SOUTHERN

SEPTEMBER 2017

GRDC

GROWNOTES™

LENTIL

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GRAINS RESEARCH & DEVELOPMENT CORPORATION

Start here for answers to your immediate Lentil crop management issues

What variety should I grow?

What paddock conditions suit lentil?

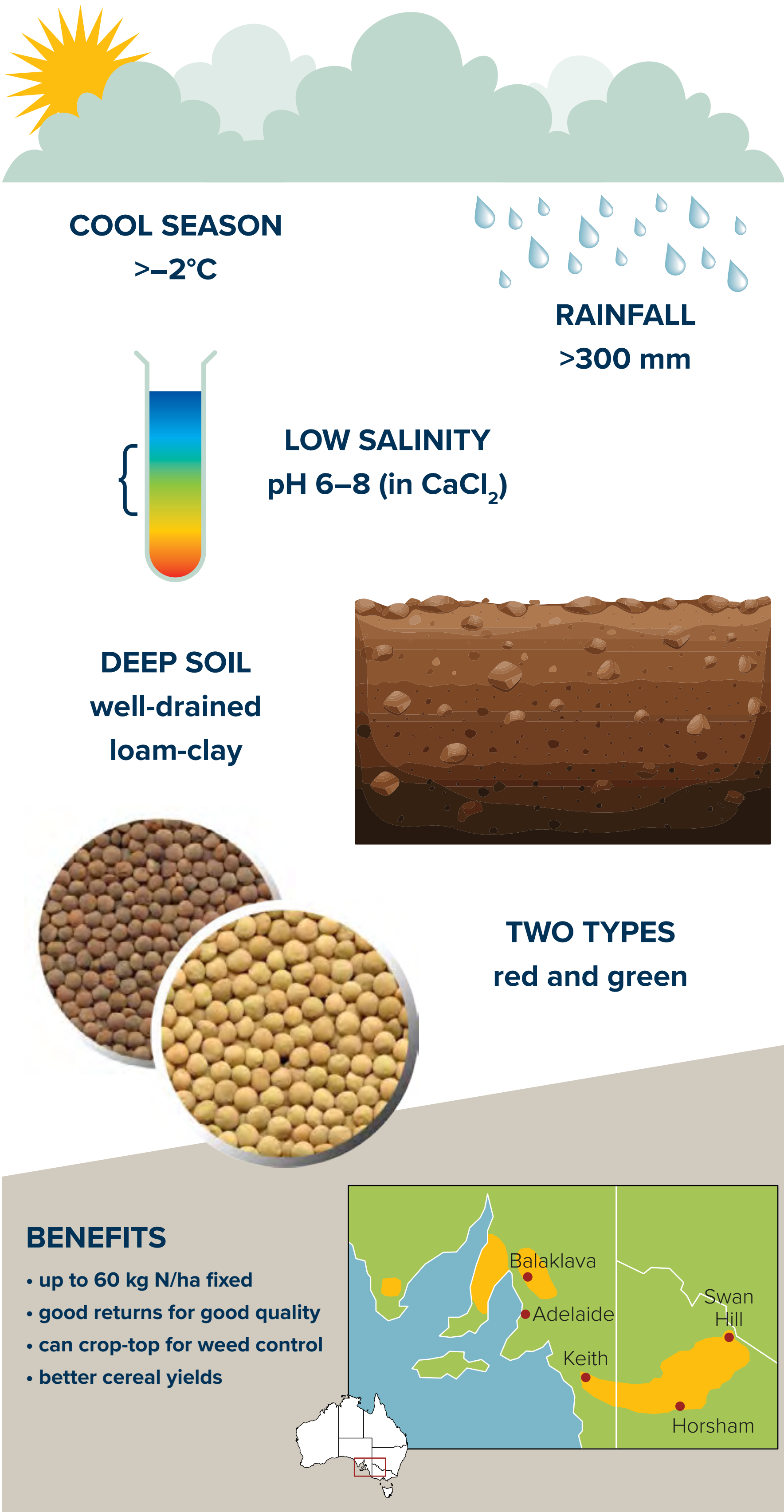
What are the key weed issues?

How are diseases managed?

What are the requirements for storing lentil?

What's the process for marketing lentil?

Lentil production



Source: Pulse Australia (2015) – Pulse Australia website

ISBN:

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12 Harvesting lentil

13 Storage and handling

Introduction

Key points

- Lentil usually commands a premium price compared to other pulse crops.
- Lentil fits well into cereal-based cropping systems.
- Lentil is mostly used for human consumption.
- Canada is the largest producer of lentil in the world.
- In Australia, lentil is predominantly grown in the semi-arid regions of South Australia and Victoria.
- Small areas of lentil are now being grown in southern New South Wales (and also Western Australia).
- Australia is a significant producer of red lentil.
- The area in Australia planted to green lentil is gradually increasing, as are the speciality types.

Keys to successful lentil production

- Paddock selection is critical. Choose free-draining soil with neutral to alkaline pH, and minimal sodicity, salinity and boron toxicity. Consider herbicide residues, likely weed presence and available weed-control options.
- Having adequate moisture for the plant to grow tall enough to be harvestable is essential. Sowing systems that retain stubble, thus aiding in reducing evaporation losses from the soil, are recommended. Consider inter-row sowing into standing cereal stubble. This helps lentil plants to grow tall and erect, making harvest more efficient.
- In choosing varieties factor in maturity, disease resistance, sowing time and farming system used. Consideration must be paid to market type, end user and delivery point when selecting varieties. Consider forward contracts if on-farm storage is not available.
- Always use quality seed and stick to recommended sowing depth (2–6 cm).
- Sowing on time (late April to May) is important to maximise yields, especially in drier situations.
- In wetter situations in southern Australia, lentil can be sown much later without significantly affecting yield. Increase the sowing rate if sowing is very late.
- Use a sowing rate that is likely to achieve a plant density of 120 plants per square metre (approximately 50–60 kg seed/ha for medium-sized seed).
- Inoculate seed with Group F rhizobia (Group E can also have some efficacy) and supply adequate nutrition (fertiliser).
- Manage pests and weeds during the crop's establishment and early growth. Monitor crops regularly for pests.
- Control foliar diseases through careful paddock selection (avoiding recent pathogen inoculum), crop canopy management and strategic fungicide applications as required.
- High humidity and excessive rainfall during the growing season encourage vegetative growth, which limits yield and can reduce seed quality.
- Excessive drought and/or high temperatures during flowering and pod-fill also reduce yields.
- Harvest as soon as the crop is mature. Lentil crops can turn brittle once fully matured and can be prone to shattering, especially following summer rainfall.
- To maximise grain quality, handle the grain carefully and avoid equipment blockages.
- Harvest during cooler conditions to improve harvest efficiency and reduce the risk of fire.
- Consider on-farm storage of lentil grain to enable access to more lucrative markets after harvest.[1]

1 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

MORE INFORMATION

A GRDC video on the value of pulses in the farming system is at https://youtu.be/ZfbW40oP0SI

1.1 The role of pulses in the farming system

Pulses have a role in the modern farming system far greater than the traditional nitrogen fixation and disease break they are best known for. They are a cash crop in their own right, and also a valuable part of the whole farming system, especially for weed control within crop rotations.

Stubble retention is commonly used for erosion protection and moisture retention, and pulses fit well into such systems. Machinery used in no-till or minimum-tillage systems can now handle stubble retention, which allows pulse crops to be sown after a cereal.

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

- to handle herbicide-resistant weeds, or delay the onset of herbicide resistance by varying herbicide options and timings for weed control;
- to control disease in all crops in the rotation;
- to spread the timing of farm operations;
- to spread risk across commodities; and
- to minimise the impact of increased costs of fertiliser nitrogen and fuel.[2]

Photo 1: *A lentil crop.*

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

1.2 Why grow lentil?

Lentil is a versatile and lucrative pulse crop in south-eastern Australia that offers a number of financial and rotational benefits in many cropping systems.

1.2.1 Economics of lentil production

Lentil usually commands a premium price compared to other pulse crops, such as pea and faba bean, with many world markets demanding lentil graded for human consumption. Lentil has recently (2014 to 2015) sustained high grain prices of $800 to 1200 a tonne. These prices are up to two to three times the average long-term (2004–2014) price. This has been due to short world supply.[3]

Although lentil prices are often higher than most other pulses (faba bean, lupin and field pea), they can be volatile due to fluctuating production world-wide. This is particularly true for countries that export close to 100% of their crop production, such as Canada and Australia.

In addition to changes in world demand and carryover surpluses, lentil that fails to meet human consumption grade may suffer a significant price drop due to potential lack of livestock feed markets.[4]

Photo 2: *Lentil plants up close.*

3 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

4 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

1.2.2 Lentil in the rotation

There are a number of **advantages** of having lentil in the rotation:

1. Lentil is a pulse break crop that can be used in rotations to effectively break the life cycle of cereal root diseases such as take-all, cereal cyst nematode and Rhizoctonia.
2. Lentil plants 'fix' their own nitrogen.
3. The shallow root system of the lentil plant, combined with a shorter growing season, means that soil moisture at depth is not fully extracted.
4. Compared to other winter crops, such as wheat or canola, the sowing window for lentil can be either early or late, depending on geographic location and variety. This can increase management options and help with the pre-sowing control of problem winter weeds.
5. In higher rainfall areas, lentil provides an opportunity to generate income from late-sown paddocks where seasonal conditions prevented the establishment of other winter crops.
6. Growing lentil can provide some management flexibility as selecting varieties with differing maturities can help spread peak demands on labour and machinery over a longer period of time.
7. Lentil fits well into cereal-based cropping systems, particularly when stubble is retained, with minimal additional machinery being required.
8. Lentil may also be sown as an opportunity crop into new areas or outside the optimum window and still produce economic yields. Examples include sowing in low-rainfall areas into a full profile of moisture following summer rainfall, sowing in spring to replace failed winter crops in a high-rainfall area, or delaying sowing to achieve better weed control.

Disadvantages of lentil in the rotation include:

1. Lentil does not have an extensive, deep root system to break up hard-pans and create channels in the soil profile that facilitate air and water movement like canola and safflower.
2. Lentil does not grow well on soils prone to waterlogging, boron toxicity or salinity.
3. Lentil is susceptible to fungal diseases such as Ascochyta blight and Botrytis grey mould.
4. Most lentil varieties are sensitive to carryover residues of Group B and Group I herbicides. PBA Herald XT⏀ and PBA Hurricane XT⏀ have herbicidal tolerance to imazethapyr when applied pre or post-emergence as per APVMA PER14369. This permit is valid until 31 August 2017. At least one product (Gemfarm imazethapyr 700wg) is now registered for use in Herald XT⏀ and Hurricane XT⏀.
5. The need to harvest the crop as soon as it is mature may be a problem for some growers, particularly larger-scale operations.[5]

5 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

1.3 Crop overview

1.3.1 History

Lentil (*Lens culinaris*) is one of the oldest domesticated crops. Originating in south-west Asia, lentil has formed part of the human diet since the beginning of agriculture.[6]

In Australia, lentil is an established, high-value pulse crop, first grown commercially in 1994.[7]

Lentil is mainly grown in the semi-arid regions of Victoria and South Australia with winterdominant rainfall patterns. Lentil consumption in Australia is gradually increasing however it is widely grown and consumed throughout the Mediterranean, the Indian subcontinent, southern Asia, and northern America.

1.3.2 Lentil end uses

Lentil is mostly used for human consumption. Compared to other pulses, lentil tends to have lower protein quality due to its low levels of sulfur amino acids and tryptophan. However, the protein is highly digestible. Lentil is lower in fat than chickpea and is a good source of iron. Lentil has a shorter cooking time than other pulses.

With approximately one-quarter of its calorific value coming from protein content, lentil (and most other pulses and legumes) is third only to soybeans and hemp in its level of protein by weight. As such a rich protein source, lentil forms an essential part of regular diet in many parts of the world, notably in the Indian subcontinent where vegetarian diets are common and fresh meat is expensive.[8]

Photo 3: *A sample of lentil.*

6 Centre State Exports (2016) Crops Marketed: Lentils. Centre State Exports Pty Ltd, http://www.centrestateexports.com.au/services/lentils.aspx

7 R Thyer (2016) Lentils push geographic boundaries. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-125--Pulse-breeding-advances/Lentils-push-geographic-boundaries

8 Centre State Exports (2016) Crops Marketed: Lentils. Centre State Exports Pty Ltd, http://www.centrestateexports.com.au/services/lentils.aspx

1.3.3 Lentil types

Lentil varieties differ physiologically by seed size, seed coat colour, kernel (cotyledon), colour and time to maturity. Australia is a significant producer of red lentil and the area planted to green lentil is gradually increasing, as is the area of specialty lentils such as 'Duy', 'Black' and 'Spanish'.

Red lentil, sometimes known as 'small' or 'Persian' lentil, is the most widely grown in Australia. It is sold split for cooking (Masur dhal). The name 'red lentil' is derived from the red kernel (cotyledon) colour, which is exposed when split and the seed coat removed. The seed coat colour varies from light grey, through brown to black, and may be speckled. Seed size is generally 4–6 mm in diameter, and red lentil varieties are classified as either small, medium or large-seeded types.

Green lentil, also known as 'large' or 'Chilean' lentil, is used whole for cooking. The seed coat is green to brown and the kernel (cotyledon) is yellow. Seed size is generally 4.5–8 mm in diameter.

Red and green lentil grains should not be mixed, nor should red lentil of different size categories be mixed.

Niche varieties for local and export markets (restaurant and specialist uses) are developing. Locally adapted varieties of these types are grown in small quantities under contract. These include Spanish varieties.[9]

Photo 4: *Good quality lentil seed.*

Photo: Paul Jones

9 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

1.4 Production

1.4.1 World lentil production

Lentil is grown throughout the world. World lentil production for 2013 was 4,975,621 metric tonnes, primarily coming from Canada, India and Australia.[10]

About a quarter of worldwide production of lentil comes from India, most of which is consumed in the domestic market. Canada is the largest export producer of lentils in the world.

Table 1: Lentil production ('000 mt) for selected major producers.

Crop Year/Country	2013–14	2014–15	2015–16	2016–17	2017–18
Australia	246	250	260	900	550
Canada	1,886	1,987	2,373	3,581	3,600
United States	198	153	240	450	450
Turkey	305	345	425	450	450
Syria	10	10	10	5	5
Morocco	30	60	55	35	35
India	425	585	800	825	825
Bangladesh/ Pakistan	85	90	90	90	90
Other	600	600	600	600	600
Total	3,785.3	4,080.0	4,853.0	6,416	6,605

MORE INFORMATION

Information on the Australian pulse industry, including lentil, can be found in a GRDC update paper 'Viable growth in the pulse industry'see https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/viable-growth-in-the-pulse-industry

1.4.2 Australian lentil production

Australia's lentil industry has benefited from the release of ever-improving varieties, which offer wider adaption, improved agronomic features, plant physiology, plant architecture and yield. These varieties, along with improved crop-management techniques, provide growers with the confidence to grow this high-value crop.

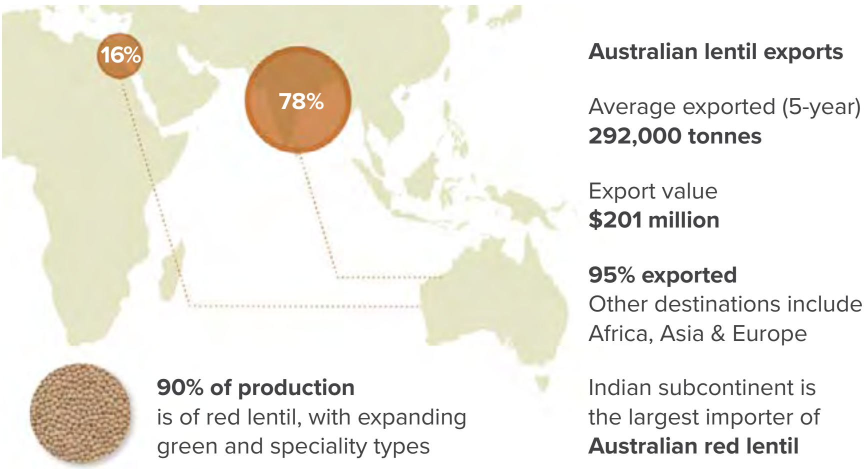

Figure 1: *Australian lentil production and exports.*

Source: P Semmler (2016), Pulse market update factors likely to impact supply demand and pricing in the next six to twelve months, (2016), Grains Research and Development Corporation, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/08/Pulsemarket-update-factors-likely-to-impact-supply-demand-and-pricingRole of lentils in southern region farming systems

10 United Nations Food & Agriculture Organization, Statistics Division (2016) http://faostat3.fao.org/home/E

MORE INFORMATION

Visit the GRDC website for information on maximising pulse performance in South Australian farming systems. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/maximising-pulse-performance-in-south-australian-farming-systems

Or for information on pulse opportunities in the Mallee see https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/07/new-opportunities-for-pulses-in-the-mallee

A GRDC Video on pulse breeding 'Pulse Breeding Australia Retrospective' is at https://grdc.com.au/archive/video/2011/07/gctv4-july2011/tmmloc9gsm0

Lentil in Australia is predominantly grown in the semi-arid regions of South Australia and Victoria with winter dominant rainfall patterns. Specifically, this is the Victorian Wimmera and Mallee areas, and the mid-north and Yorke Peninsula of South Australia.[11, 12]

The traditional growing area for lentil has expanded and is now being grown in low-rainfall, Mallee-type environments.[13]

Small areas of lentil are now being grown southern New South Wales (and Western Australia).

1.5 GRDC's lentil investment

The breeding strategy for pulse crops as a whole (including lentil) has been driven since 2006 by Pulse Breeding Australia (PBA).

