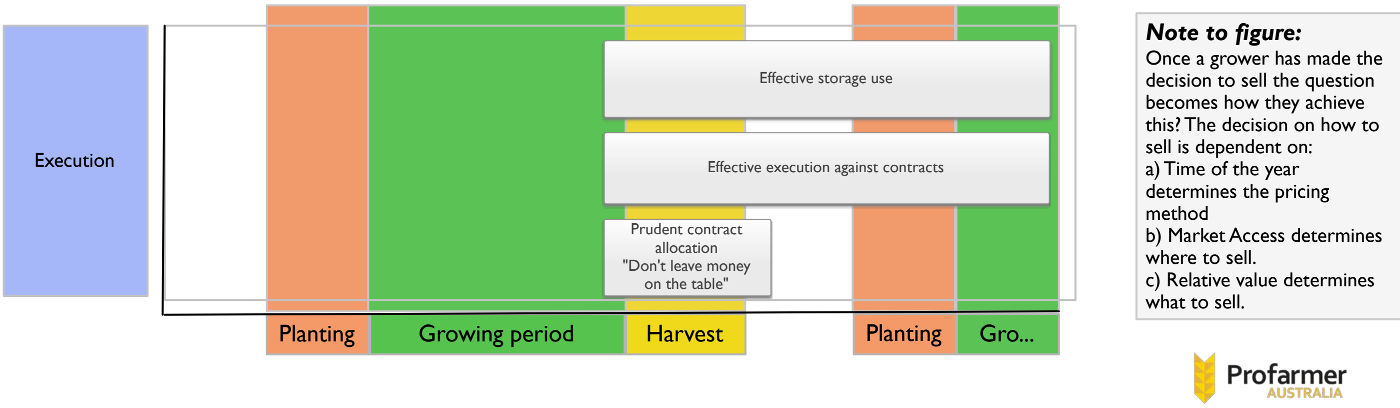


Figure 13: *Storage decisions are influenced by selling decisions and the timing of all farming activities.*

Source: Profarmer Australia

Storage and logistics

The return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access so as to maximise returns as well as harvest logistics.

Storage alternatives include variations of bulk handling, private off-farm storage, and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity (Figure 14).

Principle: Harvest is the first priority.

During harvest, getting the crop into the bin is the most critical aspect of business success; hence storage, sale and delivery of grain should be planned well ahead of harvest to allow the grower to focus on the harvest itself.

Bulk export commodities requiring significant quality management are best suited to the bulk-handling system. Commodities destined for the domestic end-user market, (e.g. feedlot, processor, or container packer), may be more suited to on-farm or private storage to increase delivery flexibility.

Storing commodities on the farm requires prudent quality management to ensure that the grain is delivered to the agreed specifications. If not well planned and carried out, it can expose the business to high risk. Penalties for out-of-specification grain arriving at a buyer's weighbridge can be expensive, as the buyer has no obligation to accept it. This means the grower may have to incur the cost of taking the load elsewhere, and may also have to find a new buyer.

On-farm storage also requires that delivery is managed to ensure that the buyer receives the commodities on time and with appropriate weighbridge and sampling tickets.

Principle: Storage is all about market access.

Storage decisions depend on quality management and expected markets.

For more information on on-farm storage alternatives and economics, Section 13: Storage.

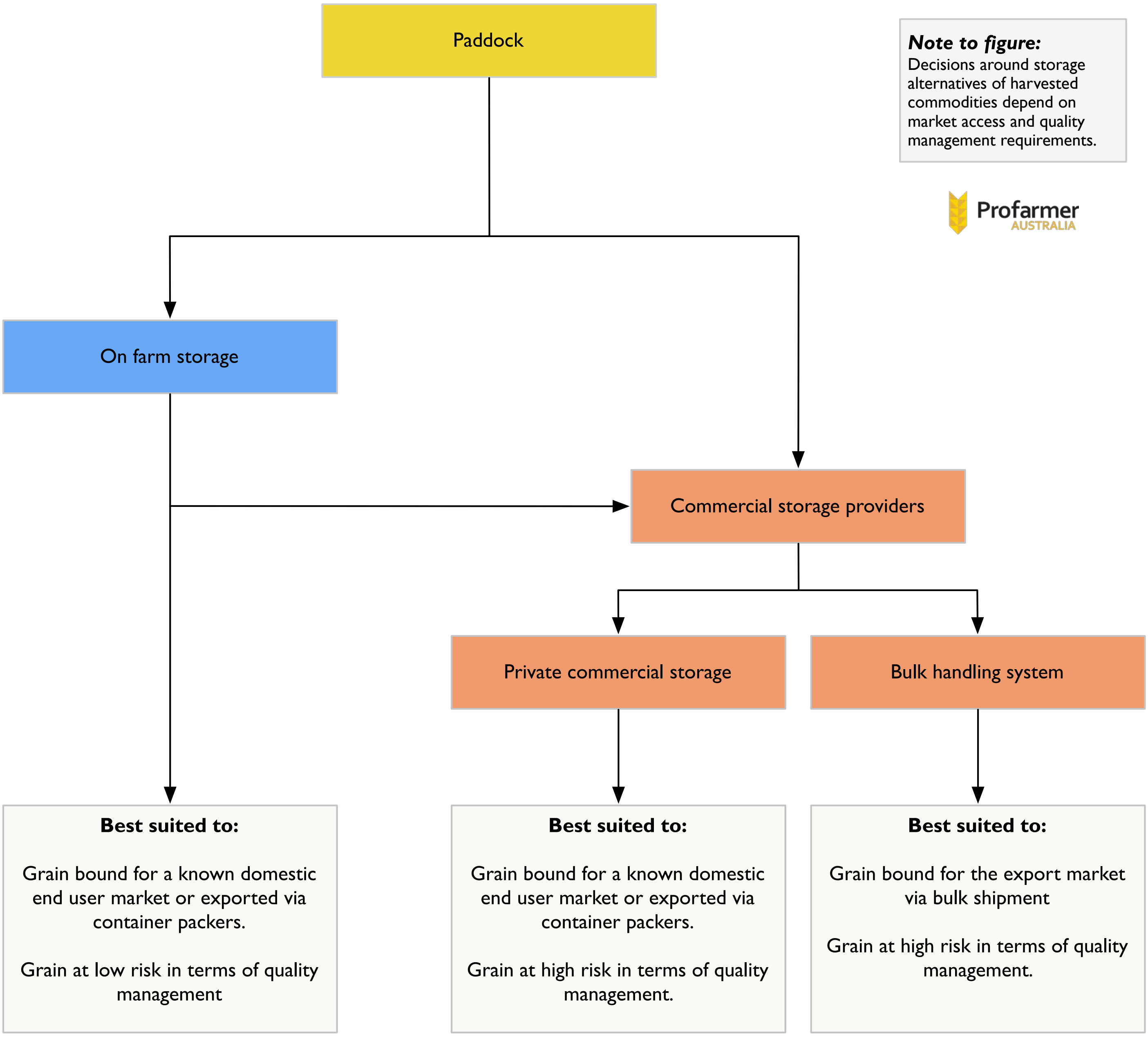


Figure 14: *Grain storage decision-making.*

Source: Profarmer Australia

Cost of holding grain

Storing grain to access sales opportunities post-harvest invokes a cost to 'carry', or hold, the grain (Figure 15). Price targets for carried grain need to account for the cost of carrying it. Carrying costs are typically $3–4/t per month and consist of:

- monthly storage fee charged by a commercial provider (typically ~$1.50–2.00/t).
- monthly interest associated with having wealth tied up in grain rather than available as cash or for paying off debt (~$1.50–$2.00/t, depending on the price of the commodity and interest rates).

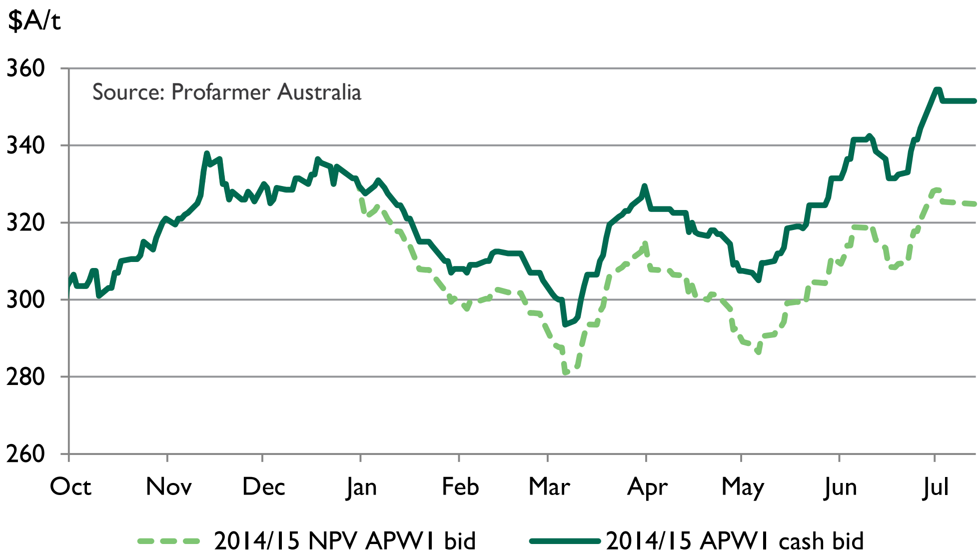
The price of carried grain therefore needs to be $3–4/t per month higher than the price offered at harvest.

The cost of carrying also applies to grain stored on the farm, as there is the cost of the capital invested in the farm storage plus the interest component. A reasonable assumption is a cost of $3–4/t per month for on-farm storage.

Principle: Carrying grain is not free.

The cost of carrying grain needs to be accounted for if holding it for sale after harvest is part of the selling strategy.

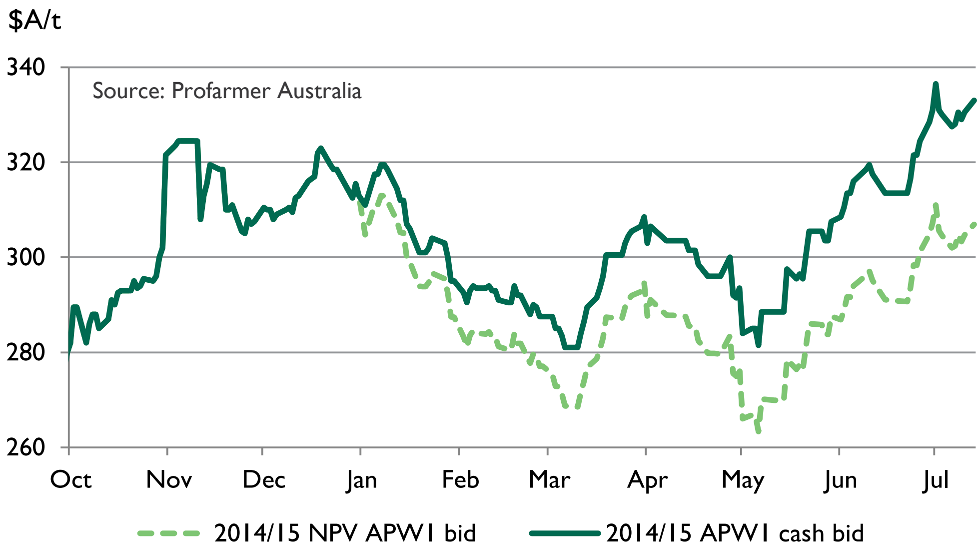
If selling on a cash contract with deferred delivery, a carrying charge can be negotiated into the contract. For example, a March sale for March–June delivery on the buyer's call at $300/t + $3/t carrying per month would generate revenue of $309/t for grain delivered in June. The price per tonne will, of course, vary depending on the market the grower is selling into (compare Figures 15 and 16).



Note to figure:
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 of APW1 wheat for March-June delivery on buyers call at $300/t + $3/t carry per month, if delivered in June would generate $309/t delivered.

Figure 15: *How adding a carrying charge changes the total paid in the Brisbane APW2 cash market.*

Source: Profarmer Australia



Note to figure:
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 of APW1 wheat for March-June delivery on buyers call at $300/t + $3/t carry per month, if delivered in June would generate $309/t delivered.

Figure 16: *How adding a carrying charge changes the total paid in the Newcastle APWI cash market. Note differences between this market and that in Figure 15.*

Source: Profarmer Australia

Optimising farm-gate returns involves planning the appropriate storage strategy for each commodity so as to improve market access and ensure that carrying costs are covered in the price received.

15.1.5 Converting tonnes into cash

This section provides guidelines for converting the selling and storage strategy into cash by effective execution of sales.

Set up the toolbox

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox for converting tonnes of grain into cash includes the following.

1. Timely information—this is critical for awareness of selling opportunities and includes:

- market information provided by independent parties.
- effective price discovery including indicative bids, firm bids and trade prices.
- other market information pertinent to the particular commodity.

2. Professional services—grain-selling professional services and cost structures vary considerably. An effective grain-selling professional will put their clients' best interests first by not having conflicts of interest and by investing time in the relationship. A better return on investment for the farm business is achieved through higher farm-gate prices, which are obtained by accessing timely information, and being able to exploit the seller's greater market knowledge and greater market access.
3. Futures account and a bank-swap facility—these accounts provide access to global futures markets. Hedging futures markets is not for everyone; however, strategies which utilise exchanges such as the Chicago Board of Trade (CBOT) can add significant value.

How to sell for cash

Like any market transaction, a cash–grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components, with each component requiring a level of risk management (Figure 17):