PBA is an unincorporated joint venture between:

- the Department of Economic Development, Jobs, Transport and Resources, Victoria (DEDJTR);
- the South Australian Research and Development Institute (SARDI) ;
- the Department of Agriculture and Fisheries Queensland (QDAF);
- the New South Wales Department of Primary Industries (NSW DPI);
- the Department of Agriculture and Food Western Australia (DAFWA);
- the University of Adelaide;
- the University of Sydney;
- Pulse Australia; and
- the Grains Research and Development Corporation (GRDC).

Prior to 2006 the lentil breeding investment was conducted through the Coordinated Improvement Program for Australian Lentils (CIPAL).

Before Australia's lentil breeding strategy was driven by PBA, an Australian lentil improvement program had been ongoing for some time, with the last GRDC project completed in 2000. During the last two years of the final project (2004–2006), three new varieties were released (Cumra, Cassab, and Nugget), all being selected from imported lines.

Genotypes with traits such as early flowering, high vigour, increased height, lodging resistance, Asochyta blight resistance, Botrytis grey mould resistance, tolerance to high soil boron and superior quality had been identified through CIPAL. These genotypes gave the period of investment a sound base to produce further improvements in new varieties.

The principal outputs of these lentil investments by the GRDC have been improved varieties. Important traits from these improved varieties have been yield, yield stability and disease resistance. Improvements in these traits were delivered in the new varieties released from 2008 to 2012. Further improvements are expected in releases between 2012 and 2016. Higher yields and increased disease resistance can translate into higher profits from the lentil crop, in turn potentially increasing the attractiveness of lentil in rotations.

The total investment by the GRDC of $20 million (present value terms) has been estimated to produce total gross benefits of $60 million (present value terms) providing a net present value of $40 million.[14]

11 J Brennan, A Aw-Hassan, K Quade, T Nordblom (2002) Impact of ICARDA Research on Australian Agriculture. Economic Research Report No. 11, NSW Agriculture. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/146461/err-11-Impact-of-ICARDA-Research-on-Australian-Agriculture.pdf

12 R Thyer (2016) Lentils push geographic boundaries. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-125--Pulse-breeding-advances/Lentils-push-geographic-boundaries

13 R Thyer (2016) Mallee growers break through cereals' ceiling. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-125-NovemberDecember-2016/Mallee-growers-break-through-cereals-ceiling

14 Grains Research and Development Corporation (2013) An Economic Analysis of GRDC Investment in the Lentil Breeding Program, GRDC. https://grdc.com.au/Research-and-Development/Impact-Assessment

Planning and paddock preparation

Key points

- **Lentil requires annual rainfall greater than 300 mm**
- **When annual rainfall is greater than 550 mm, delayed or spring sowing may be necessary.**
- **Soil needs to be heavy and deep enough to hold sufficient water to finish the season.**
- **Soil needs to be friable without setting excessively hard on the surface.**
- **A soil pH between 6 and 8 (in calcium chloride) is required for lentil.**
- **Lentil requires free-draining soil as it does not tolerate waterlogging.**
- **Lentil paddocks need to be free of surface stones and sticks, and relatively flat.**
- **Plant-back periods and rainfall must accounted for to avoid herbicide residue damage when growing lentil.**
- **Low weed burdens for broadleaf weeds and herbicide-resistant annual ryegrass are required for growing lentil.**
- **Lentil should be sown into standing cereal stubble.**

2.1 Lentil requirements

Checklist for lentil paddock selection:

- Is annual rainfall >300 mm?
- If the annual rainfall is >550 mm, is delayed or spring sowing possible?
- Is the soil heavy and deep enough to hold sufficient water to finish the season?
- Is the soil friable and will not set excessively hard on the surface?
- Is the soil pH between 6 and 8 (in calcium chloride)?
- Is the soil free draining (no waterlogging)?
- Is the paddock free of surface stones and sticks, and relatively flat?
- Are plant-back periods and rainfall accounted for to avoid herbicide residue impacts?
- Are the weed burdens low for broadleaf weeds and herbicide-resistant annual ryegrass?
- Is the control of weeds possible?[1]

2.2 Rainfall and soil moisture

Lentil is best suited to locations that receive an annual rainfall of 350–500 mm. In drier or colder areas, lentil plants may not grow tall enough to be harvested efficiently.[2]

Lentil prefers the better, deeper, wheat-growing soils with higher water-holding capacity and good drainage ("Table 1: Soil requirements for pulse crops." on page 4).[3]

Lentil is particularly sensitive to waterlogging. Spring sowing may be an option on some deeper, heavier soils in higher rainfall areas.

Lentil varieties have an indeterminate growth habit in the environment with crop maturity in some being significantly affected by moisture supply.

Changes in soil type and moisture-holding capacity across a paddock can lead to uneven crop maturation, delayed harvesting, and increased risk of weather damage or high harvest losses. Desiccation can mitigate these risks.

Attention should be paid to the amount of stored soil moisture and received rainfall as this can have an impact on herbicide residues.

Photo 1: *Lentil dying under waterlogged conditions.*

Source M Raynes, formerly Pulse Australia

1 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

2 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

3 W Hawthorne (2007) Residual Herbicides and Weed Control. Pulse Australia Southern Pulse Bulletin, PA 2007 #03, http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides

2.3 Soil type

Paddocks that have an even soil type are relatively easier to manage and are preferred for lentil.[4] Changes in soil type across a paddock can lead to uneven crop maturation, which has implications for harvest. Implications include delayed harvesting, grain losses and increased risk of weather damage (all of which can be alleviated with desiccation).

Soil tests and paddock records should be examined, with particular attention paid to the following soil characteristics:

- pH 6 to 8 ($CaCl_2$);
- soil type – loams to self-mulching clays;
- low sodicity;
- low salinity/chloride; and
- no soild compaction and low bulk density.[5]

pH

Lentil is well suited to neutral to alkaline soils with a pH range of 6 to 8 ($CaCl_2$). A soil pH near 7 is best for lentil production.

Lentil performs poorly in acidic soils. Acid soils delay and limit nodulation and hence reduce yields. They can also cause growth and yield variation within a paddock. Reasonable yields can be achieved in paddocks with pH as low as 5 where aluminium and manganese levels are low (aluminium below 20 micrograms per gram and/or manganese below 50 μg/g.[6]

Soils with extreme low or high pH should be avoided.

Soil type

Lentil is best adapted to soil types of high fertility, from heavy clays to loamy sands. Lentil grows well in the self-mulching, grey clays of the Wimmera and will also grow successfully on loamy sands of the Mallee.

When grown on sandy loams, lentil requires a deep soil that is high in phosphorus and potassium.

Lentil will cope in loam and clay loam soils of low fertility. However, paddocks with low fertility will exacerbate the effects of waterlogging, salinity and high boron levels. Effects include variation in plant growth and reduced yield.

Sodicity and boron toxicity

Lentil is very intolerant to sodicity and boron toxicity. Excessive boron or sodic subsoil within the crop root zone can cause plant death and severely limit lentil yields.

Sodic soils are those with a sodium adsorption ratio (SAR) greater than 15. Tolerance to sodicity in the root zone (to 90 cm) is likely to be similar or less than chickpea. Less than 1% exchangeable sodium percentage (ESP) on the surface and less than 5% ESP in subsoil[7] (see Table 1).

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4 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

5 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

6 Agriculture Victoria (2005) Acid Soils. Agriculture Victoria AgNote Number: AG1182, http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/soils/acid-soils

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

Table 1: Soil requirements for pulse crops.

Crop	Soil type	Soil pH ($CaCl_2$)	Exchangable aluminium (%)	Drainage tolerance ** Rating (1–5)	Sodicity in root zone (90 cm) ESP ***
Lentil (estimate)	Loams – self-mulching clay loams	5.2–8.0	Nil	Very sensitive (1)	<1 surface <5 subsoil
Lupin - albus	Sandy loams, clay loams	4.6–7.0	Up to 8%	Very sensitive (1)	<1 surface <3 subsoil
Lupin – narrow leaf	Sandy loams	4.2–6.0	20% tolerant	Sensitive (2)	<1 surface <3 subsoil
Chickpea	Loams – self-mulching clay loams	5.2–8.0	nil	Very sensitive (1)	<1 surface <5 subsoil
Field pea	Sandy loams, clay	4.6–8.0	Up to 5–10%	Tolerant (3)	<5 surface <8 subsoil
Faba bean	Loams – clay loams	5.4–8.0	nil	Very tolerant (4)	<5surface <10 subsoil
Lucerne	Loams – clay loams	5.0–8.0	nil	Sensitive to tolerant (1-3)	<3 surface <5 subsoil
Canola	Loams – clay loams	4.8–8.0	0–5%	Tolerant (3)	<3 surface <6 subsoil

* Estimated to be the same as chickpea cited by Mullen (2004). ** No hard-pans and good drainage (no puddles after 24 hours from a 50 mm rain event). Hardpans – can aggravate waterlogging and cause artificial waterlogging. *** ESP = exchangeable sodium percentage.

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

Salinity

Lentil is very susceptible to salinity.

Saline soils are defined as those with an electrical conductivity (EC) of the saturated soil extract greater than 4 dS/m. Lentil is particularly salt-sensitive compared to cereal crops and other pulses. Yield reduction has been reported in lentil at about 20% at an EC of 2 dS/m and 90–100 % at an EC of 3 dS/m.[8]

There are small differences between varieties (moderately intolerant versus intolerant) that can be of practical significance, particularly in combination with boron sensitivity. (See variety “Table 3: Red lentil agronomic traits.” on page 17 and “Table 7: Green lentil agronomic traits.” on page 23)

Waterlogging

Effective drainage is essential as **lentil does not tolerate flooding or waterlogged soils**. Lentil plants will die if exposed to even short periods of waterlogging or flooding. Free-draining soils are a must when growing lentil.

8 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

2.4 Seedbed requirements

Surface condition, along with uniformity of soil type and topography, are all important criteria in assessing whether a paddock is suitable for growing lentil.

Lentil plants are short (15–80 cm) and can lodge at maturity, resulting in harvesting near-ground level. This means **paddocks must be flat** to allow harvesters to operate at a low cutting height. This is particularly an issue in dry seasons when crop height is low.

Heavily contoured and 'crab hole' country should be avoided when selecting paddocks for growing lentil.

Furthermore, with the increasing width of harvester fronts, small variations in paddock topography can lead to big variations in cutting height. This results in increases in harvest losses.

The soil surface of paddocks selected for lentil should be levelled as much as possible, either prior to, or at, sowing.

Cloddy or badly ridged paddocks are likely to cause soil contamination in the lentil sample during harvest.

Stones and sticks in paddocks are also an issue for growing lentil. Harvest losses increase dramatically if the harvester front needs to be raised, to avoid serious mechanical damage to the harvester, due to sticks and stones. Small stones and wood fragments can also contaminate the grain sample and downgrade quality.

MORE INFORMATION

For more information on rolling go to Section 5: Post-planting.

Foreign material must not exceed 3% by weight, of which no more than 0.3% must be un-millable material (soil, stones and non-vegetable matter). Lentil that does not meet this export standard needs to be graded at a cost to the grower of around $25 per tonne.[9]

The use of a roller after sowing is a common practice when growing lentil as it is a valuable aid for efficient harvesting. The purpose of rolling is to level out ridges in the soil caused by sowing, and push clods of soil and small stones and sticks down, level with the soil surface.

Photo 2: *A roller in a lentil crop.*

Photo: M. Raynes, formerly Pulse Australia

9 M Peoples (2015) Break crops should be a profitable choice. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Break-crops-should-be-a-profitable-choice

Photo 3: *Ridges in a lentil crop prior to rolling.*

Photo 4: *Clods can be a lentil harvest hazard: soil can contaminate the sample if the paddock is not rolled after sowing.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 5: *Stones can be a harvest hazard in lentil paddocks, highlighting the importance of rolling after sowing.*

Photo: W.Hawthorne, formerly Pulse Australia

IN FOCUS

Stubble bunching or clumping can occur when sowing lentil into retained stubble if inter-row sowing techniques are not utilised. The process of sowing can result in blockages of stubble that are left in clumps in the paddock which, in turn, becomes problematic at harvest. These mounds of stubble are often picked up in the harvester front, causing mechanical blockages and contamination of the sample if they contain excessive amounts of soil.

Options for dealing with stubble clumping include:

- using a zero-till (disc) seeder, or other seeder capable of handling heavy stubble;
- modifying existing air seeders (tyne shape and lifting some tynes);
- sowing before soil and stubble become too wet;
- using rotary harrows to spread and level stubble; or
- burning or slashing standing stubble if sowing equipment with good trash flow is not available.

Photo 6: *Flat paddocks assist with harvesting efficiency.*

Photo: T.Bray, formerly Pulse Australia

2.5 Stubble management

Stubble retention is when the stubble of the previous crop is left standing on the soil surface of the paddock or incorporated (buried) into the soil.

Lentil should be sown into standing cereal stubble.[10]

Photo 7: *Lentil sown into cereal stubble establishes well and loses less soil moisture than if sown into bare soil.*

Photo: W. Hawthorne, formerly Pulse Australia

Lentil fits well into stubble-retention systems such as minimum-tillage, direct drilling, no-tillage or zero-tillage. This is provided the physical sowing process is not affected by blockages of stubble in the seeder at sowing.

Yield increases of 10% and higher can be expected when lentil is sown into standing stubble utilising inter-row sowing.

Using GPS-guidance and auto-steer systems means lentil can be sown inter-row, between standing stubble rows. This aids in stubble clearance during sowing, often reduces herbicide throw and damage, and the lentil plant grows taller and more erect, achieving greater harvest efficiency.

Reducing the stubble load with livestock

Stubble can be grazed over the summer to benefit livestock and, importantly, reduce the stubble load in preparation for growing lentil.

It is important to note that stubble, which grazing animals have trampled, is lodged or brittle from summer rainfall can present difficulties at sowing, even when sowing inter-row.[11]

Rolling lentil

Rolling lentil after sowing, for harvest efficiency or herbicide safety reasons, partially flattens standing stubble. Partially flattened standing stubble still provides trellising support for the growing plant.

10 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

11 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Erosion

On sandy and light soils, stubble retention lessens the risk of wind erosion. Stubble loads are often low on these soils and do not usually present a barrier to minimum-tillage sowing or direct drilling. Stubble retention and reduced tillage also provide protection from water erosion on hills and steep slopes, especially during summer rainfall or storms.

Slugs and snails

Stubble retention is often not possible in areas where slugs and snails are a major problem at establishment, or where snails are a concern at harvest, particularly in higher rainfall zones.

In southern Australia, late burning of high stubble loads just before sowing can assist with sowing (by reducing likelihood of blockages due to excess stubble), and the control of pests such as slugs and snails.

After a late stubble burn the soil surface is exposed, which increases the risk of erosion. It also allows weeds to establish more readily, compared to retained stubble.[12]

Stubble from drought-affected cereal or hay

Lentil crops that follow a drought-affected cereal or a hay cut may not benefit from the limited amount of stubble retained. This is particularly so when sowing is aggressive, causing a high level of soil disturbance and incorporation of the remaining stubble.[13]

Photo 8: *Stubble management trials on lentil.*

Photo: M. Lines, formerly Southern Pulse Agronomy

12 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

13 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

MORE INFORMATION

Go to the GRDC website for the following information:

The value of break crops in low rainfall farming systems and which ones perform best.
https://grdc.com.au/news-and-media/news-and-media-releases/south/2015/04/lentils-benefit-from-stubble-support

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

2.6 Rotation history

Pulses have an important, complementary role in crop rotations, by enabling better management of weeds, diseases, herbicide residues and soil nitrogen.[14]

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

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

Recent research in Victoria and southern New South Wales showed that canola and pulse crops were frequently as profitable, and, in some cases, considerably more profitable, than wheat. Furthermore, wheat following break crops (including pulses) was consistently more profitable than a wheat-on-wheat rotation.[15]

Some growers have adopted a pulse–wheat–barley sequence as a basic rotation.

However, where a pulse can be grown with other crops, growers are increasingly adopting a continuous pulse–cereal–oilseed–cereal rotation.[16]

Successive cropping with the same pulse is likely to result in rapid build-up of root and foliar diseases and weeds. **Extreme care must be taken if growing the same crop in the same paddock without a break of at least three years.**

Where possible, different pulse crops should be alternated when in a continuous rotation with cereals.

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

15 M Peoples (2015) Break crops should be a profitable choice. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Break-crops-should-be-a-profitable-choice

16 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

2.7 Herbicide residues in soil

Lentil is extremely sensitive to some residual herbicides.[17]

Residues from herbicides used in the previous crop (sometimes previous two crops) can cause damage to the lentil plant. This is particularly so when summer rainfall has been minimal, as adequate rainfall and time are required to break down herbicide residues in the soil profile.

It is very important to know the chemical history of the paddock for at least two seasons. This includes:

- the chemical used;
- the group to which the chemical belongs;
- the plant-back periods;
- the soil pH;
- rainfall; and
- other requirements for herbicide breakdown.[18]

Herbicides applied two season ago can still have an impact, as can the presence of cereal stubble containing herbicides like Lontrel®. In some situations, some herbicides from more than two seasons ago can still have an impact.

Reading the herbicide label is critical to ensure adherence to plant-back periods. The plant-back period is the period of time required from spraying a herbicide to when it is safe to grow a new crop. It is deemed safe because the herbicide residues have broken down in the soil and can no longer damage the new crop.

Pulses and other crop types differ in their sensitivity to residual herbicides, meaning plant-back periods vary for crop types and also among varieties.

Most lentil varieties are particularly sensitive to soil carryover residues of Group B herbicides and Group I herbicides. Group B herbicides include sulfonylurea (SU) and imidazolinone (IMI). Examples of sulfonylurea herbicides include Ally®. Imidazolinone herbicides include On Duty® and Spinnaker®. Clopyralid and picloram are examples of Group I herbicides.

The recently released varieties PBA Hurricane XT⚘ and PBA Herald XT⚘ varieties show less sensitivity to sulfonylurea and imidazolinone (Group B) herbicide carryover residues.

These varieties (released in 2014 and 2012) have tolerance to imazethapyr. These XT⚘ varieties allow a lentil crop to be grown without the risk of yield loss from herbicide damage.

Not all chemical labels include lentil in the plant-back information. Extra caution and advice, from the manufacturer and an experienced agronomist, are recommended when planning rotations for lentil.

MORE INFORMATION

For detailed information on herbicide residues go to Section 4.6 and Section 8.7.

17 W Hawthorne (2007) Residual Herbicides and Weed Control. Pulse Australia Southern Pulse Bulletin, PA 2007 #03, http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides

18 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

2.8 Weed status of paddock

Lentil competes poorly against weeds and paddocks with high weed burdens should be avoided for growing lentil. This particularly refers to broadleaf weeds that cannot be controlled by herbicides and high levels of herbicide-resistant ryegrass.[19]

Photo 9: *Weed infestations are difficult to control in paddocks planted to lentil.*

Photo: M. Ryanes, formerly Pulse Australia

Problem weeds

Some weeds are often more difficult to control in lentil than in other pulse crops. It is important to control these problem weeds in the years prior to growing lentil. These weeds include:

- vetches;
- tares;
- bifora;
- medics;
- self-sown peas;
- bedstraw;
- herbicide-resistant ryegrass;
- wild radish;
- beans;
- ball mustard;
- cleavers;
- soursob; and
- marshmallow.[20]

Attention must be given to preventing seedset of weeds in paddocks in the years prior to growing lentil.

19 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

20 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

Contamination

To avoid seed contamination at harvest, **lentil should not be grown in paddocks with a history of vetch.**

Cereal grains are not easily cleaned from lentil grain so self-sown cereals must be removed from lentil crops using grass herbicides.

Control

It is rarely possible to select a paddock with a weed-free status. Consequently, there are a range of herbicides available to provide effective weed control in lentil.

It is important to note that herbicides can affect lentil yield. Furthermore, there are differing degrees of sensitivity to specific herbicides in lentil varieties.

Close attention must be paid to weed control during the cropping season as weed numbers are likely to increase, resulting in reduced yields and potentially affecting future crops.

MORE INFORMATION

For detailed information on weed control go to Section 8: Weed control.

MORE INFORMATION

See Section 10: Diseases and Nematodes for further information.

2.9 Disease status of paddock

Foliar diseases

To minimise foliar disease, it is recommended lentil crops should be separated from the previous year's lentil stubbles (and other pulse stubbles) by at least 500 m, and up to 1 km in areas where old stubble is prone to movement (for example, down slope and on flood plains).[21] The practicalities of achieving this are difficult. Current practice tends not to be sowing into a previous pulse stubble. However, sowing next to a paddock with a previous pulse stubble is considered acceptable.

This helps to reduce the spread of Botrytis grey mould and Ascochyta blight, both foliar and stubble-borne diseases.

Root diseases

Cereal cyst nematode

Cereal cyst nematode (CCN), or eelworm, was considered the most serious root disease in the majority of cereal-growing districts in the 1980s and 1990s. CCN requires a cereal or grass host to develop. Therefore, a pulse crop (a grass-free crop) following a cereal crop results in a significant reduction in the severity of the disease.

Pulses are one of the key factors in an overall long-term management strategy to control or avoid CCN.

Take-all (haydie)

Take-all, like CCN, must have a cereal or grass host to develop. As non-hosts, pulses, such as lentil can be used very effectively as a one-year disease break crop in a cereal rotation.

Rhizoctonia

Rhizoctonia has a very wide host range and so, unlike CCN or take-all, attempting to reduce the problem through crop rotation is not as effective. However, sowing and tillage practices can be very effective.

Another key factor in controlling Rhizoctonia is the availability of nitrogen in the soil. Including a pulse in a cereal rotation increases the amount of available nitrogen to the following crop. It is this increase in nitrogen that both masks some of the effects of the disease and helps the crop in recovering after an attack of Rhizoctonia.

*Root-lesion nematode (*Pratylenchus *spp)*

Either of the two species of root-lesion nematode (*Pratylenchus neglectus* or *P. thorneii*) can reduce cereal crop yields. Growing a pulse crop that is resistant to root-lesion nematode (for example, lentil) can increase cereal yields by reducing the nematode population.

Disease combinations

In a normal cropping rotation, it is unusual for cereal root diseases to occur independently. Consequently, the ability of a pulse crop to reduce the severity of most major cereal root diseases is considerable.

The effectiveness in controlling cereal root diseases is dependent on grass weed control in non-cereal phases. In other words, **the success of the pulse in the rotation hinges on the control of all grassy weeds and volunteer cereals during the pulse phase**. Grassy weeds and volunteer cereals that survive in the pulse phase can carry over cereal root diseases.

For take-all, one year of a grass-free break crop is enough to gain maximum benefit. With CCN, several years of a break are required. Hence, maximum benefit is achieved through a crop rotation that includes pulses in combination with resistant cereal varieties, grass-free pastures and canola.

21 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

MORE INFORMATION

For information on nitrogen fixation go to the following GRDC Factsheets:

Nitrogen fixation of crop legumes: basic principles and practical management
https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/07/grdc-fs-nfixation-legumes

Nitrogen fixation benefits of pulse crops
https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2009/09/nitrogen-fixation-benefits-of-pulse-crops

MORE INFORMATION

For detailed information on nutrition requirements for lentil go to Section 7: Nutrition and fertiliser.

2.10 Nutrition status of paddock

Soil fertility

The move by many growers to adopt more intensive cropping rotations, including lentil, can have a negative impact on soil fertility if it is not actively managed.

Using pulses in the rotation assists in maintaining soil fertility. A trial in South Australia aimed to determine the effects of rotation on soil nitrogen (Table 2). After 10 years of continuous cereal and pulse cropping soil fertility was maintained in terms of both total soil nitrogen and organic matter.

Table 2: Effect of rotation on total soil nitrogen (%) and organic carbon (%) in the surface soil (0–10 cm).

	Total soil nitrogen (%)	Total soil nitrogen (%)	Organic carbon (%)	Organic carbon (%)
Rotation	**At start**	**5 years later**	**At start**	**5 years later**
Continuous wheat	0.087	0.079	0.93	0.88
Wheat/field pea	0.090	0.088	0.99	0.95
Wheat/lupin	0.089	0.102	0.95	0.92
Wheat/faba bean	0.094	0.095	0.98	0.95
Wheat/volunteer pasture	0.087	0.088	0.95	1.01
Wheat/sown pasture	0.092	0.099	0.98	1.12
Wheat/fallow	0.090	0.086	0.98	0.88

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

When choosing paddocks for growing lentil, it is important to take into account the ability of plants to fix their own nitrogen.

Additional nutritional requirements can be met with the application of fertiliser.

Pre-planting

Key points

- Lentil varieties differ physiologically by seed size, seed coat colour, kernel (cotyledon), colour and time to maturity.
- Red lentil is split or de-hulled for human consumption.
- Contamination of 'off-type' lentil varieties can lead to marketing concerns.
- Green lentil is predominantly used whole for cooking.
- Seed coat colour can be influenced by environmental conditions before harvest, post-harvest handling, time in storage and storage method.
- A variety's seed size is influenced by rainfall, soil type and seasonal conditions.
- Disease management is still a primary concern when growing lentil.
- Herbicide-tolerant (XT) lentil varieties are available to assist in weedy situations.
- High-intensity cropping can change the disease resistance ratings of varieties.
- Seed quality is very important in producing high grain yields.
- Quality seed has good germination and vigour.

MORE INFORMATION

For more information on variety cross-contamination, see: http://pulseaus.com.au/growing-pulses/bmp/lentil/variety-cross-contamination

3.1 Lentil types

Lentil varieties grown in Australia are divided into two main types. The red lentil types have red cotyledons and the green lentil types have yellow cotyledons.

It is critical that there is not contamination of other variety types in lentils delivered to markets.Variety contamination is restricted to 1% at delivery,and includes lentils of differing seed coat colour or size (even if the seed colour is the same) or type (red vs green).

Table 1: Australian lentil varieties.

Seed coat colour	Seed size and type				
	Small red	Medium red	Large red	Medium green	Large green
Grey	Nipper[(b)1] PBA Bounty[(b)1] PBA Herald XT[(b)2] PBA Hurricane XT[(b)1]	Nugget[3] PBA Ace[(b)3] PBA Blitz[(b)3] PBA Bolt[(b)3] Digger[3]	PBA Jumbo[(b)4] PBA Jumbo2[(b)4]		
Tan	Northfield[1]	–	–	–	–
White – green	–	PBA Flash[(b)3] Cobber[3]	Aldinga[4]	Matilda[5] PBA Greenfield[(b)5]	Boomer[6] PBA Giant[(b)6]

1 SRP = small red (premium round) 2 SRS = small red (split) 3 MRD = medium red (dual purpose) 4 LRS = large red (split)
5 MG = medium green 6 LG = large green

Source: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

3.1.1 Red lentil

Red lentil, sometimes known as small or Persian lentil, is the most commonly grown in Australia and is split or de-hulled for human consumption.[1]

Red lentil is so named because of their red kernel (cotyledon) that is exposed when the seed coat is removed and the seed split.

The cotyledon (kernel) colour required for international trade is red, but seed coat colour can vary from light grey, black to brown or red and may be speckled. The predominant seed coat colour targeted in Australia is grey and this, to a large extent, is genetically determined and highly heritable.[2]

Seed coat colour can be influenced by environmental conditions before harvest, post-harvest handling, time in storage and storage method.

Seed size can vary according to the variety (Table 1) and is influenced by rainfall, soil type and seasonal conditions.

1 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

2 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Photo 1: *Whole red lentils.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

Photo 2: *Split red lentils.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

3.1.2 Green lentil

Green lentil, also known as large or Chilean lentil, is predominantly used whole in cooking.[3]

The seed coat is green to brown and the kernel colour is yellow. Seed size can vary from 6 to 10 mm in diameter. French green lentil, another green type, is a very small, dark-coloured lentil with a green kernel.

The cotyledon (kernel) colour required for international trade is yellow with a green-white seed coat that is unblemished. Colour is genetically determined and highly heritable, but blemishing is weather dependent.

Seed coat colour can be influenced by environmental conditions before harvest, post-harvest handling, time in storage and storage method. Canada sets the market standard for seed size by supplying large (Laird types), medium (Eston types) and small (Richlea types) green lentils.[4]

3 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

4 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Seed size and market category of current Australian varieties vary between the large and medium grades. There is currently no Australian variety in the small green lentil grade. However, there are breeding lines that could meet this market grade in the future.[5]

A variety's seed size is influenced by rainfall, soil type and seasonal conditions.

Photo 3: *Green lentils.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

3.2 Selection of varieties

MORE INFORMATION

For more information on variety choice in weedy situations see Section 8: Weed control

IN FOCUS

When choosing a variety both marketability and agronomic traits must be considered.

Marketability includes colour, size, shape and texture. Price paid can differ between varieties and premiums or discounts can be based on colour, type, size, and supply and demand.

Lentil varieties differ in their agronomic traits including disease tolerance, yield and time to maturity. Growing more than one variety might be an option for spreading risk.

Disease management is still a primary concern when growing lentil. Varieties must have the desired trait to manage disease for the location grown.

Herbicide-tolerant (XT) varieties may also drive variety choice in weedy situations.

5 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

MORE INFORMATION

For more information on the development of herbicide tolerance in lentil go to the GRDC website:

Lentil research in progress including herbicide tolerance in the pipeline. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/08/lentil-research-in-progress-including-herbicide-tolerance-in-the-pipeline

Developing improved herbicide tolerance in pulse crops. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/developing-improved-herbicide-tolerance-in-pulse-crops

3.2.1 Area of adaptation

Lentil varieties are bred for, and selected in, a range of different environments. Hence, individual varieties have specific areas of adaptation for maximising yield and reliability. Specific adaptation of a variety depends on rainfall, geography, temperature, disease pressure and soil types.

Pulse Breeding Australia has defined five regions in Australia for growing pulses (Figure 4). The production area for lentil is confined to two regions based on rainfall and geographic location:

- Region 4 – medium to high rainfall (Mediterranean/temperate); and
- Region 5 – low to medium rainfall (Mediterranean/temperate).

These regions cross state borders and are target zones for breeding programs and variety evaluation.

Results from breeding and the National Variety Trial (NVT) program highlight specific adaptation of varieties within a region (see Table 2 to Table 9). Some varieties have been found to be better adapted to specific parts of regions.

Lentil varieties are targeted to Regions 4 and 5.

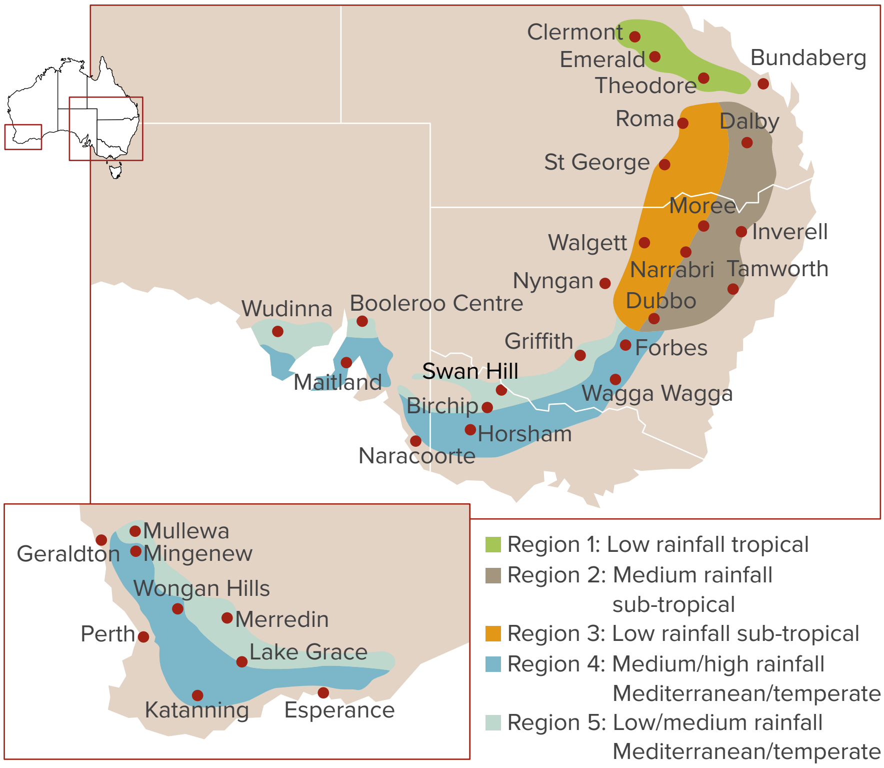

Figure 1: *Regions for growing pulses.*

Source: Pulse Breeding Australia via Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

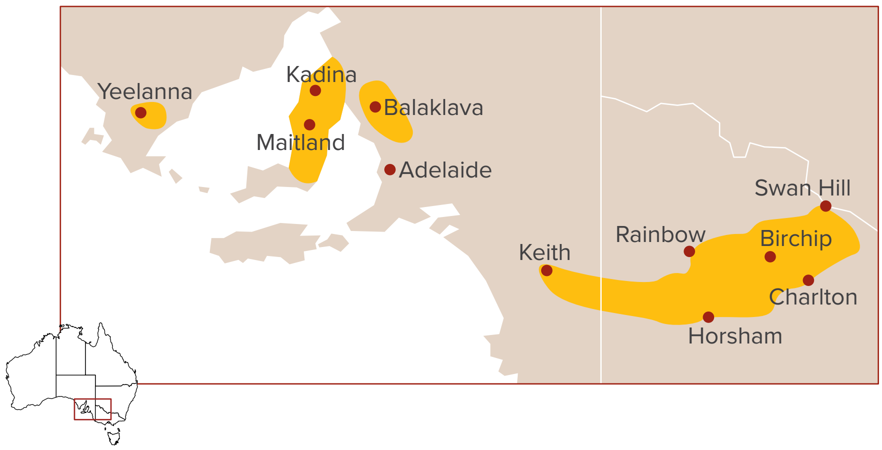

Figure 2: *The principal lentil-growing areas are in South Australia and Victoria.*

Source: Pulse Breeding Australia via Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

MORE INFORMATION

For more information see http://pulseaus.com.au/storage/app/media/crops/pulses/2016_Pulse-Variety-Charts-web.pdf

Victorian lentil variety information

For Victorian information on lentil, see the Victorian Winter Crop Summary 2017: http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary

South Australian lentil variety information

For South Australian information on lentil, see the SA Sowing Guide 2017: http://www.pir.sa.gov.au/research/services/reports_and_newsletters/crop_performance

New South Wales lentil variety information

Limited research and trials have been conducted on lentil in New South Wales. Consequently, there are no local management guides or yield data for this region. Information should be sourced from South Australia and Victoria.

For specific information on lentil in NSW see:

'Agronomy and production of lentil in southern NSW 2016' by Richards *et al.* (2016): https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Agronomy-and-production-of-lentil-in-southern-NSW-2016

3.3 Red lentil varieties

3.3.1 Small red varieties

PBA Hurricane XT⊕

PBA Hurricane XT⊕ is a small, red-seeded lentil with mid flowering and maturity.

PBA Hurricane XT⊕ has tolerance to imazethapyr with an interim permit for pre or post-emergent application to 2017. It has improved tolerance to the herbicide flumetsulam plus reduced sensitivity to some sulfonylurea and imidazolinone herbicide residues.

Product label rates, plant-back periods and all label directions for chemical use must be adhered to when growing PBA Hurricane XT⊕.

PBA Hurricane XT⊕ is the highest yielding small red lentil available in Australia and has improved yields over PBA Herald XT⊕, Nipper⊕ and Nugget, but lower than PBA Ace⊕.[6]

It is moderately resistant (MR) to foliar Ascochyta, resistant (R) to seed Ascochyta and moderately resistant–moderately susceptible (MR-MS) to Botrytis grey mould.

PBA Hurricane XT⊕ was released in 2013 and is commercialised by PB Seeds. It has an End Point Royalty of $5.50 per tonne.

It is adapted to Regions 4 and 5.