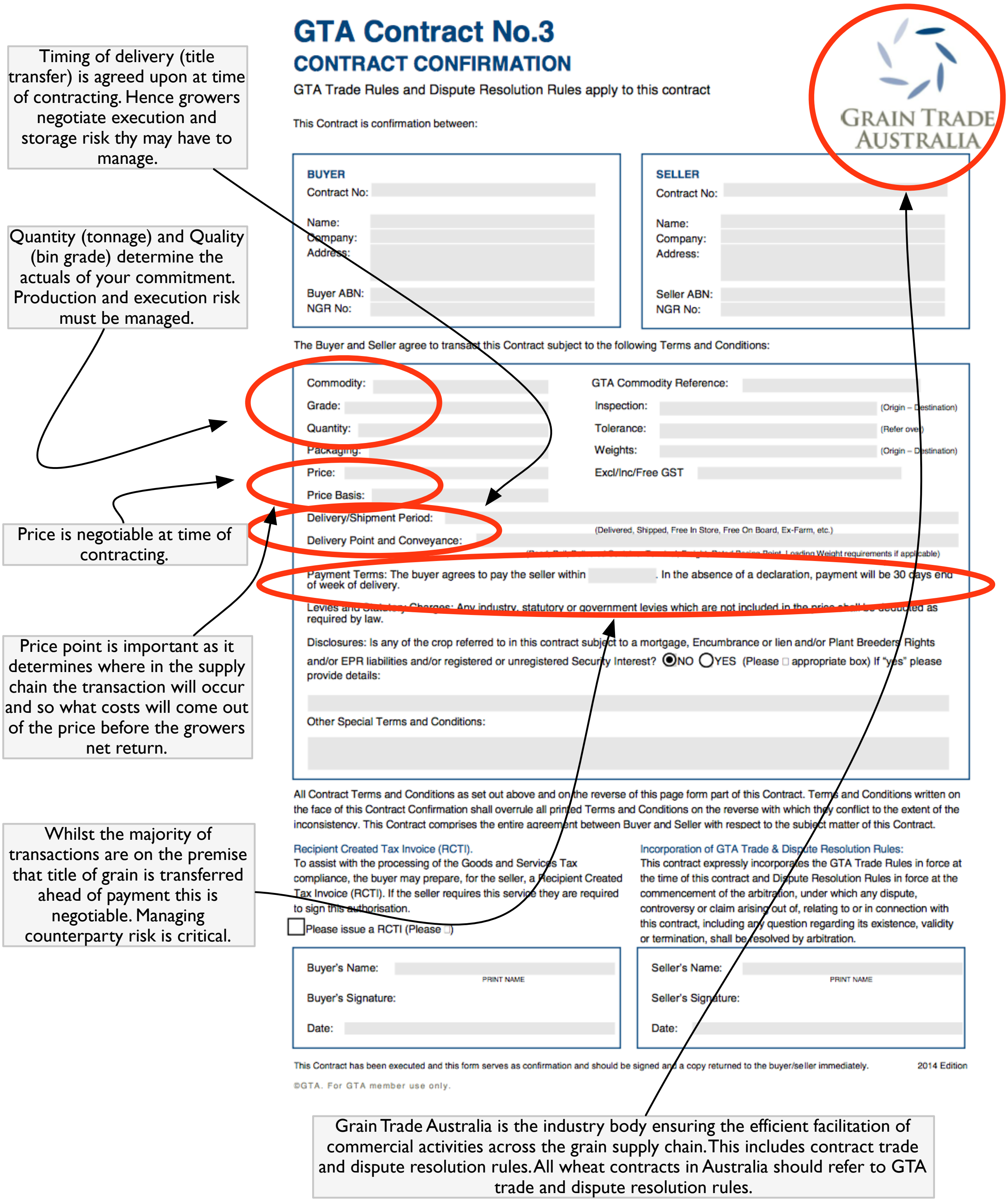
- Price—future price is largely unpredictable, so devising a selling plan to put current prices into the context of the farm business is critical to managing price risk.
- Quantity and quality—when entering a cash contract, you are committing to deliver the nominated amount of grain at the quality specified, so production and quality risks must be managed.
- Delivery terms—the timing of the title transfer from the grower to the buyer is agreed at time of contracting. If this requires delivery direct to end users, it relies on prudent execution management to ensure delivery within the contracted period.
- Payment terms—in Australia, the traditional method of contracting requires title on the grain to be transferred ahead of payment, so counterparty risk must be managed.

MORE INFORMATION

Access to buyers, brokers, agents, products and banks through Grain Trade Australia

Commodity futures brokers

ASX, Find a futures broker



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/Inc/Free GST

Delivery/Shipment Period:
(Delivered, Shipped, Free In Store, Free On Board, Ex-Farm, etc.)
Delivery Point and Conveyance:
(... Loading Weight requirements if applicable)

Payment Terms: The buyer agrees to pay the seller within . In the absence of a declaration, payment will be 30 days end of week of delivery.

Levies and Statutory Charges: Any industry, statutory or government levies which are not included in the price shall be deducted as required by law.

Disclosures: Is any of the crop referred to in this contract subject to a mortgage, Encumbrance or lien and/or Plant Breeders Rights and/or EPR liabilities and/or registered or unregistered Security Interest? NO YES (Please ☐ appropriate box) If "yes" please provide details:

Other Special Terms and Conditions:

All Contract Terms and Conditions as set out above and on the reverse of this page form part of this Contract. Terms and Conditions written on the face of this Contract Confirmation shall overrule all printed Terms and Conditions on the reverse with which they conflict to the extent of the inconsistency. This Contract comprises the entire agreement between Buyer and Seller with respect to the subject matter of this Contract.

Recipient Created Tax Invoice (RCTI).
To assist with the processing of the Goods and Services Tax compliance, the buyer may prepare, for the seller, a Recipient Created Tax Invoice (RCTI). If the seller requires this service they are required to sign this authorisation.
☐ Please issue a RCTI (Please ☐)

Incorporation of GTA Trade & Dispute Resolution Rules:
This contract expressly incorporates the GTA Trade Rules in force at the time of this contract and Dispute Resolution Rules in force at the commencement of the arbitration, under which any dispute, controversy or claim arising out of, relating to or in connection with this contract, including any question regarding its existence, validity or termination, shall be resolved by arbitration.

Buyer's Name: PRINT NAME
Buyer's Signature:
Date:

Seller's Name: PRINT NAME
Seller's Signature:
Date:

This Contract has been executed and this form serves as confirmation and should be signed and a copy returned to the buyer/seller immediately. 2014 Edition

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Figure 17: *Typical terms of a cash contract.*

Source: Grain Trade Australia

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. Figure 18 depicts the terminology used to describe these points and the associated costs to come out of each price before growers receive their net return.