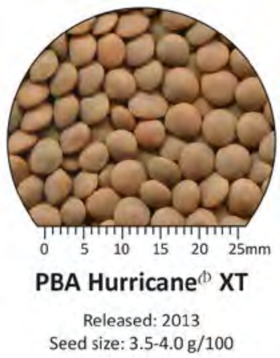

Photo 4: *PBA Hurricane XT⊕.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

MORE INFORMATION

Go to the GRDC website for the brochure on this PBA Hurricane XT⊕: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

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

PBA Herald XT⁽ᵇ⁾

PBA Herald XT⁽ᵇ⁾ is a small red-seeded lentil best adapted to longer growing seasons with medium to higher rainfall.

PBA Herald XT⁽ᵇ⁾ was the first lentil with improved tolerance to imazethapyr with an interim permit for pre or post-emergent application to 2017. It has improved tolerance to the herbicide flumetsulam plus reduced sensitivity to some sulfonylurea and imidazolinone herbicide residues.

Product label rates, plant back periods and all label directions for chemical use must be adhered to when growing PBA Hurricane XT⁽ᵇ⁾.

PBA Herald XT⁽ᵇ⁾ has been outclassed by the new PBA Hurricane XT⁽ᵇ⁾.

PBA Herald XT⁽ᵇ⁾ is R to foliar and seed ascochyta and Botrytis grey mould. Disease resistance assists this variety in achieving high grain quality.[7]

PBA Herald XT⁽ᵇ⁾ is commercialised by PB Seeds. It has an End Point Royalty of $5 per tonne.

Area of Adaptation: Regions 4 & 5

MORE INFORMATION

Go to the GRDC website for the brochure on PBA Herald XT⁽ᵇ⁾: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

Photo 5: *PBA Herald XT⁽ᵇ⁾.*

Photo: Southern Lentil Best Management Practices Training Course (2016), Pulse Australia

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

Nipper⦹

Nipper⦹ is similar to Northfield in many characteristics, including relatively short height and seed shape, but it has a grey seed coat.

Nipper⦹ is MR-MS foliar Ascochyta blight, MR to seed Ascochyta and resistant to Botrytis grey mould. It is also resistant to the exotic disease Fusarium wilt.[8]

Nipper⦹ has improved salinity tolerance and generally lodges less than other varieties.

Nipper⦹ is well established in markets, and has attracted a premium price in some years.

Nipper⦹ is commercialised by Seednet and has an End Point Royalty of $5.50 per tonne.

It is adapted to Regions 4 & 5.

MORE INFORMATION

For more information on Nipper⦹ see: http://www.pulseaus.com.au/storage/app/media/crops/2011_VMP-Rlentil-Nipper.pdf

Photo 6: *Nipper⦹.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

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

3.3.2 Medium red varieties

Nugget

Nugget is a mid-season variety with a medium-sized seed and a grey seed coat. It became the market 'standard' for medium-sized lentils with a grey seed coat

Nugget is MR-MS to foliar Ascochyta blight, moderately resistant to seed Ascochyta and resistant to Botrytis grey mould.

Nugget has now been superseded by PBA Jumbo2⁽ᴾ⁾ (although Jumbo2⁽ᴾ⁾ is a large-seeded lentil), PBA Ace⁽ᴾ⁾ and PBA Bolt⁽ᴾ⁾.

It is adapted to Regions 4 and 5.

MORE INFORMATION

For more information on Nugget see: http://www.pulseaus.com.au/storage/app/media/crops/2011_VMP-Rlentil-Nugget.pdf

Photo 7: *Nugget.*

Photo: Southern Lentil Best Management Practices Training Course (2016), Pulse Australia

PBA Ace⁽ᴾ⁾

PBA Ace⁽ᴾ⁾ is a medium-sized red lentil with grey seed.

Its maturity is mid-season. PBA Ace⁽ᴾ⁾ has been one of the highest-yielding varieties across all areas, especially in Victoria and New South Wales. It can be lower yielding in short, dry seasons.[9]

PBA Ace⁽ᴾ⁾ is best suited to longer-season areas replacing Nugget and PBA Jumbo⁽ᴾ⁾.

PBA Ace⁽ᴾ⁾ is R to Ascochyta and MR-MS to Botrytis grey mould. It is intolerant to salinity and boron.

PBA Ace⁽ᴾ⁾ has a high milling quality.

PBA Ace⁽ᴾ⁾ was released in 2012 and is commercialised by PB Seeds and has an End Point Royalty of $5.50 per tonne.

It is adapted to regions 4 and 5.

Photo 8: *PBA Ace⁽ᴾ⁾.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

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

PBA Blitz⁽ᵇ⁾

PBA Blitz⁽ᵇ⁾ is a medium-sized red lentil with a grey seed coat.

It is an early flowering variety suited to the short growing seasons of South Australia. It is not recommended for Victorian growers.

PBA Blitz⁽ᵇ⁾ has improved early vigour and an erect growth habit which is suited to no-till and inter-row sowing.[10]

PBA Blitz⁽ᵇ⁾ is MR to foliar Ascochyta, MR-MS to seed Ascochyta and MR to Botrytis grey mould.

This variety is intolerant of soil boron and salinity.

It has demonstrated similar but generally improved milling characteristics compared to Nugget.

PBA Blitz⁽ᵇ⁾ was released in 2010 and is commercialised by PB Seeds. It has an End Point Royalty of $5.50 per tonne.

It is adapted to Regions 4 and 5.

Photo 9: *PBA Blitz⁽ᵇ⁾*.

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

MORE INFORMATION

Go to the GRDC website for the brochure on PBA Blitz⁽ᵇ⁾: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

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

PBA Bolt(b)

PBA Bolt(b) is a medium-sized red lentil with grey seed.

It is adapted to the Mallee and northern Wimmera regions of Victoria and the low to medium rainfall zones of South Australia.

While similar to PBA Flash(b) with early to mid maturity and salinity tolerance, it performs better in the southern Mallee as it is MR to foliar Ascochyta blight and R to seed Ascochyta blight. Its susceptibility to Botrytis grey mould makes it less suited to medium to high rainfall areas in wetter years and with early sowing.[11]

Like PBA Flash(b), PBA Bolt(b) is a good variety for timely crop-topping to control weeds.

An erect habit and good lodging resistance make it easier to harvest in dry conditions.

PBA Bolt(b) was released in 2012, is commercialised by PB Seeds and has an End Point Royalty of $5.50 per tonne.

It is adapted to Regions 4 and 5.

Photo 10: *PBA Bolt(b).*

Photo: Southern Lentil Best Practices Management Training Couse (20160, Pulse Australia

MORE INFORMATION

Go to the GRDC website for the brochure on PBA Bolt(b): https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

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

PBA Flash⁽ᵇ⁾

PBA Flash⁽ᵇ⁾ is an early-maturing, high-yielding red lentil with a medium seed size. It has a green/white seed coat but is smaller than Aldinga.

It is suited to all current lentil-growing areas; in particular, shorter season growing areas.

PBA Flash⁽ᵇ⁾ has improved tolerance to boron and salinity compared to Nugget, which along with its height and erectness, has contributed to its popularity in the Mallee.

It is MS to foliar and seed Ascochyta blight, and MR-MS to Botrytis grey mould. The disease susceptibility of PBA Flash⁽ᵇ⁾ means that it is no longer a recommended lentil variety and has now been superseded by PBA Bolt⁽ᵇ⁾

PBA Flash⁽ᵇ⁾ has improved standing ability at maturity relative to other lentil varieties, which may make it more prone to pod drop in windy environments, timely harvest is required.[12]

It is well suited to medium red-lentil grain markets, particularly for splitting.

PBA Flash⁽ᵇ⁾ was released in 2009 and is commercialised by PB Seeds. It has an End Point Royalty of $5.50 per tonne.

It is adapted to Regions 4 and 5.

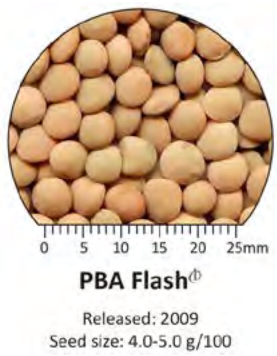

Photo 11: *PBA Flash⁽ᵇ⁾*.

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

MORE INFORMATION

Go to the GRDC website for the brochure on PBA Flash⁽ᵇ⁾: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

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

3.3.3 Large red varieties

PBA Jumbo2⏀

PBA Jumbo2⏀ is direct replacement for PBA Jumbo⏀ and Aldinga.

PBA Jumbo2⏀ is the highest-yielding large-seeded red lentil, approximately 10% higher than PBA Jumbo⏀.[13]

PBA Jumbo2⏀ is suited to medium to high rainfall regions where it produces uniform larger seed size well suited to premium large red split markets.

It is mid flowering and has a maturity similar to PBA Jumbo⏀.

PBA Jumbo2⏀ has a similar seed size to PBA Jumbo⏀ and Aldinga with a grey seed coat.

It is well suited to no-till inter-row sowing into standing stubble.

PBA Jumbo2⏀ is R to Ascochyta and Botrytis grey mould. Its tolerance to soil boron is similar to PBA Flash⏀.

PBA Jumbo2⏀ was released in 2014 and is commercialised by PB Seeds with an End Point Royalty of $5.50 per tonne.

It is adapted to Regions 4 and 5.

Photo 12: *PBA Jumbo2⏀*.

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

MORE INFORMATION

Go to the GRDC website for the brochure on PBA Jumbo2⏀: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

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

PBA Jumbo⏀

PBA Jumbo⏀ is suited to medium to high rainfall regions where it produces uniform larger seed size for the premium large red split markets.

PBA Jumbo⏀ is a high-yielding, large-seeded red lentil with a grey seed coat.

It is mid-flowering with a maturity similar to Nugget. This variety is suited to no-till inter-row sowing into standing stubble.[14]

PBA Jumbo⏀ is MR-MS to foliar Ascochyta blight and S to seed Ascochyta and MS to Botrytis grey mould. The disease susceptibility of PBA Jumbo⏀ means that it is no longer a recommended lentil variety and has now been replaced by PBA Jumbo2⏀.

Tolerance to soil boron is similar to PBA Flash⏀.

PBA Jumbo⏀ was released in 2010, is commercialised by PB Seeds and has an End Point Royalty of $5.5 per tonne.

It is adapted to Regions 4 and 5.

MORE INFORMATION

Go to the GRDC website for the brochure on PBA Jumbo⏀: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

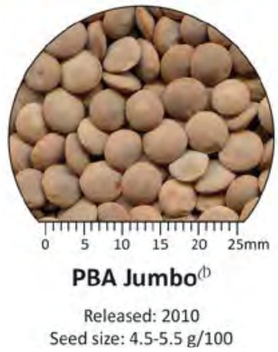

Photo 13: *PBA Jumbo⏀.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

3.3.4 Superseded red lentil varieties

Red lentil varieties that have been superseded by new, improved varieties include:

- Northfield;
- PBA Bounty⏀;
- Cassab;
- Cumra;
- Cobber;
- Digger; and
- Aldinga.

Digger and Cobber pioneered the lentil industry in Victoria, while in South Australia, Northfield and Aldinga kicked-started the industry.

More recently, Nugget has been superseded. It was the industry medium-sized standard for some years.

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

3.3.5 Trial data of red lentil varieties

Table 2: Long-term red lentil yields as a percentage of Nugget (2007–2013).

Variety	South Australia					Victoria		New South Wales	
	Yorke Peninsula	Mid North	Lower Eyre Peninsula	Mallee	South East	Wimmera	Mallee	South East	South West
Small red lentil									
Nipperⓓ	97	96	100	94	96	95	87	85	90
Northfield	88	92	90	91	95	93	92	88	89
PBA Bountyⓓ	102	102	105	105	92	99	103	109	101
PBA Herald XTⓓ	90	92	92	102	98	96	93	89	91
PBA Hurricane XTⓓ	105	107	107*	119	114	110	111	111	104
Medium red lentil									
Nugget	100	100	100	100	100	100	100	100	100
PBA Aceⓓ	107	111	105	112	99	102	96	124	115
PBA Blitzⓓ	106	106	115	112	99	102	96	101	93
PBA Boltⓓ	101	109	108	126	120	114	119	119	101
PBA Flashⓓ	105	109	114	116	114	109	103	105	94
Large red lentil									
Aldinga	96	98	99	100	95	97	101	102	97
PBA Jumboⓓ	110	108	112	107	103	105	102	106	103
PBA Jumbo2ⓓ	119	117	118*	129*	117*	118	121	126*	117*
Yield of Nugget (t/ha)	**2.78**	**2.28**	**1.40**	**1.22**	**1.59**	**1.51**	**1.13**	**1.15**	**1.31**

* Variety has had limited evaluation in this region so treat results with caution.

Source: NVT, PBA, SARDI, Victoria DPI, NSW DPI

Table 3: Red lentil agronomic traits.

Variety	Seed coat colour	Seed size (as % of Nugget)	Crop vigour	Height	Flowering time	Maturity	Pod drop	Shattering	Boron	Salt
Small red lentil										
Nipperⓓ	Grey	75–80	Poor/Mod	Short	Mid/Late	Mid	MR	MR	I	MT
Northfield	Tan	80	Poor/Mod	Short	Mid	Mid	MR	MR	I	I
PBA Bountyⓓ	Grey	90	Moderate	Med/short	Mid/Late	Mid	R	R	I	MI
PBA Heraldⓓ XT	Grey	75	Poor/Mod	Short	Mid/Late	Mid/Late	MR	R	I	I
PBA Hurricaneⓓ XT	Grey	85	Moderate	Medium	Mid	Mid	MR	R	I	I
Medium red lentil										
Nugget	Grey	100	Moderate	Medium	Mid	Mid/Late	MR	R	I	I
PBA Aceⓓ	Grey	100	Good	Medium	Mid	Mid	R	MR-MS	I	I
PBA Blitzⓓ	Grey	115–120	Mod/Good	Med/Tall	Early	Early	MR	MR	I	I
PBA Boltⓓ	Grey	100	Mod/Good	Medium	Early/Mid	Early/Mid	R	R	MI	MI
PBA Flashⓓ	Green	100–110	Moderate	Medium	Early/Mid	Early/Mid	MR	MR	MI	MI
Large red lentil										
Aldinga	Green	120	Moderate	Medium	Mid	Mid	MR	MR	I	MI
PBA Jumboⓓ	Grey	120	Moderate	Medium	Early/Mid	Mid	MR	MR	MI	I
PBA Jumbo2ⓓ	Grey	120	Mod/Good	Medium	Mid	Mid	MR	R	MI	I

VS = Very Susceptible; S = Susceptible; MS = Moderately Susceptible; MR = Moderately Resistant; R = Resistant. I = Intolerant; MI = moderately Intolerant, MT = Moderately Tolerant.

Source: Pulse Breeding Australia

MORE INFORMATION

For detailed disease information go to Section 10: Disease

Table 4: Red lentil disease traits.

Variety	Botrytis grey mould	Ascochyta blight	
		Foliar	Seed
Small red lentil			
Nipper⊕	R	MR-MS	MR
Northfield	S	MR-MS	MR
PBA Bounty⊕	MS	MR-MS	MS
PBA Herald⊕ XT	R	R	R
PBA Hurricane⊕ XT	MR-MS	MR	R
Medium red lentil			
Nugget	MR-MS	MR-MS	MR-MS
PBA Ace⊕	MR-MS	R	R
PBA Blitz⊕	MR	MR	MR-MS
PBA Bolt⊕	S	MR	R
PBA Flash⊕	MR-MS	MS	MS
Large red lentil			
Aldinga	MS	MR-MS	MS
PBA Jumbo⊕	MS	MR-MS	S
PBA Jumbo2⊕	R	R	R

VS = Very Susceptible; S = Susceptible; MS = Moderately Susceptible; MR = Moderately Resistant; R = Resistant

Source: Pulse Breeding Australia

Due to the high intensity of lentil cropping on the Yorke Peninsula and in the Lower Mid North of South Australia changes have occurred in the virulence of Ascochyta blight pathogens. This has resulted in increased levels of infection of Ascochyta blight in PBA Flash⊕ and Nipper⊕, and, to a lesser extent, PBA Jumbo⊕.[15]

Vegetative and podding sprays for Ascochyta blight are now recommended for these varieties in disease-prone areas. Note there are changes to the disease rating (Table 4).

15 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Table 5: Availability of red lentil varieties.

Variety	PBR	Licensee or agency	Commercial partner	Seed-supplying agents	Telephone	EPR ($/t incl GST) & market restriction
Small red lentil						
Nipper⏀	PBR	Victorian DPI	Seednet	Seednet	1800 007 333	$5.50
Northfield	Terminated	SARDI	AFCA	None	–	None
PBA Bounty⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50
PBA Herald XT⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50
PBA Hurricane XT⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	TBA
Medium red lentil						
Nugget	None	Victorian DPI	Seedmark	Heritage	1800 007 333	$5.50
PBA Ace⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50
PBA Blitz⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50
PBA Bolt⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50
PBA Flash⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50
Large red lentil						
Aldinga	None	–	–	–	–	None
PBA Jumbo⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50
PBA Jumbo2⏀	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50

Source: Pulse Breeding Australia

MORE INFORMATION

For further variety information go to the Variety Central website: www.varietycentral.com.au

3.4 Green lentil varieties

3.4.1 Medium green varieties

PBA Greenfield⍉

PBA Greenfield⍉ is a medium-sized green lentil. It has broad adaptation, being best-suited to the medium-rainfall lentil-growing regions.

PBA Greenfield⍉ is the highest yielding green lentil variety, with yields similar to PBA Ace⍉.[16]

PBA Greenfield⍉ has improved tolerance to salinity.

It is resistant to shattering, although timely harvest is still required.

PBA Greenfield⍉ is moderately resistant–moderately susceptible (MR-MS) to foliar and seed Ascochyta and moderately resistant (MR) to Botrytis grey mould.

PBA Greenfield⍉ was released 2014 and is licensed to PB Seeds. It has an End Point Royalty of $5.50 per tonne.