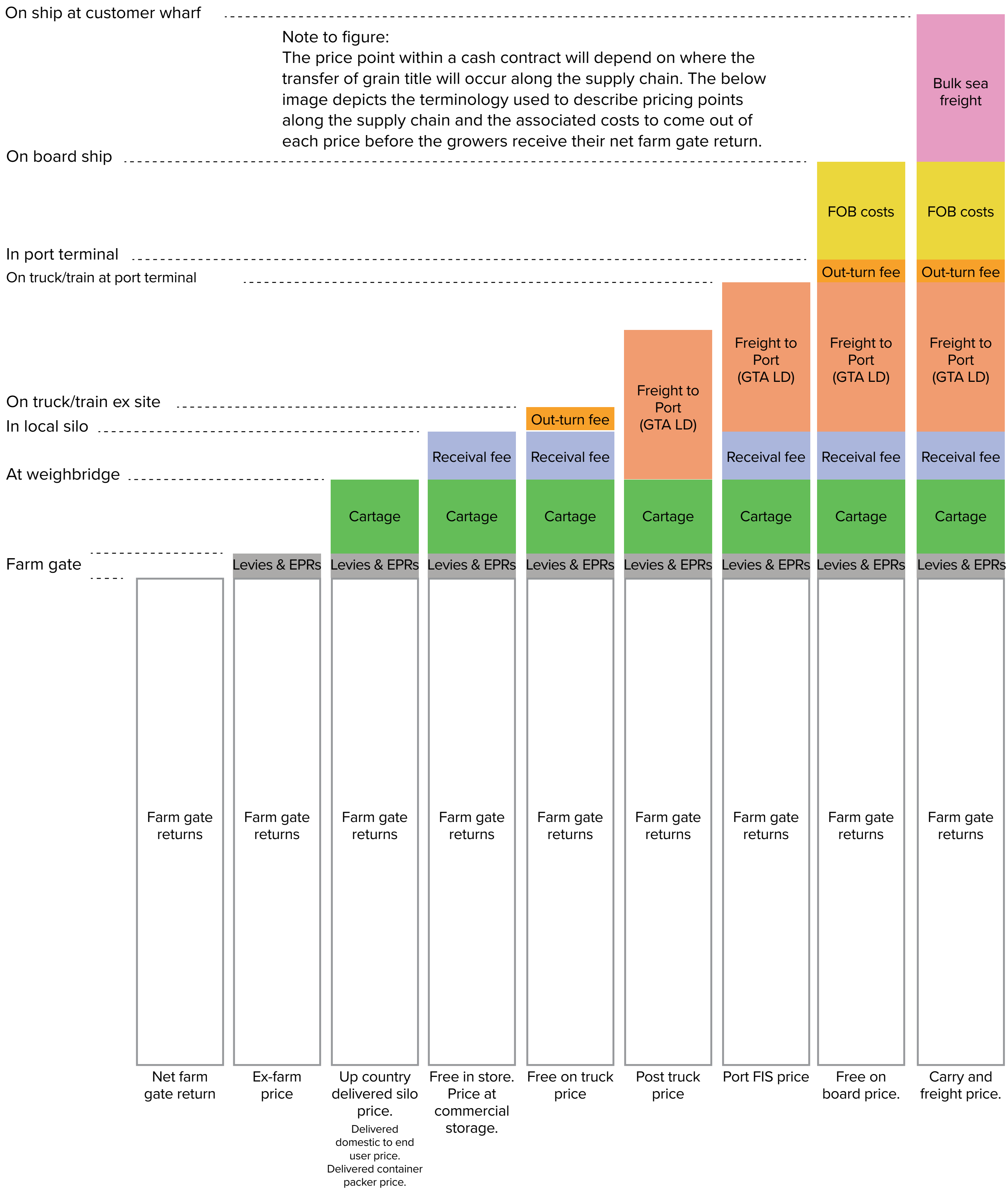


Figure 18: *Cost and pricing points throughout the supply chains.*

Source: Profarmer Australia

MORE INFORMATION

Grain Trade Australia, A guide to taking out grain contracts

Grain Trade Australia, Trading standards

GrainTransact Resource Centre

GrainFlow

Emerald Grain

Clear Grain Exchange, Getting started

Clear Grain Exchange, Terms and conditions

MORE INFORMATION

GTA, Managing counterparty risk

Clear Grain Exchange's title transfer model

GrainGrowers, Managing risk in grain contracts

Leo Delahunty, Counterparty risk: A producer's perspective

Cash sales generally occur through three methods:

- Negotiation via personal contact—traditionally prices are posted as a public indicative bid. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and is available for all commodities.
- Accepting a public firm bid—cash prices in the form of public firm bids are posted during harvest and for warehoused grain by merchants on a site basis. Growers can sell their parcel of grain immediately by accepting the price on offer via an online facility and then transfer the grain online to the buyer. The availability of this option depends on location and commodity.
- Placing an anonymous firm offer—growers can place a firm offer price on a parcel of grain anonymously and expose it to the entire market of buyers, who then bid on it anonymously using the Clear Grain Exchange, which is an independent online exchange. If the offer and bid match, the particulars of the transaction are sent to a secure settlement facility, although the title on the grain does not transfer from the grower until they receive funds from the buyer. The availability of this option depends on location and commodity. Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

Counterparty risk

Most sales involve transferring the title on the grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

Principle: Seller beware.

There is not much point selling for an extra $5/t if you don't get paid.

Counterparty risk management includes:

- Dealing only with known and trusted counterparties.
- Conducting a credit check (banks will do this) before dealing with a buyer they are unsure of.
- Selling only a small amount of grain to unknown counterparties.
- Considering credit insurance or a letter of credit from the buyer.
- Never delivering a second load of grain if payment has not been received for the first.
- Not parting with the title before payment, or requesting and receiving a cash deposit of part of the value ahead of delivery. Payment terms are negotiated at time of contracting. Alternatively, the Clear Grain Exchange provides secure settlement whereby the grower maintains title on the grain until they receive payment, and then title and payment are settled simultaneously.

Above all, act commercially to ensure the time invested in implementing a selling strategy is not wasted by poor management of counterparty risk.

Relative values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well, and to hold commodities that are not well priced at any given time. That is, give preference to the commodities with the highest relative value. This achieves price protection for the overall revenue of the farm business and enables more flexibility to a grower's selling program while achieving the business goal of reducing overall risk.

Principle: Sell valued commodities, not undervalued commodities.

If one commodity is priced strongly relative to another, focus sales there. Don't sell the cheaper commodity for a discount. For example, a farmer with wheat and barley to sell would sell the one that is getting good prices relative to the other, and hold the other for the meantime (see Figure 19).

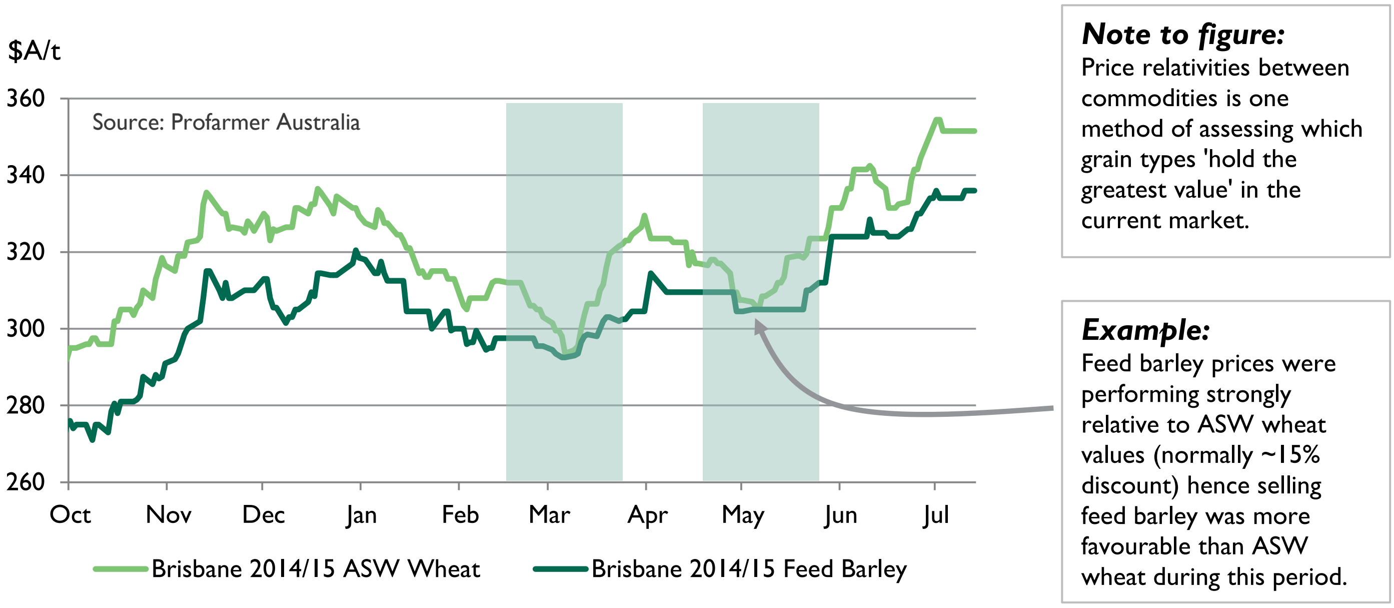


Figure 19: *Brisbane ASW wheat v. feed barley are compared, and the barley held until it is favourable to sell it.*

Source: Profarmer Australia

If the decision has been made to sell wheat, CBOT wheat may be the better choice if the futures market is showing better value than the cash market (Figure 20).