It is adapted to Region 4.

Photo 14: *PBA Greenfield⍉.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

MORE INFORMATION

Go to the GRDC website for the brochure on Greenfield⍉: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

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

3.4.2 Large green lentil varieties

Boomer

Boomer is a large-seeded green lentil. It is tall, bulky and vigorous but can lodge when growing conditions are favourable.

Sowing early can increase lodging and result in smaller seed.

Early harvest is important to prevent shattering and produce good coloured seed.

Boomer was released 2008 and is licensed to Seednet with a $5.50 per tonne End Point Royalty.

Boomer is expected to be superseded by PBA Giant⍉.

It is adapted to Region 4.

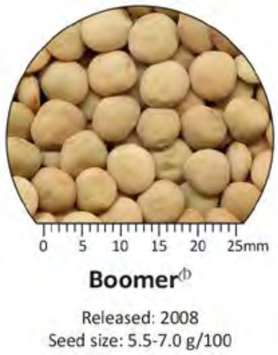

Photo 15: *Boomer.*

Photo: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

MORE INFORMATION

Go to the GRDC website for the brochure on Boomer: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

MORE INFORMATION

Variety contamination can be an issue for marketing lentils, although it is less so now that red lentil varieties are grey-seeded types.

That said, it is an agronomic issue when it comes to paddock management, variety selection/change-over and marketing. A 1% maximum visual contamination applies at delivery. So admixture of reds and greens, reds of differing seed coat colour or different seed size within the same seed coat colour must be considered and avoided.

Please see the following for more information: http://pulseaus.com.au/growing-pulses/bmp/lentil/variety-cross-contamination

MORE INFORMATION

Go to the GRDC website for the brochure on PBA Giant(D): https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

PBA Giant(D)

PBA Giant(D) is the largest seeded green lentil in Australia with an average seed diameter of 5.8 mm (approximately 7 g/100 seeds).[17]

PBA Giant(D) is broadly adapted but best suited to the medium-rainfall lentil-growing regions.

It has similar yield and improved shattering resistance to Boomer, although timely harvest is still required to minimise shattering.

PBA Giant(D) is more resistant to lodging at maturity than Boomer.

It is MR to foliar Ascochyta, and MS to seed Ascochyta and Botrytis grey mould.

PBA Giant(D) was released 2014 and is licensed to PB Seeds with a $5.50 per tonne End Point Royalty.

It is adapted to Region 4.

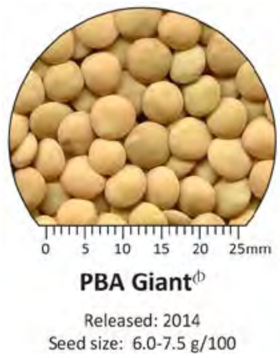

Photo 16: *PBA Giant(D)*.

Photo: Southern Lentil Best Management Practices Training Course (2016), Pulse Australia

3.4.3 Superseded green lentil varieties

The only green lentil variety that has been superseded by new, improved varieties is Matilda.

3.4.4 Trial data of green lentil varieties

Table 6: Long-term green lentil yields as a percentage of Nugget (2007–2013).

Variety	South Australia					Victoria		New South Wales	
	Yorke Peninsula	Mid North	Lower Eyre Peninsula	Mallee	South East	Wimmera	Mallee	South East	South West
Medium green lentil									
PBA Greenfield(D)	111	111	–	114*	113*	112	114	116*	110*
Large green lentil									
Boomer	102	102	101	97	103	102	102	102	102
PBA Giant(D)	98*	103*	–	–	–	106*	112*	112*	103*
Yield of Nugget (t/ha)	**2.78**	**2.28**	**1.40**	**1.22**	**1.59**	**1.51**	**1.13**	**1.15**	**1.31**

* Variety has had limited evaluation in this region so treat results with caution.

Source: NVT, PBA, SARDI, Victorian DPI, NSW DPI

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

Table 7: Green lentil agronomic traits.

Variety	Seed coat colour	Seed size (as % of Nugget)	Crop vigour	Height	Flowering time	Maturity	Pod drop	Shattering	Boron	Salt
Medium green lentil										
PBA Greenfield⁽ᵖ⁾	Green	130	Good	Tall	Mid	Mid/Late	R	MR	I	MI
Large green lentil										
Boomer	Green	140–160	Good	Tall	Mid	Mid/Late	MR	S	MI	I
PBA Giant⁽ᵖ⁾	Green	170	Good	Tall	Mid	Mid/Late	R	MR-MS	MI	I

VS = Very Susceptible; S = Susceptible; MS = Moderately Susceptible; MR = Moderately Resistant; R = Resistant. I = Intolerant; MI = moderately Intolerant, MT = Moderately Tolerant. Source: Pulse Breeding Australia

Table 8: Green lentil disease traits.

Variety	Botrytis grey mould	Ascochyta blight	
		Foliar	Seed
Medium green lentil			
PBA Greenfield⁽ᵖ⁾	MR	MR-MS	MR-MS
Large green lentil			
Boomer	MR-MS	MR	MR-MS
PBA Giant⁽ᵖ⁾	MS	MR	MS

VS = Very Susceptible; S = Susceptible; MS = Moderately Susceptible; MR = Moderately Resistant; R = Resistant
Source: Pulse Breeding Australia

MORE INFORMATION

For detailed disease information go to Section 10: Disease

Table 9: Availability of green lentil varieties.

Variety	PBR	Licensee or agency	Commercial partner	Seed-supplying agents	Telephone	EPR ($/t incl GST) & market restriction
Medium green lentil						
PBA Greenfield⁽ᵖ⁾	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50
Large green lentil						
Boomer	PBR	DPI Vic	Seednet	Seednet	03 5389 0150	$5.50
PBA Giant⁽ᵖ⁾	PBR	PBA	PB seeds	PB seeds	03 5383 2213	$5.50

Source: Pulse Breeding Australia

MORE INFORMATION

For further variety information go to the Variety Central website: www.varietycentral.com.au

3.5 Seed

3.5.1 Seed quality

Seed quality is very important in producing high grain yields.

High yields are produced by achieving optimum plant populations. Optimum plant populations are achieved with quality seed. Quality seed has good germination and vigour. Good germination and vigour allows for sowing rates to be calculated accurately resulting in optimum plant populations.[18]

Factors affecting seed quality include:

- variations in seed size (due to seasonal conditions);
- poor germination percentage (can result in inaccurate calculation of sowing rates);
- harvest and post-harvest seed damage (produces abnormal seedlings without vigour); and
- seed-borne diseases (cause reduced germination).

Grower-retained seed, if not tested, might have reduced germination and vigour, as well as being infected with seed-borne pathogens. Infected seed has the potential to introduce and/or spread disease onto the property.

The only way to accurately measure seed germination rate, vigour and disease is to have it tested.

Key parameters for ensuring high seed quality include:

- 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.
- Always check the germination report of purchased seed.
- Seed should be treated with a thiram-based fungicide for the prevention of seed-borne diseases.
- Careful attention should be paid to the harvest, storage and handling of seed intended for sowing.
- Calculate sowing rates in accordance with seed quality (germination, vigour and seed size).
- **All seed over 12 months old all should be retested for germination and vigour.**[19]

It is important to know the germination requirement when calculating sowing rates.

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

19 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

3.5.2 Seed testing

Germination tests are conducted by seed-testing laboratories. The sample required for seed testing lentil is 1 kg for each 10 tonnes of seed.

Failure to obtain a true sample will result in inaccurate test results that could then lead to poor establishment in the paddock.

The sample should be random and consist of numerous sub-samples.

Sub-samples can be taken when seed is being moved:

- out of the harvester;
- into or out of the truck;
- into or out of the silo; and
- into or out of the seed cleaner.

Seed testing is best done as soon as possible after harvest:

- if there is a suspected quality issue;
- prior to grading and seed treatment; and
- to provide more time to source replacement seed if needed.

Seed testing in Australia

The Australian Seeds Authority (ASA) is responsible for controlling seed certification in Australia and oversees two certification schemes:

- the Organisation for Economic Co-operation and Development (OECD) Schemes for the Varietal Certification or the Control of Seed Moving in International Trade; and
- the Australian Seed Certification Scheme.

Other seed tests

There are numerous other seed tests available for:

- vigour;
- accelerated ageing vigour;
- conductivity vigour;
- cool germination and cold;
- tetrazolium (TZ) vigour;
- weed contamination;
- disease; and
- major pathogens.

MORE INFORMATION

The Australian Seeds Authority provides a listing of the laboratories in Australia that test and certify seed for both international and domestic purposes. They can be found on the ASA website: http://aseeds.com.au/testing

3.5.3 Grower-retained seed

Poor quality grower-retained seed

Seed quality issues can occur when a crop is harvested in less than ideal moisture conditions or poor seasonal conditions. A sharp seasonal finish where maturity is achieved suddenly, a wet harvest or a delayed harvest can all have a significant impact on seed quality.

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

The fragile nature of pulse seed, particularly faba and broad bean, lupin, kabuli chickpea and lentil seeds, makes them more vulnerable to mechanical damage during harvest and handling. This damage is not always visually apparent. Damage can be minimised by reducing the harvester thresher speed and opening the concave, or by reducing auger speed and lowering the flight angle and fall of grain.

Rotary harvesters and belt conveyers are ideally suited to pulse grain. Both reduce seed damage that often results in abnormal seedlings which germinate but do not develop further due to poor vigour.

Establishment of weak seedlings can be caused by low temperature, disease, insects, sowing depth, soil crusting and compaction. Seedlings that do emerge are unlikely to survive for long, or produce less biomass, and make little or no contribution to final yield.

Achieving high quality grower-retained seed

Achieving high quality grower-retained seed requires the best area of a paddock being selected prior to harvest. Best areas have a low weed burden, an absence of diseases, and a crop that is vigorous and healthy and likely to mature evenly with good grain size.

Seed should be harvested first (prior to grain) and ideally in conditions with 11–12% moisture. Harvesting seed at low moisture deems it susceptible to cracking.

When desiccating a paddock for seed, careful attention must be paid to the herbicide used.

DO NOT use glyphosate to desiccate or crop-top lentil if the seed is to be retained for sowing.

Glyphosate can have a significant impact on germination, normal seed count and vigour.

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

MORE INFORMATION

See Section 11: Pre-harvest treatments and Section 13: Storage and handling

GRDC Videos on retained seed and aerated storage are at: https://youtu.be/5lq9T6_f6Tg

Ensure seed viability with aerated storage: https://youtu.be/8HFilsCnka0

3.5.4 On-farm seed testing

A simple preliminary on-farm test can be conducted to assess germination and vigour. Ideally this should be followed up with a laboratory test from which sowing rates can be calculated.

On-farm seed-testing process:

1. Use a flat, shallow tray about 5 cm deep.
2. Place a sheet of newspaper in the base to cover drainage holes.
3. Fill with clean sand, potting mix, or a freely draining soil.
4. Temperature must be less than 20°C, so the test may need to be conducted indoors.
5. Randomly count out 100 seeds, including any damaged seeds.
6. Sow 10 rows of 10 seeds in a grid at the correct sowing depth.
7. Place the seed on the levelled soil surface and gently push each in with a pencil marked to the required depth. Cover seed holes with a little more soil and water gently.
8. Keep the soil moist, but not wet (overwatering will result in fungal growth and possible rotting.
9. After seven to 14 days most viable seeds will have emerged.
10. Only count normal, healthy vigorous seedlings at seven and 14 days. This number is the germination percentage.

Figure 3: *On-farm seed testing.*

Photo: Emma Leonard

3.5.5 Handling bulk seed

The large size, awkward shape and fragile nature of many pulses means they need careful handling to prevent seed damage. Seed grain should be handled carefully to ensure good germination.

To prevent seed damage, forward planning is required to minimise grain handling between harvest and sowing.

Auguring from the harvester should be treated with as much care as later during handling and storage because it has the same potential for seed damage.

Augers with steel flighting can damage pulses, even small-seeded types like lentil. This problem can be partly overcome by reducing auger speed.

Tubulators or belt elevators are excellent for handling pulses as little or no damage occurs.

Cup elevators are less expensive than tubulators and cause less damage than augers. They have the advantage of working at a steeper angle than tubulators. However, cup elevators generally have lower capacities.

Combine loaders that throw or sling the seed, rather than carry, can cause severe damage to germination and should be avoided.

3.5.6 Safe storage of seed

Most grower-retained seed will need to be stored for a period of 180 days or more.

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

Lentil seed quality can deteriorate in storage (like other grain). Deterioration occurs most rapidly under conditions of high temperature and moisture. These conditions may result in poor seed germination and emergence.

Reducing moisture and temperature increases the longevity of the seed. Conversely, moisture at very low levels (>10%) may render lentil more vulnerable to mechanical damage during subsequent handling (see Table 10 for an example involving chickpea).

Table 10: Effect of moisture content and temperature on storage life of chickpea seed.

Storage moisture (%)	Storage temperature (C)	Longevity of seed (days)
12	20	> 200
12	30	500–650
12	40	110–130
15	20	700–850
15	30	180–210
15	40	30–50

Source: R Ellis, K Osei-Bonsu, E Roberts (1982) The Influence of Genotype, Temperature and Moisture on Seed Longevity in Chickpea, Cowpea and Soya bean. Annals of Botany (1982) 50 (1): 69-82, http://aob.oxfordjournals.org/content/50/1/69

Under Australian conditions, storage of seed above 13% moisture is not recommended.

Reducing temperature in storage is the easiest method of increasing seed longevity. It will also reduce the potential for insect damage.

Options for reducing seed temperature in silos include painting the outside of the silo with white paint and aeration. Painting can reduce temperature by as much as 4–5°C and can double storage life. Aeration results in dry, ambient air which, as well as reducing storage temperature, also reduces the moisture of seed harvested at high moisture.

Heat drying of lentil seed should be limited to temperatures below 40°C.

MORE INFORMATION

For detailed information refer to Section 13: Storage and handling

3.6 PBR and royalties

Plant Breeder's Rights and End Point Royalties provide an incentive to companies and individuals to invest in plant breeding. This value adding to the grains industry, by producing superior varieties, has numerous benefits:

- increased productivity with higher yields;
- improved price received for grain due to improved quality;
- protection from productivity losses caused by diseases and environmental stresses; and
- improving the profitability of grain growing.[20]

3.6.1 Plant Breeder's Rights

Plant Breeder's Rights (PBR) relate to legislation covered in the *Plant Breeders Rights Act (1994)*.

PBR is a copyright that protects the plant breeder's intellectual property rights for new and uniquely different plant varieties.

PBR provides the legal mechanism by which a breeder can license a variety to a grower and impose an End Point Royalty (EPR). The EPR aids in recovering the costs of breeding and allows re-investment into future variety development.

PBR allows the breeder/owner of the variety to place restrictions on what the grower and others in the supply chain can do with the protected variety.

The grower enters into a contract with the breeder/owner at the point of seed purchase of a PBR variety.

The contract between the grower and breeder/owner may place restrictions on what the grower can do with the grain produced from the seed when planted as a crop.

PBR restrictions can differ between varieties and breeders/owners.

The PBR legislation allows the variety breeder/owner to prevent growers from selling seed to other growers and any other third parties including traders and end-users.

The PBR legislation allows the grower to save seed on-farm for use in the sowing/planting of the following year's crop.

3.6.2 End Point Royalties

An End Point Royalty (EPR) is a fee paid by growers for every tonne of grain produced and sold as grain for each variety.

The EPR amount is set by the variety owner (breeder) when the variety is released. This may vary between varieties.

The EPR represents a performance based equitable return to the breeder/owner for successful crop breeding. Breeding a new cultivar is expensive, taking from eight to 12 years with an estimated cost of at least $2 million per variety[23].

An EPR shares the risk between the breeder and the grower, whereas a seed royalty places all the risk on the grower.

For example, with EPR if the grower has a failed crop, the breeder receives no royalty. With a seed royalty, the grower pays a fee regardless of whether the crop is a success or failure.

20 Australian Grain Technologies (2016) PBR and EPR Information. Australian Grain Technologies, http://www.agtbreeding.com.au/sourcing-seed/pbr-and-epr

Planting

Key points

- **Choice of sowing date should take into consideration the location (district) and the variety.**
- **Ideal sowing time is a compromise between early sowing (to increase yield) and delayed sowing (to reduce yield-loss factors such as heat and frost at flowering).**
- **Plant densities of 120 plants/m^2 are recommended for lentil.**
- **Lentil should be sown at a depth of 2–6 cm.**
- **Sowing into standing stubble ensures taller, more erect plants with pods higher above the ground and reduces lodging before harvest.**
- **Dry sowing can be successful in lentil, provided weeds like medic and vetch are not a problem.**
- **Lentil varieties differ in their sensitivity to residual herbicides.**
- **Lentil is very sensitive to fertiliser toxicity when fertiliser is sown with the seed.**
- **Lentil can 'fix' its own nitrogen.**
- **Inoculation of lentil may not be required on some alkaline soils if inoculated and well-nodulated field peas, faba beans or lentils have recently been grown in the paddock.**

4.1 Time of sowing

Time of sowing of lentil is critical for several reasons:

- to maximise yield;
- to control disease;
- to avoid frost during flowering; and
- to prevent heat damage during flowering.

The ideal sowing time largely depends on location and includes:

- rainfall;
- soil type and fertility;
- dates of risk periods, such as frost and heat stress; and
- soil moisture at sowing time.

In some areas, the ideal sowing date will be a compromise between optimum yields achieved by early sowing, and delaying sowing until risk factors (heat and frost at flowering) have been reduced to an acceptable level.

4.1.1 Ideal sowing time

The ideal time of sowing will ensure that the lentil crop:

- has finished flowering before being subject to periods of heat stress. This is, generally, when maximum day temperatures over a week average 25°C or more (refer to Section 6: Plant growth and physiology); and
- will produce sufficient growth to flower over an extended period, and encourage a better pod-set and filling of the pods.

In other words, there can be a significant difference between the optimum sowing time (for maximum potential yields) and the ideal sowing time (reducing yield- loss factors).