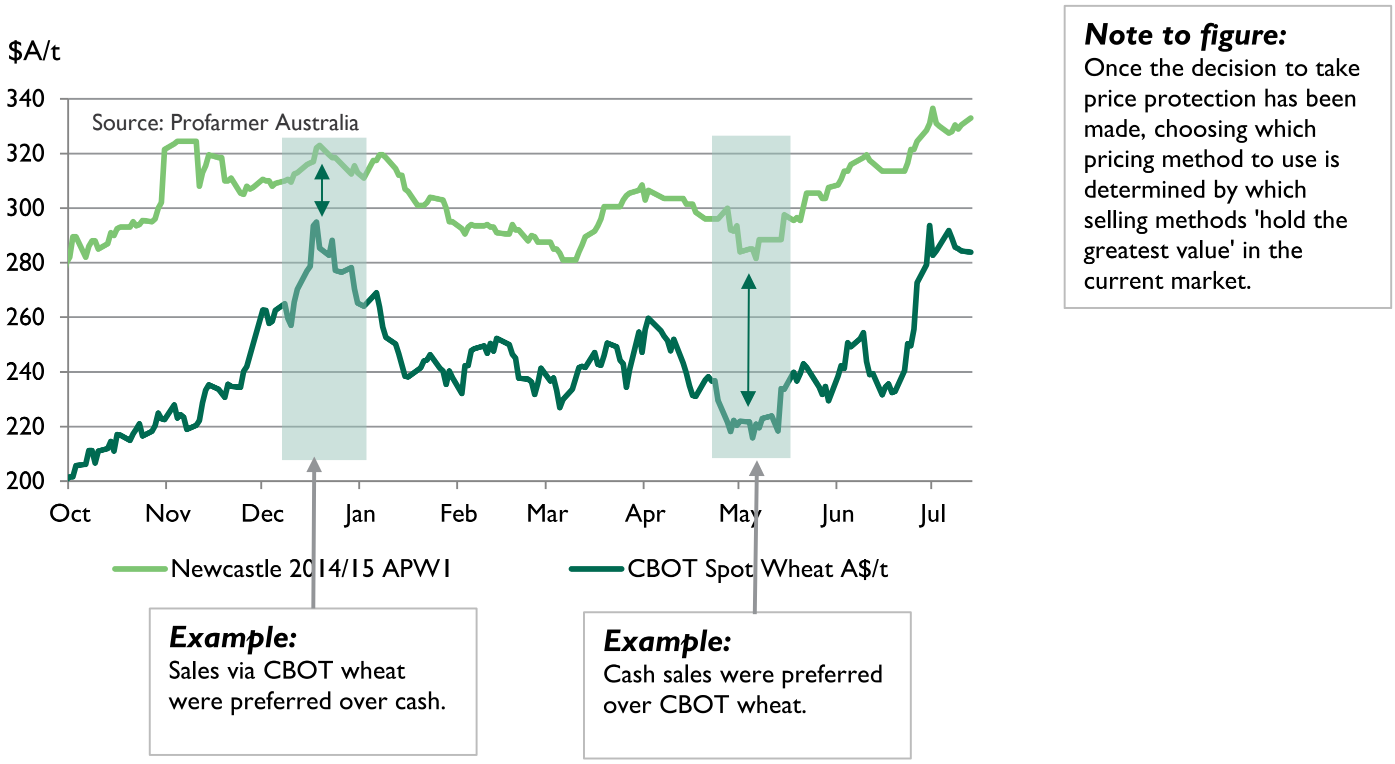


Figure 20: *By comparing prices for Newcastle APWI v. CBOT wheat, the grower can see which market to sell into.*

Source: Profarmer Australia

Contract allocation

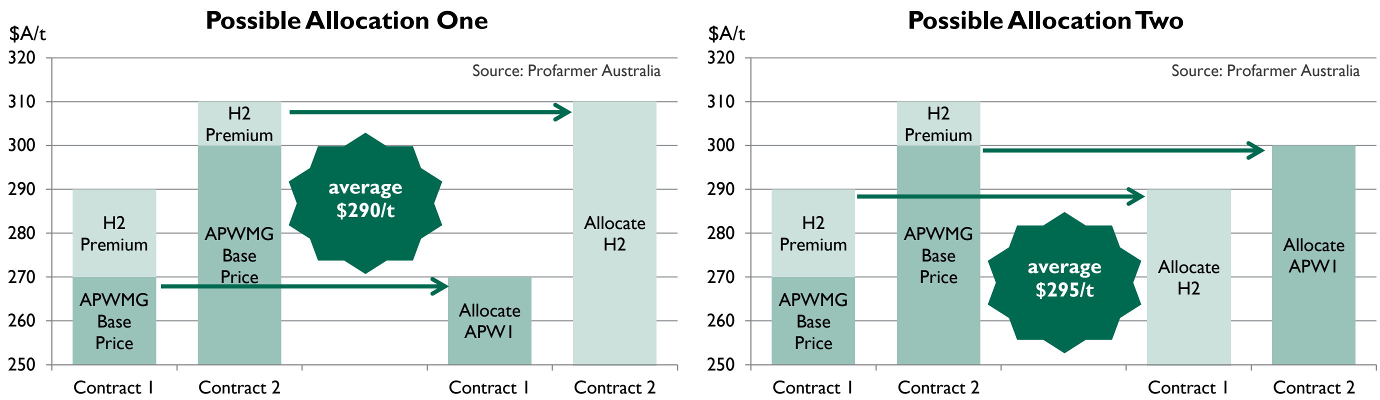
Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (e.g. price, premiums-discounts, oil bonuses), and optimising your allocation reflects directly on your bottom line.

Principle: Don't leave money on the table.

Contract allocation decisions don't take long, and can be worth thousands of dollars to your bottom line.

To achieve the best average price for their crop growers should:

- allocate lower grades of grain to contracts with the lowest discounts
- allocate higher grades of grain to contracts with the highest premiums (Figure 21).



Note to figure:
In these two examples the only difference between acheiving an average price of $290/t and $295/t is which contracts each parcel was allocated to. Over 400/t that equates to $2,000 which could be lost just in how parcels are allocated to contracts.

Figure 21: *How the crop is allocated across contracts can have an impact of earnings from the crop. Although this example uses wheat, the same principle applies for field peas.*

Source: Profarmer Australia

Read market signals

The appetite of buyers to buy a particular commodity will differ over time depending on market circumstances. Ideally growers should aim to sell their commodity when buyer appetite is strong, and stand aside from the market when buyers are not very interested.

Principle: Sell when there is buyer appetite.

When buyers are chasing grain, growers have more market power to demand the price they want.

Buyer appetite can be monitored by:

- The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate that buyer appetite is strong. However, if one buyer is offering $5/t above the next best bid, it may mean that cash prices are susceptible to falling $5/t as soon as that buyer satisfies their appetite.
- Monitoring actual trades against public indicative bids. When trades are occurring above indicative public bids it may indicate strong appetite from merchants and the ability for growers to offer their grain at price premiums to public bids.

The selling strategy is converted to maximum business revenue by:

- ensuring timely access to information, advice and trading facilities

- using different cash-market mechanisms when appropriate
- minimising counterparty risk by conducting effective due diligence
- understanding relative value and selling commodities when they are priced well
- thoughtful contract allocation
- reading market signals to extract value from the market or to prevent selling at a discount.

15.2 Northern field peas: market dynamics and execution

15.2.1 Price determinants for northern field peas

Northern field pea production has ranged from 7,000 to 16,000 tonnes in the five years to 2016. The domestic stockfeed industry is the traditional primary end-user; however, at least 50% of the field peas grown are varieties that are suitable for human consumption. Based on soil type, the region has the potential to produce at least 30,000 tonnes of field peas.

Field peas can make up 10–40% of pig rations and 5–30% of poultry rations. They are an efficient source of protein and energy, with a desirable amino acid profile and low levels of anti-nutritional factors (compounds that reduce the availalbility of nutrients).

2013 and 2014 saw direct export containers from central western NSW, and traders are now viewing the central west as a viable source of field peas for human consumption as well as for stockfeed.

Given the strong influence of international cropping and cultural events, Australian field pea growers should take the global cropping calendar into account when making decisions about field peas (Figure 22).