4.1.2 Time of sowing for southern region

- Rainfall <400 mm → mid-May to early June.
- Rainfall 400–450 mm → late May to late June.
- Rainfall 450–500mm → late May to early July.
- Rainfall 500–600mm → early June to mid-July.
- Rainfall >600mm → early August to mid-September.[1]

Sowing date of lentil needs to take into account the location (district) and the variety.

1 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Table 1: Optimum time of sowing for lentil in southern Australia.

Region (annual rainfall)	May 1	May 2	May 3	May 4	June 1	June 2	June 3	June 4	July 1	July 2	July 3	July 4
350–375 mm	Marginal	Preferred	Preferred	High								
375–400 mm		Marginal	Marginal	Preferred	Preferred	High						
400–450 mm				Marginal	Preferred	Preferred	Preferred	High	High			
450–500 mm					Marginal	Preferred	Preferred	Preferred	High	High	High	
500–600 mm					Marginal	Marginal	Preferred	Preferred	Preferred	Preferred	High	High

Marginal area or low disease risk area; Preferred sowing time; High disease risk areas or more susceptible varieties

NOTE: 1. Sowing time may need to vary with flowering and maturity time of the variety. 2. Preferred sowing time for spring-sown lentils is August-September 3. Sow later to reduce the disease risk if: a more susceptible variety (e.g. PBA Flash⁽ᴰ⁾, Northfield); or in districts with milder winter temperatures where Botrytis grey mould (BGM) is a regular problem (e.g. Yorke Peninsula, Lower Eyre Peninsula, Upper SE of SA).

Source: Pulse Australia

MORE INFORMATION

The interaction between sowing date and different stubble handling methods on lentil grain yield at Mallala (South Australia) in 2010. (M. Lines & L. McMurray, Southern Pulse Agronomy Project)

The interaction between sowing date and lentil genotype on grain yield at Curyo (Victorian Mallee region) in 2012. (J. Brand, Southern Pulse Agronomy Project)

The interaction between sowing date and lentil genotype on grain yield at Rupanyup (Vic Wimmera) 2012. (J. Brand, Southern Pulse Agronomy Project)

The interaction between sowing date and lentil genotype on grain yield at Wagga Wagga (NSW) 2011. (L. Gaynor, NSW DPI, Southern Pulse Agronomy Project)

The interaction between sowing date and lentil genotype on grain yield at Wagga Wagga (NSW) in 2012. (L. Gaynor, NSW DPI, Southern Pulse Agronomy Project)

The interaction between sowing date and lentil genotype on grain yield at Yenda (NSW) in 2012. (L. Gaynor, NSW DPI, Southern Pulse Agronomy Project)

4.1.3 Yield

Lentil sown 'on time' has an excellent chance of producing very high yields. However, lentil sown earlier or later than recommended will often suffer from reduced yield.

A number of lentil trials examining the relationship between time of sowing and yield have been conducted in recent years.

4.1.4 Disease

Most lentil varieties are either susceptible or moderately susceptible to Botrytis grey mould (BGM), caused by Botrytis cinerea. This means that sowing times in southern Australia may need to be delayed in some circumstances to reduce the risk of BGM infection.[2]

Most new lentil varieties are either resistant or moderately resistant to Ascochyta blight. This means time of sowing no longer needs to be delayed to reduce the risk of Ascochyta blight infection with these varieties. However, under intensive lentil rotations, this resistance can change as the organism adapts. Therefore, complacency is not an option due to the changing nature of the disease.

If the variety is more susceptible to Botrytis grey mould, or in districts with milder winter temperatures where BGM is a regular problem (coastal areas), then sowing needs be delayed to reduce disease risk.

2 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

MORE INFORMATION

For further information on frost go to Section 14: Environmental issues

MORE INFORMATION

For further information on heat stress go to Section 14: Environmental issues

4.1.5 Frost

Planning time of sowing to avoid frost or cold conditions during flowering is an important consideration. This is especially true in areas with long growing seasons where sowing time may need to be delayed to avoid Botrytis grey mould.

Lentil seed can germinate in soil as cold as 5°C; however, emergence will be slow. Seedling vigour will be greater if soil temperatures are at least 7°C.

Lentil seedlings are tolerant of frost.

In lentil, selection of sowing date is a trade-off between:

- sowing early with high yield potential – important in those years where moisture stress occurs early, or excessive frosts or high temperatures are to be avoided; and
- lower yield potentials with delayed sowing to ensure flowering occurs in warmer temperature and sunlight conditions but before temperatures become excessive or moisture stress sets in.

4.1.6 Heat

Significant reductions occur in yield and seed quality of lentil when heat stress occurs during flowering and pod-filling. Time of sowing needs to minimise this factor as much as possible.

4.1.7 Water-use efficiency

Water-use efficiency for lentil is commonly in the range of 8–12 kg grain per hectare per millimetre of water for sowing during the preferred sowing window. Very late or very early sowing will result in reduced water use efficiency of 4–6 kg grain/ha/mm. of water-use[33]

4.1.8 Sowing too early

Early sowing, even dry sowing, is a priority in some drier areas or where sowing is completed early to optimise operations and enable optimum sowing times for cereals. Actual time of sowing may depend on:

- the maturity of the variety being sown;
- the disease susceptibility of the variety;
- expected plant height;
- row spacing; and
- overall attitude towards risk from disease.

Sowing prior to the recommended sowing window results in a more vegetative lentil plant.[4] The plant can suffer from:

- poor early podset because of low light or low temperatures (10°C) at the start of flowering;
- a higher risk of Botrytis grey mould, after canopy closure, coinciding with flowering and podding;
- increased likelihood of lodging;
- increased frost risk at flowering and early podding;
- higher water use prior to effective flowering;
- earlier moisture stress during flowering and podding; and
- increased risk of Ascochyta blight in susceptible varieties.

3 H Cutforth, B McConkey, D Ulrich, P Miller, S Angadi (2002) Yield and water use efficiency of pulses seeded directly into standing stubble in the semiarid Canadian prairie. Can. J. Plant Sci. 82: 681-686

4 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

Early sowing can often produce the highest potential yields in lentil, but requires greater attention to disease control, particularly for Botrytis grey mould (BGM).

Some lentil varieties with best resistance to BGM and shorter height (PBA Hurricane XT⁽ᵈ⁾) enable earlier sowing in many areas. Wider row spacing (skip row or wider) delays canopy closure and so lessens disease risk associated with early sowing.

Other varieties (PBA Bolt⁽ᵈ⁾, PBA Flash⁽ᵈ⁾, PBA Blitz⁽ᵈ⁾) can respond less to early sowing because they have to set early pods under cold, frosty or more shaded conditions.

The higher risk of fungal disease is particularly pertinent to medium and high rainfall areas.

Weed control

Weed control can be an issue with sowing early. Sowing too early can result in conditions not suitable for controlling broadleaf weeds. This is because there are limited or risky post-emergence broadleaf weed control options available in lentil. This might result in lentil crops with a high weed burden.

4.1.9 Sowing too late

Late sowing produces short, low-yielding crops with less disease.

Lentil sown too late is more likely to suffer from:

- high temperatures and moisture stress during flowering and podding;
- greater native budworm pressure;
- less branching and flowering sites; and
- shorter plants and lower podset, which makes harvest more difficult.

Late-sown crops run the risk of being too short to harvest satisfactorily in many areas, along with the risk of high temperatures and dry conditions during flowering and pod- fill reducing yields. Spring sowing is desirable in some higher rainfall areas, or areas with a longer growing season.

Pulse Australia states that yield losses of up to 200 kg/ha of lentil can be expected for every week sowing is delayed.

Lentil sowing dates are often a compromise between delaying sowing to reduce disease without severely reducing yield potential with delays.

IN FOCUS

4.1.10 Low-rainfall areas

In low-rainfall areas lentil must be sown relatively early. Hot winds in spring cause lentil to stop flowering and prompt premature ripening. Compacted soils or those with a boron/salt subsoil that do not allow root penetration will exaggerate this effect.

4.1.11 High-rainfall areas

In the higher-rainfall districts (>600 millimetres' annual rainfall), some pulses like field pea, lentil and chickpeas can be sown in August or September (spring sowing) to avoid waterlogging and to reduce foliar diseases. Lentil can therefore be sown as spring-sown option in these areas, despite the long, cool growing season.

Having a deep, fertile soil profile that retains moisture is important. Crop height and onset of hot conditions become yield-limiting factors.[5]

5 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

4.2 Sowing rate / target population

Plant densities of approximately 100 to 120 plants per square metre are recommended for lentil.[6]

Sowing rate (kilograms per hectare) is calculated for individual varieties based on their germination percentage and seed weight.

The number of seeds that actually emerge is often less than the viable seed number sown. This can be due to non-vigorous seedlings, disease, herbicide damage or poor soil structure. Sowing rate may need to be increased to take into account these factors.[7]

4.3 Sowing depth

Lentil should be sown at a depth of 2–6 cm (Table 2)[8] to help minimise herbicide damage.

Lentil emerges faster than most other pulses, despite its seed size, but plant growth is slow during winter. If germination coincides with soil temperatures below 5°C, complete emergence may take up to 30 days.

Lentil emerges fast, despite its seed size, but plant growth is slow during winter.

Sowing depth of lentil must take into account:

- soil type;
- herbicide used;
- diseases likely to be present; and
- soil temperature at sowing time, i.e. how long the crop will take to emerge.

Table 2: Sowing depth for pulses.

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

* Note if applying a pre-emergent herbicide, a deeper depth should be used.

Source: Pulse Australia

6 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

7 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

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

Photo 1: *Lentil is capable of emerging through thick cereal stubble.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 2: *Lentil sown too shallow is vulnerable to herbicide damage, especially if left in a deep furrow enabling herbicide 'wash' into the seed row.*

Photo: W. Hawthorne, formerly Pulse Australia

There is a maximum depth at which lentil can be safely sown to avoid poor establishment and lower seedling vigour. Sowing seed outside the suggested range (Table 7) will delay emergence and slow seedling growth.

The deepest sowings tend to be in sandy soil with warm soil temperatures, or dry sowing. The shallowest sowings tend to be in heavy soils with cold soil temperatures, or late sowing.[9]

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

4.3.1 Sowing depth and herbicide interaction

Pulses can be more tolerant of some herbicides if shallow sowing is avoided.

For example, **lentil is less affected by metribuzin applied post-sowing pre-emergent (PSPE) if it is sown deeper**.[10,11] Simazine* and metribuzin can result in 'crop 'effect' in lentil if wet conditions prevail after sowing. This means sowing up to 10 centimetres' depth may be required to avoid herbicide damage. (*Simazine not registered for use in lentil but commonly used.)

Lighter textured soils can be more prone to herbicide leaching in wet winters. Hence, deeper sowing in sandier soils is often recommended if applying a pre-emergent herbicide.

Leaving the soil ridged (instead of rolling), increases the risk of post-sowing pre-emergent herbicide washing into the furrow (Image 9), especially on sandy soil. As pre-sowing applications of herbicide may be less effective in the furrows, The Grain Legume Handbook (2008) suggests a split herbicide application to ensure effective weed control while avoiding the risk of herbicide damage.

MORE INFORMATION

For information on deep seeding strategies, please refer to: http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/deep-seeding

4.3.2 Deep sowing

Deep sowing of faba bean and chickpea is used in northern Australia to sow into dry surfaces with wet sub-surface moisture.[11]

Deep sowing may be of use in southern Australia to ensure timely sowing of lentil into moisture when the soil surface is dry. Otherwise dry sowing is required while awaiting a germinating rain.

Deep sowing also allows more time to apply a knockdown herbicide prior to crop emergence.

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

11 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

4.4 Row spacing

Lentil crops in southern Australia are increasingly being sown at wider than 'standard' (18–25 cm) row spacing. This is when sown into standing stubble as part of a whole farming system. If used, wider row and 'skip' row lentil crops (30–50 cm) must be part of an overall system.[12]

Standing stubble is essential when sowing on wider rows to avoid moisture loss and prevent weed infestation inter-row. **Standing stubble ensures taller, more erect plants with pods higher above the ground, and reduces lodging before harvest.**

When sowing wider rows, any non-sowing tynes should be lifted so inter-row soil disturbance is minimised.[13] This reduces the risk of weeds germinating where there is no crop competition.

Reasons for choosing wider rows with lentil vary depending on location, farming system and grower preference, and include:

- better yields and yield consistency;
- availability of equipment with better stubble clearance and other sowing practicalities;
- improved water-use efficiency (drought tolerance);
- delay of canopy closure to minimise disease risk and for easier management;
- option to sow early and minimise foliar disease risks with a bigger crop canopy;
- better weed control through minimised soil disturbance;
- option of shielded sprayers for weed control inter-row; and
- improved harvesting speeds and efficiency.[14]

If row spacing is doubled, the sowing rate per row must also be doubled to achieve the same plant density.[15] This is significant for seeders with one seed meter per row, but relatively unimportant in air seeders where one meter supplies all or part of the machine. Sowing rate calibrations must be carefully managed.

The same considerations apply for fertiliser rates. However, the risk of toxicity to seed is increased when fertiliser is more concentrated in the seeding furrow. Sowing pulses into wider rows may require deep placement or side banding of the fertiliser. (See section 4.7 Safe rates of fertiliser sown with the seed.)

Trials have been conducted on the effects of row spacing on lentil.

MORE INFORMATION

Refer to the following trials for more information:

The interaction between sowing date, row spacing and lentil genotype on lentil yields (t/ha) at Minyip (Vic Wimmera) in 2009. J. Brand, Southern Pulse Agronomy Project

The interaction between sowing date*, row spacing and lentil genotype on lentil yields (t/ha) at Curyo (Vic Mallee) in 2009. J. Brand, Southern Pulse Agronomy Project

The effect of the interaction between sowing date and row space treatment on grain yield (t/ha) at Curyo in 2009. J. Brand, Southern Pulse Agronomy Project

12 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

13 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

14 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

15 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

4.5 Dry sowing

Dry sowing is a means of getting crops sown on time in seasons with a delayed autumn break. The autumn break is the "*first significant rainfall of the winter growing season … the time for successful grain sowing.*"[16]

Dry sowing can be successful in lentil, provided weeds like medic and vetch are not a problem. Rather than waiting for the correct moisture status, lentil can be sown according to date to ensure that sowing is completed on time, and/or to avoid interfering with other cropping operations.

Paddock selection is particularly important for dry sowing lentil. The following should be considered:

- paddock history of weed seeds, herbicide resistance and available weed control options;
- a seed inoculation method that is suited to dry soil conditions, such as granular inoculants;[17]
- soil type and ability to sow at required depth;
- ease of sowing into dry soil, soil tilth and uniformity of sowing depth;
- ability to physically access paddock after rain and before emergence (for harrowing, rolling or spraying pre-emergent herbicides);
- 'cloddiness' of soil after dry sowing for herbicide application and harvesting;
- whether additional levelling is required to flatten the ridges, cover press-wheel furrows or flatten clods; and
- whether time is available to apply herbicides before crop emergence.

4.5.1 Herbicide options with dry sowing

Herbicides react differently when applied to dry soil compared to moist soil.

The following factors are important with regard to herbicide use with dry sowing:

- pre-sowing application is often less effective because of herbicide breakdown over time and untreated soil remaining in the inter-row;
- when spraying post-sowing pre-emergence (PSPE) the soil surface may need levelling. This is especially so when sowing with press wheels in order to prevent herbicide from being washed into seed furrows by rain;[18]
- PSPE herbicides may not always be effective with dry sowing. Post-emergent herbicides might need to be considered;
- alternative options for weed control and harvesting need to be considered. This is especially so when it becomes too wet to spray or roll after the germinating rains and pre-emergent treatments are unable to be undertaken;
- crop emergence times may differ with dry sowing (bean and chickpea are slow, pea is intermediate, lentil, lupin and vetch are quickest to emerge);
- there may be an increased disease risk due to emergence soon after opening rains; and
- a longer growing season will lengthen the time the plant is exposed to diseases and, hence, the period it may need to be protected with foliar fungicides. Varieties with superior disease resistances should be chosen or, alternatively, paddocks with low disease risk should be selected.[19]

Lentil is one of the quickest pulses to emerge with dry sowing.

16 M Pook, S Lisson, J Risbey, C Ummenhoffer, P McIntosh, M Rebbeck (2008) The autumn break for cropping in southeast Australia: trends, synoptic influences and impacts on wheat yield. International Journal of Climatology DOI 10.1002/joc

17 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

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

19 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

MORE INFORMATION

See more on herbicide residues in Section 8.7 "Herbicide residues"

4.6 Herbicide residues

When growing pulses it is important to be aware of:

- possible herbicide residues impacting on crop-rotation choices when rainfall has been minimal;
- herbicide residues that could influence crop rotations more than disease considerations.
- weed burdens in the new crop (based on seed-set from last year); and
- herbicide efficacy and crop safety of the new crop and how it can suffer if the soil is dry at time of application.[20]

Pulses differ in their sensitivity to residual herbicides.[21] It is important to check each herbicide prior to use for sensitivity to residues.

Group B

- **Standard lentil varieties are extremely sensitive to the imidazolinones (IMIs)[22];**
- 'XT' varieties are tolerant to IMIs. For example, PBA Hurricane XT⚖ and PBA Herald XT⚖.
- Lentil cannot immediately follow after bean or field pea if IMIs or sulfonamides were used.
- Lentil and chickpea are most vulnerable to sulfonylurea residues, with field pea, faba and broad bean the least. Residues persist longer in high pH soil.
- Lentil, faba and broad bean, and lupin are more sensitive to sulfonamide residues, particularly on shallow duplex soils where breakdown is slower.
- At low pH (<6.5) faba and broad bean are more sensitive to Monza® residues (sulfonylurea) than lentil, chickpea, lupin and field pea. All are sensitive at higher pH (>6.5).

Group I

- All pulses are vulnerable to pyridine residues (Lontrel®). Lontrel® is more likely to persist in stubble-retention systems.
- Spikes (dicamba) added to knockdown sprays may persist under dry conditions and can reduce pulse crop establishment. Dicamba plant-backs require 15 mm of rain. **Lentil and faba bean are not listed on label**.
- Picloram and aminopyralid applied to previous summer fallows are more likely to persist and damage crops under dry conditions.

Group C

- Triazine herbicides applied in-crop can potentially cause crop damage in some circumstances.

Group F

- Lentil cannot follow straight after chickpea if Balance® has been used in the chickpea.

20 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

21 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016, NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

22 GRDC (2014) Imidazolinone residues, https://grdc.com.au/Media-Centre/Media-News/South/2014/04/Imidazolinone-residues

Table 3: Minimum re-cropping intervals and guidelines.

Group and type	Product	pH (H_2O) or product rate (ml/ha) as applicable	Minimum re-cropping interval (months after application), and conditions Pulses
I, pyridine	clopyralid e.g. Lontrel®	Rate <300 ml	Chickpea, faba bean, pea, lentil, lupin, vetch = 9 >150 mm rainfall, with >25 mm summer–autumn
		Rate of 300–500 ml	Chickpea, faba bean, pea, lentil, lupin, vetch = 12
		Rate 500 ml	>150 mm rainfall, with >25 mm summer-autumn
I, pyridine	aminopyralid +fluroxypyr Hotshot®	Rate 500 ml southern/western areas	Chickpea, faba bean, pea, lentil, lupin = 20 (southern) >150 mm rainfall, with >25 mm summer–autumn
		Rate 750 ml northern Australia	Chickpea, faba bean = 9 >100 mm on black cracking clays
F, isoxazoles	isoxaflutole e.g. Balance®	> 7.0 < 7.0	Chickpea = 0 Faba bean, pea = 9 (>250 mm rainfall) Lentil = 21 (>500 mm rainfall) Prolonged dry or cold periods may extend re-cropping intervals May result in extended re-cropping intervals
B, sulfonylurea (SU)	chlorsulfurons e.g. Glean®, Seige®, Tackle®	< 6.5	Faba bean, pea, lupin = 12 Others >>18 (rainfall not specified)
		6.6–7.5	Faba bean, pea = 22 (all states) minimum 700 mm Lupin = 22 (Victoria, NSW), but >> 22 (other states) minimum 700 mm Others >> 22
		7.6–8.5	24 + (if test strip grown to maturity year before)
		> 8.6	NR
B, sulfonamide	flumetsulam e.g. Broadstrike®	NA	Pea, chickpea =3 Faba bean, lupin = 9, but = 24 on shallow duplex soils (sand over clay) with low organic matter (rainfall not specified)
B, sulfonyl urea (SU)	triasulfuron, e.g. Logran®, Nugrain®	< 6.5	Faba bean, pea, lupin, chickpea = 12 (> 300 mm rainfall spraying to sowing) Lentil, others >> 18
		6.6–7.5	Faba bean, pea, lupin = 22 chickpea = 12 (NSW/Queensland) or 22 (rest) (> 500 mm rainfall spraying to sowing) Lentil, others >> 22
		7.6–8.5	Chickpea (NSW/Queensland) = 12 (500 mm spraying to sowing rainfall). Chickpea (rest), lupin, faba bean, pea =24 (> 700 mm rainfall spraying to sowing) Lentil, others >> 22
		> 8.6	Chickpea, lupin, faba bean, pea =24 (> 700 mm rainfall spraying to sowing) Lentil, others >> 24
B, sulfonamide	metosulam, e.g. Eclipse®	NA	Not specified = 9? (rainfall not specified)
B, sulfonylurea (SU)	metsulfuron e.g. Ally®, Associate®	5.6–8.5	= 9 (rainfall not specified)
		> 8.5	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area

Source: W Hawthorne (2007) Residual Herbicides and Weed Control. Pulse Australia Southern Pulse Bulletin, PA 2007 #03, http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides
Note that herbicide-tolerant (XT)® lentil varieties have the same plant-back periods on label as conventional lentil varieties.
There is however greater safety with these XT® varieties to residual herbicides in Group B (SUs, iMIs).

MORE INFORMATION

Nitrogen fixation of crop legume: basic principles and practical management Fact Sheet. https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/07/grdc-fs-nfixation-legumes

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

The GRDC has produced a reference manual and videos on pre-emergent herbicides. Please see *Soil behaviour of pre-emergent herbicides in Australian farming systems: a reference manual for agronomic advisers*: www.grdc.com.au/SoilBehaviourPreEmergentHerbicides

4.6.1 Herbicides in previous crops

Herbicides applied to paddocks in previous years may not have broken down adequately due to insufficient rainfall. This is because **herbicides require moist soil to break down.** For example, Lentil cannot follow straight after Lontrel® (Group I) has been used in the previous crop (e.g. canola).[23]

Where dry conditions (minimal summer–autumn rain and delayed opening rain) persist between herbicide application and sowing there is a higher risk of residual herbicide damage. This means a pulse following a cereal rotation might be a higher risk than a pulse following a pulse.[24]

The herbicide residual effect becomes far more critical for rotation choice when there has been minimal summer–autumn rain and delayed opening rain.

Furthermore, summer rainfall is not necessarily as effective as growing season rainfall in breaking down herbicide residues. Rainfall needs to be substantial and has to keep the soil wet for a specified time.[25]

Herbicides applied two years ago could still have an impact too, as could the presence of cereal stubble with herbicides like Lontrel®.[26]

It is extremely important to know the chemical used, as well as plant-back periods, soil pH, rainfall and other requirements for herbicide breakdown.

Photo 3: *Imazethapyr (e.g. Spinnaker®) injury in conventional lentil.*

Photo: W. Hawthorne, formerly Pulse Australia

23 http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides

24 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

25 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

26 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Photo 4: *Imazethapyr (e.g. Spinnaker®) injury in conventional lentil plants (page 13) compared to an 'IMI'-tolerant (XT) lentil variety (above).*

Photo: W. Hawthorne, formerly Pulse Australia

4.6.2 Herbicides for current crop

Pre-sowing herbicide applications are often considered safer and more reliable than post-sowing applications, particularly under dry conditions. To ensure weed control, in the sowing furrow and to minimise crop damage, a combination of pre and post-sowing applications may be required.[27]

Under adverse seasonal or soil conditions, most post-sowing pre-emergent herbicides can damage lentil.

To reduce the risk of herbicide damage when using metribuzin or other soluble products post-sowing pre-emergent (PSPE) on lentil:

- sow at a depth of 5 cm or deeper;
- apply the herbicides to a level soil surface (after prickle chaining or rolling);
- recognise that rolling after press wheels may not be enough to level out the furrow;
- avoid applying these herbicides post-sowing to dry soils;
- choose the correct herbicide rate for the soil type (lighter soils require lower rates than heavier soils);
- check susceptibilities of varieties; and
- consider splitting the applications between pre-sowing and PSPE.[28]

Post-emergent applications can cause crop damage in some circumstances. In most cases damage can be attributed to the product solubility and agronomic or environmental factors.[29]

To reduce the risk of herbicide damage when using broadleaf control herbicides post-emergent on lentil:

- sow at a depth of 5 cm or deeper;
- ensure soil conditions are similar as for spraying PSPE; and
- apply post-emergent herbicides under warmer (>5°C) conditions during a period where some rain has fallen and there are no frosts (see Table 3 Minimum re-cropping intervals and guidelines on page 12).

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

28 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

29 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

4.7 Safe rates of fertiliser sown with the seed

Germinating seeds can be damaged by fertiliser placed too close or applied at too high rates.

Increased row spacing and zero-till sowing can result in more fertiliser being placed in the sowing row, causing damage to emerging seedlings. This risk can be reduced by increasing the spread of seed and fertiliser in the row, reducing in-furrow fertiliser rates, or separating seed and fertiliser bands.

There are several factors that contribute to the safe amount of fertiliser that can be placed with the seed:

- crop type;
- fertiliser type;
- soil type and environment; and
- machinery configuration.[30]

4.7.1 Crop type

Overall canola and lentil are particularly sensitive to fertiliser toxicity, while wheat and barley are relatively tolerant. The order of sensitivity for crop species can vary based on fertiliser type. In general, the order from most to least sensitive in major grain crops is:

canola > lentil > peas > oats > wheat > barley.[31]

Lentil is very sensitive to fertiliser toxicity when fertiliser is sown closely with the seed.

4.7.2 Fertiliser type

Fertilisers can affect delicate germinating seeds in at least three ways:

Salt index: Most fertilisers are salts. Salts can affect the ability of the seedling to absorb water. Too much fertiliser salt can 'burn' the seedling. Most common nitrogen and potassium fertilisers have higher salt index than phosphorus fertilisers. Sulfate fertilisers tend to have lower salt indexes.

Ammonia in fertiliser: Free ammonia (a form of nitrogen) can be toxic to seed. **Placement in-furrow of urea (nitrogen-based fertiliser) is usually not advisable.**

Polymer coatings or urease inhibitors slow the rate of ammonia production. Utilising these products can reduce the risk of seed damage caused by ammonia-based fertilisers.

4.7.3 Soil type and environment

The risk of fertiliser damage increases with lighter soil texture (sands) and in drier soil conditions. Environmental conditions that induce stress or slow germination (cold temperature) prolong fertiliser and seed contact, thus increasing the likelihood of damage.

30 R Norton, G Sandral (2016) Give seeds the best chance by avoiding fertiliser damage. Extension Hub, https://extensionhub.com.au/web/crop-nutrition/-/give-seeds-the-best-chance-by-avoiding-fertiliser-damage?inheritRedirect=true

31 R Norton, G Sandral (2016) Give seeds the best chance by avoiding fertiliser damage. Extension Hub, https://extensionhub.com.au/web/crop-nutrition/-/give-seeds-the-best-chance-by-avoiding-fertiliser-damage?inheritRedirect=true

4.7.4 Machinery configuration

The type of point used in sowing equipment and the spacing between rows affect the concentration of fertiliser placed near seed and, therefore, the likelihood of damage.

Row spacing: The safe rate of fertiliser per hectare increases as row spaces narrow. Narrower row spacings have the effect of diluting fertiliser over the length of row.

Twin-chuting systems: Separate seed and fertiliser delivery chutes, either to different tynes or to different parts of the same tyne, provide separation of seed and fertiliser. Fertiliser is placed in bands either to the side or below the seed band. A separation distance of 3–5 cm is considered adequate to prevent seed damage.[32]

Seed bed utilisation: The more scatter there is between seed and fertiliser in the seed band the less risk of fertiliser damage to the seed.

The concept of seed bed utilisation (SBU) is used to address this factor.

SBU is the seed row width divided by the tyne spacing or row width; in other words, it is the proportion of row width occupied by seed row.

The wider the seed row for a specific row width the greater the SBU. As SBU increases so does the safe rate of in-furrow fertilisation.[33]

Liquid fertilisers

There are few guidelines for in-furrow liquid fertiliser application. As a general rule, the same rules for granulated (solid) products should be applied for in-furrow liquid fertiliser application.

MORE INFORMATION

Information on seed bed utillisation and fertiliser crop combination thresholds can be found at International Plant Nutrition Institute: http://anz.ipni.net/article/ANZ-3074

MORE INFORMATION

For further information on fertiliser placement with seed go to:

Give seeds the best chance by avoiding fertiliser damage https://extensionhub.com.au/web/crop-nutrition/-/give-seeds-the-best-chance-by-avoiding-fertiliser-damage?inheritRedirect=true

Care with fertiliser and seed placement https://grdc.com.au/Resources/Factsheets/2011/05/Fertiliser-Toxicity

32 R Norton, G Sandral (2016) Give seeds the best chance by avoiding fertiliser damage. Extension Hub, https://extensionhub.com.au/web/crop-nutrition/-/give-seeds-the-best-chance-by-avoiding-fertiliser-damage?inheritRedirect=true

33 R Norton, G Sandral (2016) Give seeds the best chance by avoiding fertiliser damage. Extension Hub, https://extensionhub.com.au/web/crop-nutrition/-/give-seeds-the-best-chance-by-avoiding-fertiliser-damage?inheritRedirect=true

4.8 Machinery for sowing

Lentil can be sown with a standard air seeder or conventional combine. Due to its small seed size, sowing lentil does not have the same issues that some of the other pulses encounter, due to their larger grain size.

Care must be taken when sowing lentil as seeds can 'bridge' (or accumulate) over the outlets causing uneven sowing. This can be eliminated by fitting an agitator. Adequate airflow is also critical: too much air pressure can cause seed damage and too little results reduced seed movement within the tubes.

4.8.1 Parameters for sowing equipment

Key elements required in sowing equipment include:

- adequate sowing mechanism to handle seed without damaging it or causing bridging or blocking;
- adequate sizes of seed and fertiliser tubes and boots to prevent blockages and bridging;
- can sow into stubble and residue, without blockages;
- sufficient down pressure to penetrate the soil, sow at the desirable depth, and place all seeds at a uniform depth;
- cover the seeds so that good seed-to-soil contact or moisture vapour ensures rapid germination;
- compact the soil with press-wheels or closers (if not a prickle chain or roller may be required later);
- disturbs the soil to the required level. This means no disturbance in zero-till with disc sowing; and
- having sufficient soil throw to incorporate herbicides (trifluralin). This can be by using either aggressive discs or narrow point set-ups in no-till, or full disturbance in more conventional or direct-drill systems.

4.8.2 Comparison of tynes

Successful plant establishment is critical. There are several options available to achieve this.

Narrow points are widely used in minimum or no-till sowing systems. There are also several other points available to achieve even plant establishment.

There are many variations within disc seeders. They differ in terms of soil disturbance and soil throw, as well as the ability to handle trash (stubble and residue) and 'sticky' conditions.

Table 4 highlights a range of functions required in tillage equipment and compares a range of no-till openers. In interpreting this table Pulse Australia[34] (2016) emphasises the following:

- With tynes, the slot created is different with the type of tyne used. Some create a vertical slot, others a 'V', while the inverted 'T' (or 'baker boot') leaves a slot with a narrow entrance and wider trench underneath. These tynes perform differently in some functions.
- Residues need to be handled in all conditions, not just when dry.
- 'Hairpins' (stubble is pressed into the slot by the disc ahead of the seed) needs to be avoided with seed placement away from the hairpin.
- Vertical slots tend to not self-close, especially in wet, clay soils.
- Ability of openers to follow ground surface variation is critical for uniform depth of sowing.

34 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

- Springs do not always apply consistent down force on openers throughout a range of soil conditions.
- Banding of fertiliser away from the seed is important for crop establishment. This is especially so when high rates or high analysis products are applied and the seed is in a narrow opening slot.
- Tines can manage stones, but can raise them to the soil surface. This means rolling is required after sowing to press stones back into the soil profile.
- Table 4 does not list 'deep working' as an opener. Deep working assists in the control of rhizoctonia. Deep working needs to be considered in situations where rhizoctonia may be an issue.

Table 4 is a basic guide to comparing openers for tillage. Consultation should be made with both an experienced agronomist and machinery dealer to assess the most appropriate system to suit paddock conditions and circumstances, and the overall cropping program.

Photo 5: *A Primary Precision Seeder fitted with hydraulic breakout for consistent penetration. It is also fitted with narrow points that form an 'inverted T' slot. It is capable of deep or side placement of fertiliser.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 6: *The DBS system parallelogram for uniform seeding depth and deep placement of seed or fertiliser.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 7: *A Case IH SDX-40 single disc drill.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 8: *One of several seeding mechanisms for uniform sowing depth using the press-wheel for depth control.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 9: *A Bio Blade or Cross slot™ disc opener with opening disc and seeding tyne, followed by paired press-wheels. Note that the seed and fertiliser tube has sharp bends and may not be wide enough to avoid blockages when larger-seeded pulses like faba or broad bean are being sown.*

Photo: W. Hawthorne, formerly Pulse Australia

Table 4: Comparison scores of no-till openers by function.

Rating basis: (1 = poor, 5 = excellent)	Narrow point	Wide point	Sweep	Double disc	Single disc	Slanted disc	Combined winged tyne & disc**
Ability to mechanically handle heavy residues without blockage	2	1	1	4	4	4	5
Leave 70%+ of original residue in place after drill has passed	3	2	2	5	4	4	5
Trap moisture vapour in the seeding slot in dry soils using residues as slot cover	3	2	3	1	2	4	5
Avoid placing seeds in 'hairpins'	5	5	5	1	2	2	5
Maximise in-slot aeration in wet soils*	3	4	3	1	3	3	5
Avoid in-slot soil compaction or smearing in wet soils*	1	1	3	1	5	5	5
Maximise soil–seed contact, even in greasy or 'plastic' conditions	4	3	4	3	3	4	5
Self-close the seeding slots	2	1	3	2	3	4	5
Mitigate slot shrinkage when soils dry out after sowing*	3	5	5	1	2	4	5
Individual openers faithfully follow ground surface variations	2	1	2	2	4	2	5
Individual openers have a larger than normal range of vertical travel	2	1	1	2	2	1	5
Maintain consistent down force on individual openers	3	1	1	2	3	3	5
Openers seed accurately at shallow depths*	2	1	1	2	2	1	5
Opener down force auto-adjusts to changing soil hardness	1	1	1	1	1	1	5
Simultaneously band fertiliser with, but separate from, the seed	5	5	5	1	2	3	5
Ensure that fertiliser banding is effective with high analysis fertilisers	5	5	5	1	1	2	5
Be able to handle sticky soils*	5	5	4	1	3	3	2
Be able to handle stony soils*	4	3	1	4	4	2	4
Avoid bringing stones to the surface*	1	1	1	5	5	3	5
Functionality unaffected by hillsides*	5	5	4	5	2	1	5
Minimal adjustments required when moving between soil conditions	3	3	3	4	1	1	5
Ability to maintain most critical functions at higher speeds of sowing	3	1	1	4	3	3	5
Wear components are self-adjusting	5	5	5	3	2	2	5
Design life of machine matches that of the tractors that pull it	4	4	4	2	2	2	5
Low wear rate of soil-engaging components	5	4	4	2	3	3	3
Wear components, including bearings, are cheap and easily replaced	5	5	4	2	2	2	4
Requires minimal draft from tractor	4	3	2	5	4	3	3
Proven, positive impact on crop yield	3	2	2	1	3	4	5
Total score (maximum = 140)	**93**	**80**	**80**	**68**	**77**	**76**	**131**
Rating score as % of maximum possible	**66**	**57**	**57**	**49**	**55**	**54**	**94**

* Functions that may be deleted in some circumstances, but all other functions are more universal. ** Combination is otherwise known as the Cross Slot™ or Bio Blade
NOTE that this is a broad GUIDE ONLY. Scores given in this table are subjective and may vary with individual openers etc. Source: C.J Baker 2010, SANTFA 12th Annual Conference pp 7-13, in Pulse Australia 2016

MORE INFORMATION

Nitrogen fixation of crop legume: basic principles and practical management Fact Sheet. www.grdc.com.au/GRDC-FS-NFixation-Legumes

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

4.9 Inoculation

How nodulation works

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

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

A well-nodulated and productive crop of lentil will fix about 120 kg of nitrogen per hectare. After grain harvest, fixed N can remain in the stubble and roots which, when mineralised, becomes available to the following crop: "on average, concentrations of soil mineral N after legumes [including lentil] can be expected to be 25–35 kg N/ha higher than following cereals".[35]

4.9.1 Inoculant groups

Lentil, in common with bean, field pea and vetch, is nodulated by *Rhizobium leguminosarum* bv. *viciae*. This species of rhizobia is produced and sold commercially as inoculant groups E and F (Table 5).