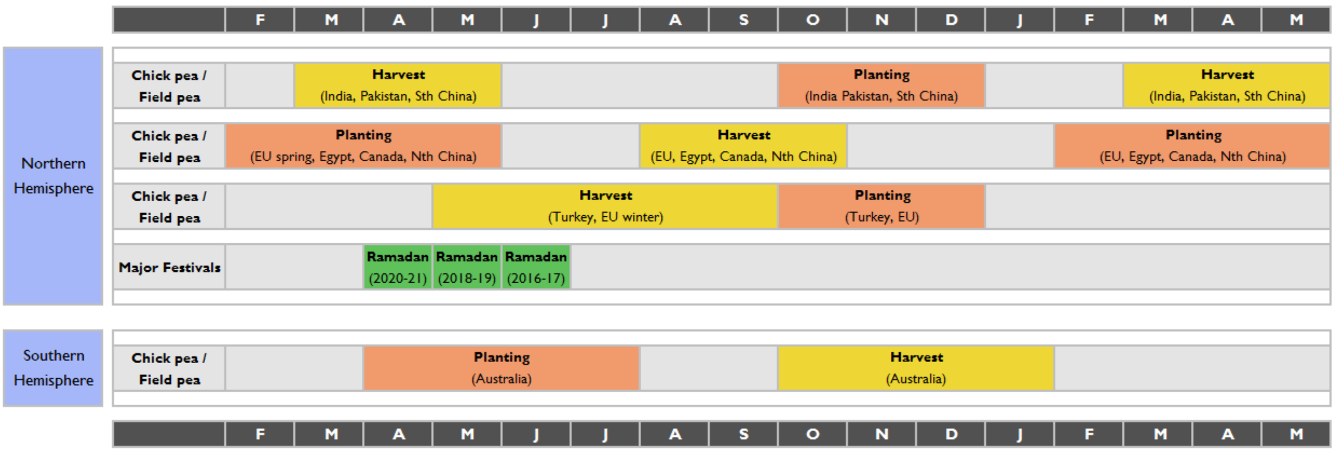


Figure 22: *Global field pea and chickpea crop calendar.*

Source: Profarmer Australia

Field pea pricing influences that affect northern growers stem also from domestic feed market forces. The factors that determine field pea stockfeed demand and feed quality price include:

1. The price of field peas relative to other sources of protein and energy that make up a least-cost ration—imported soybean meal (protein) and cereal grains (energy) are the major factors.
2. Export price opportunities—high export demand and prices for field peas flow through to domestic pricing.

3. The value of the Australian dollar—a low Australian dollar increases the import price of soybean meal and increases the export price of field peas.
4. Canadian field pea planting intentions.
5. Canadian production totals.
6. Canadian, USA and European excess production in the previous season, i.e. stocks on hand or carried over.
7. Indian domestic rabi season (harvest April–May) pulse production—any negative influences will increase the need for imports of either chickpeas or field peas.
8. The world price of chickpeas—field peas are purchased as a substitute pulse when the chickpea price is high.
9. The timing of festivals in importing countries—Ramadan is the most important festival. It occurs in the ninth month of the Islamic calendar and goes for 29 days. Ramadan occurs around June then May from 2017 to 2021 then will get closer to the end of the Australian harvest. This is favourable for supplying the Ramadan market post-harvest in Australia.

Field pea pricing is highly volatile by nature, with a large variation both within and between seasons (Figure 23). Factors contributing to price volatility include subcontinental market dynamics and trading culture, the ready substitution of chickpeas for field peas, and the chickpea and field pea crop size in Australia, competitor countries and the subcontinent.

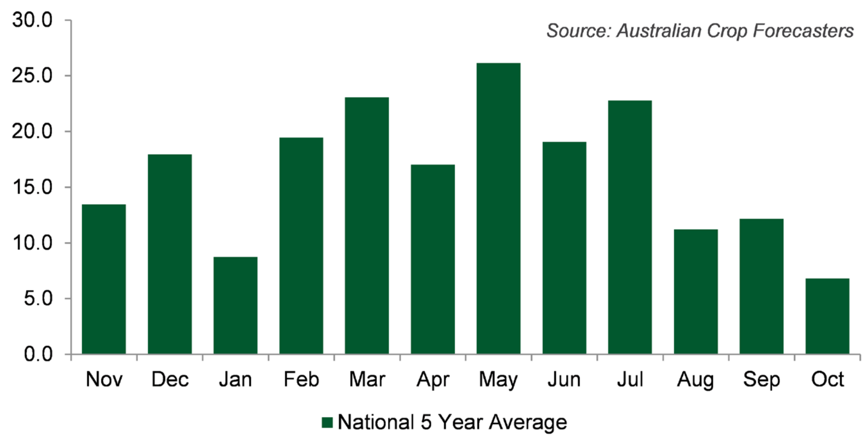


Figure 23: *The average monthly pace of Australian field-pea exports over 5 years ('000 t).*

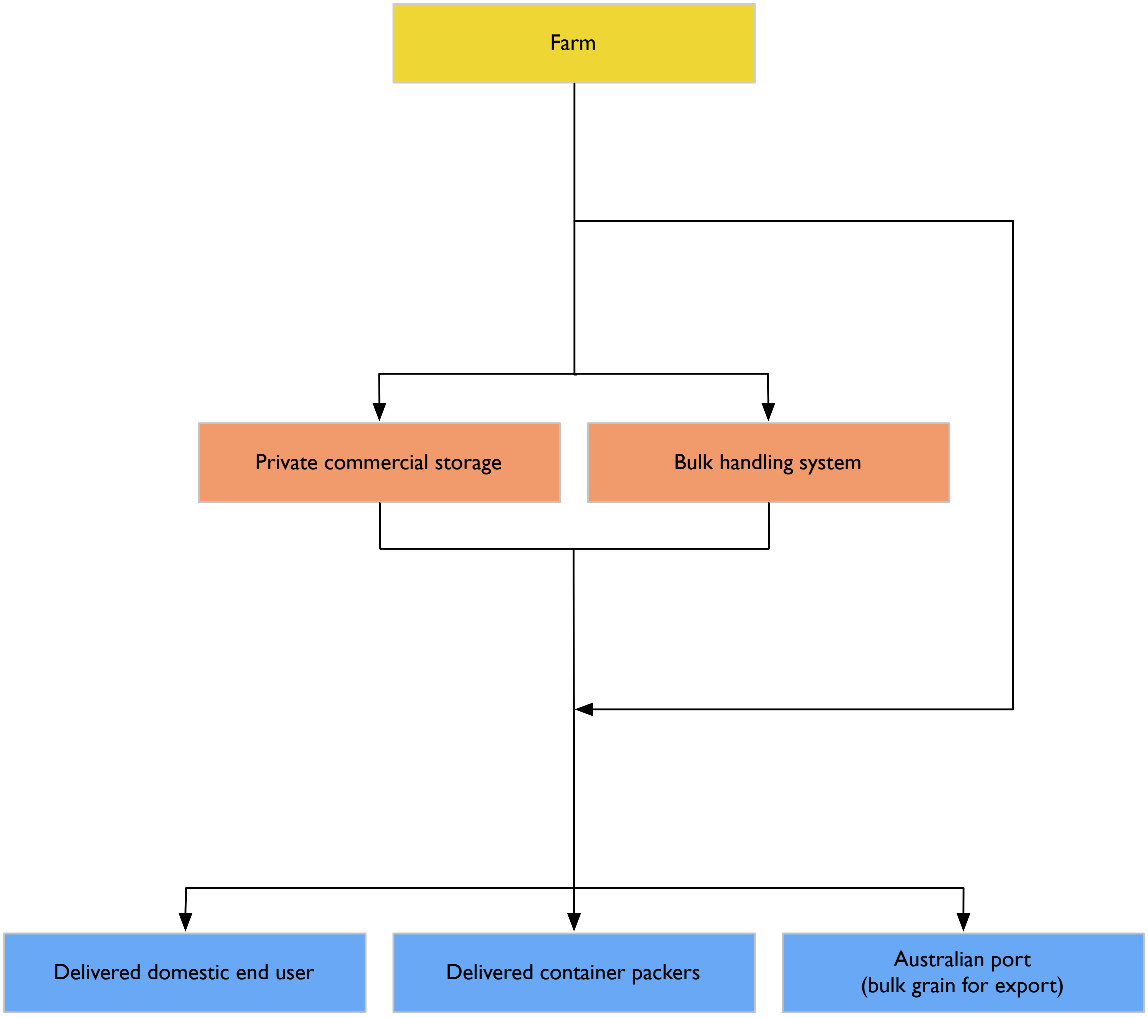
Source: Australian Crop Forecasters

15.2.2 Ensuring market access for northern field peas

The major food markets for field peas are in southern India and Sri Lanka. However, field peas in these markets face strong competition from Canadian yellow peas and chickpeas.

In domestic markets, field peas are an important source of protein in stockfeed rations, and in this instance face competition from alternative protein sources, including other pulses and imported soybean meal.

By and large, whether finding buyers in export (generally via container) or domestic markets, private commercial storage and on-farm storage both provide efficient paths to markets (Figure 24).



Note to figure: Storage decisions should be determined by assessing market access. The large majority of northern canola is exported in bulk. Hence the bulk handling system should provide efficiencies to market. NSW also services a relatively large domestic market and private commercial and on-farm storage should provide a reasonable method to access these markets.

Figure 24: *Australian supply chain flow.*

Source: Profarmer Australia

15.2.3 Converting tonnes into cash for northern chickpeas

Field pea marketability commences in the paddock by:

- ensuring that weed control has been adequate to minimise weed-seed contamination
- controlling insects and diseases to ensure good quality peas
- using a harvesting technique that minimises seed damage
- ensuring chemical withholding periods have been met.

The selling options for field peas are:

- Store on farm then sell—this is the most common option. Field peas are relatively safe to store and require less maintenance than cereal grains. It is still important to monitor and maintain quality, as field peas must meet strict quality specifications for export in order to avoid being discounted at the time of delivery. The grower must take into account the cost of storage when setting target prices.
- Cash sale at harvest—this is the least preferred option as buyer demand does not always coincide with harvest. Values can come under pressure at harvest time if a sudden increase in grower selling occurs in a small window,

subsequently providing buyers with the confidence that they can meet their short- and medium-term commitments.

- Warehouse then sell—this option provides flexibility for sales if on-farm storage is not available. The grower must take into account warehousing costs as part of the cost of production when setting target prices. Warehousing is unlikely to be available to northern growers, as the major bulk handlers do not provide this option due to the low volume of production. The availability of this option from packers within the 'delivered' market will vary depending on the individual buyer.

As with all sales, a thorough understanding of counterparty risk and the terms of the contract of sale is essential. Counterparty risk considerations are especially important for pulse marketing, as there is often a higher risk of contract default in international pulse markets than for canola or cereals, due to the markets they are traded into; the 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 buyers for their product.

The volatile nature of field pea pricing makes setting a target price difficult. To minimise the risk of taking a price that is unprofitable or holding out for an unrealistically high price that may not eventuate, growers can use decile charts (Figure 25) and price histories (Figure 26) as tools to help determine where to set their price.

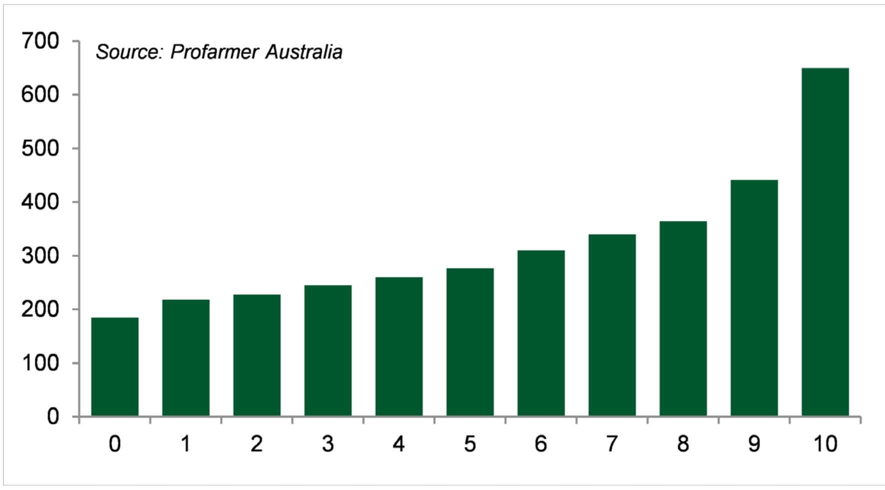


Figure 25: *Port Adelaide field pea deciles. Deciles provide an indication of price performance relative to historical values. Decile 1 indicates values in the bottom 10% of historical observations, and decile 9 indicates the top 10%.*

Source: Profarmer Australia

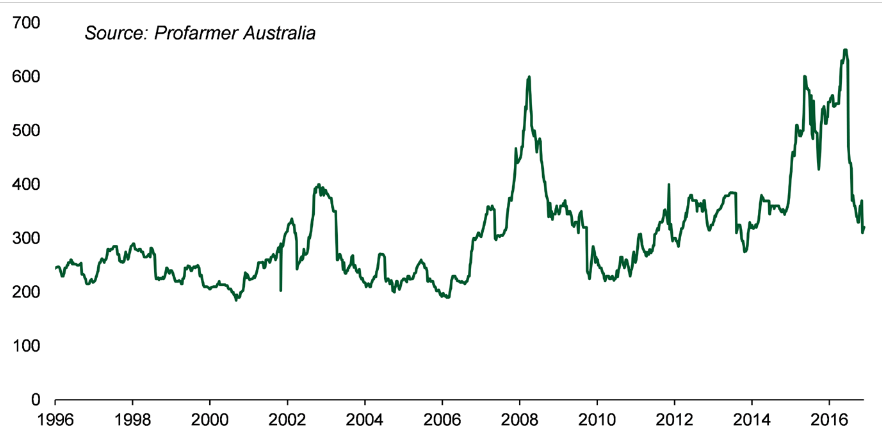


Figure 26: *Long-term Port Adelaide field pea price history.*

Source: Profarmer Australia

MORE INFORMATION

World pulse production calendar, in Pulses: Understanding global markets

Australian pulse traders

Understanding global markets: field peas

Field peas marketing and standards

AEGIC, Australian pulses

Agriculture Victoria, Growing faba bean

15.3 Variety specific marketing

Field pea production across the southern region is focussed firstly on the export human consumption markets ahead of the domestic stockfeed industry that the northern region imainly focuses on. With a small human consumption market emerging in the Central west of NSW for the blue green type peas.

Field pea varieties grown in Australia can be divided into five groups, with the most common of these being Dun followed by white and blue/green peas:

- Dun: greenish-brown (dun) coloured seed with yellow cotyledons. Traditionally dimpled, but rounded types exist now. Used for human consumption and stockfeed.
- White: (also called yellow peas in North America and Europe) 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 bird feed.
- Blue/green: 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]

Over 95% of Australian production is from dun types (i.e. grain has a coloured seed coat) of which more than 90 per cent is now 'Kaspa(D type' (e.g. Kaspa(D, PBA Gunyah(D, PBA Twilight(D). Kaspa(D type grain is preferred for snack food in southern India over other pea grain types and attracts a price premium. To avoid limiting the marketing of Kaspa(D type grain for export, growers should avoid sowing seed contaminated with Parafield or other dun types. [2]

The recent erratic supply of Australian white field pea has hampered the development of overseas markets, with the main competitor Canada producing large quantities of quality white or yellow field peas. The domestic stockfeed industry has been the major consumer of white field pea and this is expected to continue until more stable production occurs to allow export markets to be supplied on a continuing basis.

The Australian blue pea crop supplies a small niche domestic market and a few niche export markets. Quality is vital. Colour bleaching, pea weevil, *Helicoverpa* damage and contamination from other pea types are major problems that need to be addressed by growers. [3]

15.4 Links to industry boards

Pulse Australia: http://www.pulseaus.com.au/about/contact

Pulse Breeding Australia: http://www.grdc.com.au/Research-and-Development/Major-Initiatives/PBA

1 Field Peas: The Ute Guide (2009) Grains Research & Development Corporation. http://www.grdc.com.au/Resources/Bookshop/2009/12/Field-Peas-The-Ute-Guide

2 P Kennedy, J Brand, F Henry, M Raynes (2014) FIELD PEA. Victorian Winter Crop Summary 2014, http://agriculture.vic.gov.au/__data/assets/word_doc/0003/318873/Field-Pea-2016.docx

3 P Matthews, 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/agriculture/broadacre-crops/guides/winter-crop-variety-sowing-guide

Current and past research

Project Summaries www.grdc.com.au/ProjectSummaries

As part of a continuous investment cycle each year the Grains Research and Development Corporation (GRDC) invests in several hundred research, development and extension and capacity building projects. To raise awareness of these investments the GRDC has made available summaries of these projects.

These project summaries have been compiled by GRDC's research partners with the aim of raising awareness of the research activities each project investment.

The GRDC's project summaries portfolio is dynamic: presenting information on current projects, projects that have concluded and new projects which have commenced. It is updated on a regular basis.

The search function allows project summaries to be searched by keywords, project title, project number, theme or by GRDC region (i.e. Northern, Southern or Western Region).

Where a project has been completed and a final report has been submitted and approved a link to a summary of the project's final report appears at the top of the page.

The link to Project Summaries is www.grdc.com.au/ProjectSummaries

Final Report Summaries http://finalreports.grdc.com.au/final_reports

In the interests of raising awareness of GRDC's investments among growers, advisers and other stakeholders, the GRDC has available final reports summaries of projects.

These reports are written by GRDC research partners and are intended to communicate a useful summary as well as present findings of the research activities from each project investment.

The GRDC's project portfolio is dynamic with projects concluding on a regular basis.

In the final report summaries there is a search function that allows the summaries to be searched by keywords, project title, project number, theme or GRDC Regions. The advanced options also enables a report to be searched by recently added, most popular, map or just browse by agro-ecological zones.

The link to the Final Report Summaries is http://finalreports.grdc.com.au/final_reports

Online Farm Trials http://www.farmtrials.com.au/

The Online Farm Trials project brings national grains research data and information directly to the grower, agronomist, researcher and grain industry community through innovative online technology. Online Farm Trials is designed to provide growers with the information they need to improve the productivity and sustainability of their farming enterprises.

Using specifically developed research applications, users are able to search the Online Farm Trials database to find a wide range of individual trial reports, project summary reports and other relevant trial research documents produced and supplied by Online Farm Trials contributors.

The Online Farm Trials website collaborates closely with grower groups, regional farming networks, research organisations and industry to bring a wide range of crop research datasets and literature into a fully accessible and open online digital repository.

Individual trial reports can also be accessed in the trial project information via the Trial Explorer.

The link to the Online Farm Trials is Online trials - http://www.farmtrials.com.au/

Key contacts

GRDC Panel

John Minogue, Chair

John Minogue runs a mixed broadacre farming business and an agricultural consultancy, Agriculture and General Consulting, at Barmedman in south-west NSW. John is chair of the local branch of the NSW Farmers' Association, has formerly sat on the grains committee of the NSW Farmers' Association and is a winner of the Central West Conservation Farmer of the Year award. John has also been involved in the biodiversity area as a board member of the Lachlan Catchment Management Authority. His vast agricultural experience in central west NSW has given him a valuable insight into the long-term grains industry challenges.

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Penny Heuston, Deputy Chair

Penny Heuston is an agronomist based in Warren, NSW. She is passionate about the survival of the family farm and its role in the health of local economies. Penny is dedicated to ensuring research is practical, farm-ready and based on sound science and rigour. She sees 'two-way communication' as one of the panellists' primary roles and is committed to bringing issues from the paddock to 'the lab' and conversely, the science to the paddock.

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Loretta Serafin

Loretta Serafin has extensive experience as an agronomist in north-west NSW and works with the NSW Department of Primary Industries in Tamworth. As the leader northern dryland cropping systems, she provides expertise and support to growers, industry and agronomists in the production of summer crops. Loretta is a member of numerous industry bodies and has a passion for helping growers improve farm efficiency. She sees her role as a conduit between advisers, growers and the GRDC to ensure growers' research needs are being met.

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Jules Dixon

Jules Dixon has an extensive background in agronomy and an established network spanning eastern Australia and WA including researchers, leading growers and agronomy consultants through to the multinational private sector. Based in Sydney, Jules operates a private consultancy specialising in agronomy, strategy development and business review.

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Dr Neil Fettell

Neil Fettell is a part-time senior research adviser with Central West Farming Systems and runs a small irrigation farm near Condobolin, NSW. Neil has a research agronomy background, conducting field research in variety improvement, crop physiology and nutrition, Water Use Efficiency and farming systems. He is a passionate supporter of research that delivers productivity gains to growers, and of grower participation in setting research goals.

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Andrew McFadyen

Andrew McFadyen is an agronomist and manager with Paspaley Pastoral Company near Coolah, NSW, with more than 15 years' agronomy and practical farm management experience. He is an active member of the grains industry with former roles on the Central East Research Advisory Committee, NSW Farmers Coolah branch and planning committees for GRDC Updates. He is also a board member and the chair of Grain Orana Alliance.

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Jack Williamson

Jack Williamson is a private agricultural consultant and helps run a family broadacre farm near Goondiwindi, Queensland. Six years of retail agronomy and three years of chemical sales management have given Jack extensive farming systems knowledge, and diverse crop management and field work experience. He is a member of the Northern Grower Alliance local consultative committee and Crop Consultants Australia.

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Arthur Gearon

Arthur Gearon is a grain, cotton and beef producer located near Chinchilla, Queensland. He has a business degree from the Queensland University of Technology in international business and management and has completed the Australian Institute of Company Directors course. He is vice-president of AgForce Grains and has an extensive industry network throughout Queensland. Arthur believes technology and the ability to apply it across industry will be the key driver for economic growth in the grains industry.

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Dr Tony Hamilton

Tony Hamilton is a grower from Forbes, NSW, and managing director of an integrated cropping and livestock business. He is a director of the Rural Industries Research and Development Corporation. He has worked as an agricultural consultant in WA and southern NSW. With a Bachelor of Agricultural Science and a PhD in agronomy, Tony advocates agricultural RD&E and evidence-based agriculture.

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Brondwen MacLean

Brondwen MacLean was appointed to the Northern Panel in August 2015 and is the GRDC executive manager for research programs. She has primary accountability for managing all aspects of the GRDC's nationally coordinated R&D investment portfolio and aims to ensure that these investments generate the best possible return for Australian grain growers. Prior to her current appointment, Brondwen was senior manager, breeding programs, and theme coordinator for Theme 6, Building Skills and Capacity.

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David Lord, Panel Support

David Lord operates Lord Ag Consulting, an agricultural consultancy service. Previously, David worked as a project officer for Independent Consultants Australia Network, which gave him a good understanding of the issues growers are facing in the northern grains region. David is the Northern Panel and Regional Grower Services support officer.

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