Table 5: Inoculation groups E and F.

Field pea and vetch	**Strain: SU303 (group E)**
Pisum sativum, Vicia species	*Rhizobium leguminosarum* bv. *viciae*
Faba bean, broad bean and lentil	**Strain: WSM1455 (group F)**
Vicia faba, Lens culinaris	*Rhizobium leguminosarum* bv. *viciae*

Source: Drew *et al.* (2014).

Inoculant strain WSM1455 is provided for lentil and bean to optimise nitrogen fixation potential of these legume hosts. Lentil can also be nodulated by strain SU303 (e.g. from a background population of rhizobia in a soil where pea or vetch have been grown) but inoculation with this strain is not recommended.

Lentil is not nodulated by the rhizobia which nodulate chickpea (Group N), lupin (Group G) or pasture legumes.

4.9.2 When to inoculate

Lentil will be responsive to inoculation if it (or bean, field pea and vetch) has not previously been grown in the paddock. Lentil is also likely to be responsive to inoculation on acidic soils because the rhizobia of these legumes are moderately sensitive to soil acidity (Photo 10). Lentil rhizobia may be absent or their number may be sub-optimal where soil pH ($CaCl_2$) is less than 6.0, even where there has been recent history of legumes that support lentil rhizobia. See Table 6 for likelihood of response to inoculation.

35 M Peoples *et al.* (2015) Legume effects on soil N dynamics - comparisons of crop response to legume and fertiliser N. GRDC Research Updates 2015

Photo 10: *Lentils on acid soil can fail to nodulate if they are not well inoculated. Poorly nodulated plants may appear yellow, with less biomass, but above-ground symptoms are not always obvious.*

Photo: W. Hawthorne, formerly Pulse Australia

Table 6: Likelihood of response to inoculation for lentil.

Likelihood	Conditions
HIGH	• Soils with pH ($CaCl_2$) below 6.0 and high summer soil temperatures (>35°C for 40 days); OR • Legume host (pea, faba bean, lentil, vetch) not previously grown.
MODERATE	• No legume host (pea, faba bean, lentil, vetch) in previous four years (recommended pulse rotation); OR • Prior host crop not inoculated or lacked good nodulation.
LOW	• Loam or clay soils with neutral or alkaline pH and a recent history of host crop with good nodulation.

Source: Drew *et al.* (2014).

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

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

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

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

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

4.9.3 Inoculant types

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

Table 7: Inoculant formulations available to Australian growers of lentil.

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

Source: Drew *et al.* (2014).

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

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

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

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

4.9.4 Inoculum survival

Moist peat formulation provides protection while unopened inoculum is stored.

Rhizobia will lose viability as they dry out after being applied to seed, prior to sowing into moist soil.

Seed coated with peat slurry mixes should be sown as soon as possible and definitely within 24 hours.

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

Dry-dusting the peat inoculant into the seed box is not an effective means of either getting or keeping rhizobia uniformly on seed. Under some conditions, rhizobial death is so rapid where dry dusting is used that no rhizobia are alive by the time the seed reaches the soil.[36]

Dry sowing

Where lentil (or a crop using Group F or E inoculant) has not been grown in a paddock before, dry sowing is not recommended.

Inoculum viability rapidly diminishes over time in warm, dry soils. There are no guidelines to survival times, and it is best to sow as close as possible to predicted rain or as deep as is practical, where there is a likelihood of higher soil moisture content.

Rhizobia may survive for longer in granules than when applied to seed if granules are drilled into soil below the seed. Hence, **when dry sowing pulses, granular inoculant is preferred over peat and liquid injection methods.**[37]

Nodulation failure after dry sowing of inoculated seed is more likely if the soil has no suitable rhizobia present from previous crops.

4.9.5 Storing inoculants

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

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

4.9.6 Seed treatment compatability

The survival of rhizobia may be compromised when mixed with pesticides, fertilisers or other amendments. Guidelines are provided by inoculant manufacturers on the compatibility of their specific products with commonly used pesticides and fertilisers. The guidelines should be strictly followed.

More generally, consideration of the following principles will help reduce the likelihood of killing inoculant rhizobia.

- Direct mixing of rhizobia with amendments in tank mixes or during preparation of the peat slurry is most likely to kill rhizobia.
- Most rhizobia are sensitive to pH below 5 or above 8. Avoid mixing rhizobia with very acidic or alkaline products. Fertilisers and trace elements are often outside this pH range; product MSDSs usually contain information on pH of the products.
- Metals such as zinc, mercury, copper and manganese may be harmful. Sodium molybdate is toxic to rhizobia.
- When applying fungicides and insecticides to seed, minimise the time the rhizobia are exposed to the pesticide by applying the rhizobia last to the dried seed and sow as soon as possible. Where possible, sow within 6 hours of rhizobia application.
- Peat inoculant formulations may assist the survival of the rhizobia that come into contact with toxic chemicals.

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

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

4.9.7 Inoculant quality assurance

Most pulse inoculants sold in Australia must pass a rigorous quality assurance (QA) program.[38]

Cultures of inoculant are tested by the Australian Inoculants Research Group (AIRG) to establish that the correct rhizobial strain is present and the viable cell number exceeds a minimum value (Table 8).

Products which pass QA tests by AIRG bear the 'green tick' logo, either on the bag, the packet or on the box of packets.

Table 8: AIRG Quality Assurance rhizobia minimum numbers.[39]

Product	Viable rhizobia/g	Rate/ha	Rhizobia/ha	Expiry (months)
Peat	1×10^9	250 g	3×10^{11}	12–18
Liquid	5×10^9	300 ml	2×10^{12}	6
Granular	1×10^7	10 kg	1×10^{11}	6
Freeze-dried	1×10^{12}	0.15 g	2×10^{11}	24

4.9.8 Inoculation methods

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

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

Peat inoculants

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

How to apply slurry to the seed:

- Through an auger: make sure the auger is turning as slowly as possible, to achieve effective mixing. Reduce the height of the auger to minimise the height of seed fall.
- Meter the peat slurry in, according to the flow rate of the auger (remember 250 g packet per 50 kg of seed).
- Through a tubulator: similar to applying through an auger, except that the tubulator reduces the risk of damaging the seed. Its mixing ability is not as effective as an auger.

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

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

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

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

Freeze-dried inoculants

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

The rhizobia become active when the inoculant is reconstituted with liquid. The product comes with a protective polymer in a separate packet, which assists survival of the rhizobia. A standard vial of inoculant will treat up to 250 kg of lentil seed.

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

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

Granular inoculants

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

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

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

4.9.9 Check for nodulation

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

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

For lentil, 20 to 50 pink nodules per plant after approximately 10 weeks' plant growth is an adequate level of nodulation Photo 11). A strong pink colour inside the nodule indicates the rhizobia are actively fixing nitrogen for use by the plant (Photo 12).

Sampling and processing

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

Nodule number and distribution

Score each plant for nodulation. At least 20 pink nodules per plant is considered adequate (Photo 12). Separate plants into adequate and inadequate groups. If the adequate group contains more than 70% of the plants then inoculation has been successful.

Photo 11: *Well-nodulated roots of lentil showing nodules clustered on the main taproot.*

Photo: Maarten Ryder; University of Adelaide

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

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

Nodule appearance

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

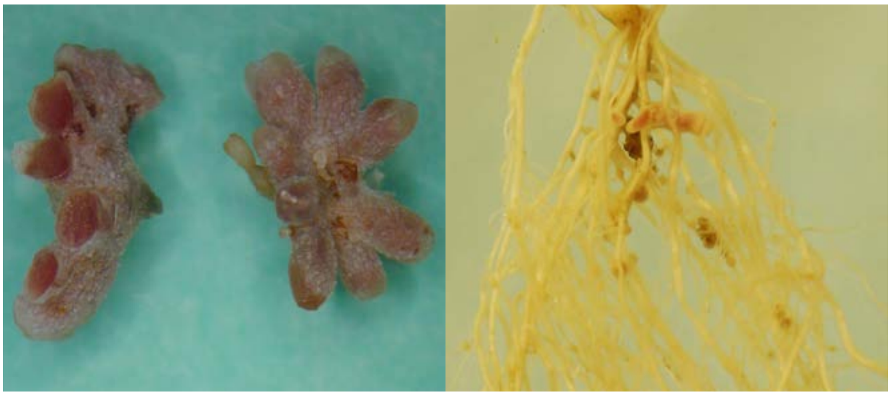

Photo 12: *Roots with large pink nodules. Young, active nodules are an intense pink colour inside.*

Photos: Liz Farquharson, SARDI; Ross Ballard, SARDI

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

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

4.10 Irrigation

Irrigating lentil, as either fully irrigated or supplementary, is not widely practised in Australia due to the high risk of yield loss with waterlogging.[40]

Nevertheless, irrigating lentil may be economical if:

- the irrigation system allows adequate drainage;
- the water quality is high; and
- the rotation with other winter and summer crops is managed to reduce disease pressure.

4.10.1 Principles

There are a number of factors to consider when irrigating lentil:

- avoid soils and irrigation layouts that do not drain freely and are subject to waterlogging;
- avoid heavy clay or dense soil types (bulk density > 1.5);
- select paddocks with good irrigation layout, such as beds or hills, and relatively good grades;
- assess layouts steeper than 1:800 grade for suitability. Runs must be short with free draining soils that can be irrigated quickly and do not remain saturated;
- rolling may also be required to flatten the ridges left by press-wheel furrows or to flatten clods; and
- irrigation can be used in activating and incorporating a number of pre-emergent herbicides.[41]

4.10.2 Management

Management requirements for irrigated lentil are the same as for dryland crops, with a greater emphasis on disease control as irrigated crops are more prone to the spread of foliar diseases. This is due to the dense canopy and potentially prolonged leaf wetness after irrigation.[42]

The amount of water to apply is dependent on rainfall and rate of evaporation.

40 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

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

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

As a shallow-rooted plant, lentil requires significant moisture to produce an optimum yield. However, lentil dies quickly when flooded. **Good drainage is essential to prevent water accumulation on the soil surface and waterlogging of the soil, particularly during planting and early flowering.** Even short periods of waterlogging can result in severe losses, particularly if the crop is stressed (from herbicides, disease, moisture, etc.).

- Pre-irrigate to fill the moisture profile prior to planting unless this has already been achieved by rainfall.
- Do not dry sow and then irrigate unless under sprinkler irrigation.
- As a general rule, in-crop irrigation should start early when there is a deficit of between 30–40 mm and around 60–70% of field capacity. Irrigating according to moisture is more important than irrigating for growth stage.
- Irrigations should commence prior to flowering to prevent moisture stress and high temperatures impacting on yield, quality and grain size.
- For furrow irrigation, every second row should be irrigated to avoid waterlogging. Doubling up siphons can increase water flow and reduce irrigation time.
- Irrigating should be completed in less than 8 hours. This includes good tail water drainage to avoid waterlogging.
- Supplemental irrigation with 1.2 cm of water may be required prior to canopy closure. This encourages pod formation and filling and carry the crops water needs to maturity.
- Avoid irrigating if there is likelihood of rain soon after.

Sprinkler irrigation is more suited to lentil as there is very little risk of waterlogging even during flowering and pod-fill. However, water quality is important, and there may be a need for greater disease control against Botrytis grey mould (BGM) or Ascochyta blight. This is due to more frequent wet leaf and soil conditions.

Salinity levels in irrigation water or the soil must be low. **Lentil is one of the more sensitive crops to salinity.** A 10% reduction in yield is expected if irrigation water measures 1.0 deciSiemens per metre (dS/m).[43]

MORE INFORMATION

For further information, go to: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

4.10.3 Irrigation findings from NSW DPI

Taking into account the differences between lentil and faba bean, lessons learnt from ‘Faba Check’ can be utilised to assist with tips for irrigated lentil production.

New South Wales (NSW) Department of Primary Industries (DPI) conducted ‘Faba Check’ monitoring of irrigated bean crops in southern NSW from 2000 to 2004. Key factors for success of irrigated faba bean crops were identified. When utilising this information for growing lentil, the greater sensitivity of lentil to waterlogging, compared to faba bean, must always be considered.

43 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Post planting

Key points

- **Rolling lentil improves harvest efficiency and minimises soil contamination at delivery.**
- **Rolling lentil helps protect the crop from post-sowing herbicide damage.**
- **A flat, firm soil surface at harvest becomes even more essential when crops are short in height at maturity due to low rainfall.**
- **The optimum timing for post-emergent rolling is when most of the crop is close to the top of the furrow: 3–5-leaf growth stage.**

Q&A

Why roll lentil?
Rolling paddocks' soil surface improves harvest efficiency and protects the crop from residual herbicide damage

When should lentil be rolled?
From the crop's pre-emergence, ideally 3–4-leaf stage, and possibly up to 4–5-leaf stage, lentil can be rolled

What sort of roller should be used?
Both rubber-tyred and steel rollers can be used to roll lentil, with the choice largely dictated by soil conditions and the type of material being rolled

When should rolling not occur?
Rolling is not usually necessary with disc tillage systems as these systems generally provide a flat harvesting surface.

5.1 Rolling lentil

5.1.1 Why roll lentil?

The practice of rolling lentil, or to be precise, rolling the soil surface of paddocks sown to lentil, is done to improve harvest efficiency and to protect the crop from post-sowing herbicide damage.

Leaving a flat, firm soil surface is essential when growing lentil because this enables a successful and trouble-free harvest with minimal harvest loss or damage to the harvester. The specific aim of rolling is to flatten any ridges and clods caused by sowing, pressing any rocks or sticks into the soil. This allows flexi and draper fronts to 'sit' on the soil surface when harvesting, for both greater efficiency and a better quality grain sample.

A flat, firm soil surface at harvest becomes even more essential when crops are short in height at maturity due to low rainfall.

Rolling lentil also prevents post-sowing herbicides from accumulating in furrows which may result in herbicide damage to the lentil plant.[1]

5.1.2 When to roll

Rolling is possible from pre-emergence of the lentil crop, ideally 3–4-leaf stage, and up to 4–5-leaf stage.

In the past rolling of paddocks sown to lentil has generally occurred before crop emergence. However, in recent years many growers have taken to post-emergent rolling of lentil at the 3–5-leaf stage (Section 4, Figure 1 and Figure 2). Reasons for this change include:

- shoot damage occurring in crops rolled as the plant is about to emerge;
- soils prone to hard setting or crusting can lead to emergence problems if rolled pre-emergence;
- greater wind and water erosion risk where soils are rolled and plants have not established, particularly on sloping soils; and
- with some heavy rollers on sandy soils, pre-emergent rolling can push herbicides into the row, resulting in possible damage to the crop.

5.1.3 Rolling post-emergence

Rolling post emergence provides the grower with a greater window to choose the right soil-moisture conditions to achieve maximum burial of stones and clumps and improved levelling of the soil surface.

The optimum timing for post-emergent rolling is when most the crop is close to the top of the furrow: 3–5-leaf growth stage. Trials on lentil in Australia and Canada have shown there is no yield loss if rolling occurs up to the 8th branching node stage.[2] This allows some flexibility with timing rolling to fit in with weed control priorities.

When rolling post-emergent lentil, the following should be considered:

- avoid rolling during the period when plants are just starting to emerge;
- do not roll for 14 days after herbicide application and, conversely, do not apply herbicides until 14 days after rolling;
- do not roll stressed or diseased plants;
- the least amount of damage occurs to the plant when it is limp, e.g. mid-afternoon; and
- avoid rolling straight after rain in heavier soil types.[3]

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1 R Rundell-Gordon (2016) Growing lentils: lessons learnt from growing lentils in central and north west Victoria. Grains Research and Development Corporation Update, 17 Mar 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Growing-lentils-lessons-learnt-from-growing-lentils-in-central-and-north-west-Victoria

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

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

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Rolling post-emergence can increase the risk of foliar diseases later.

Damaged plant tissue can become the site for Botrytis grey mould or other common diseases to develop later, particularly if cold and wet conditions follow.

Frosty conditions and wet foliage must be avoided when rolling.

5.1.4 Choice of roller

Both rubber-tyred and steel rollers can be used to roll lentil, although a lighter roller is preferred when rolling post-emergence (Figure 1).[4]

The choice of roller is largely dictated by soil conditions and the type of material being rolled. The heavier the roller the better the result of levelling heavy soil types and pushing rocks and sticks below the soil surface. Lighter rollers work well on sandier soils.

Photo 1: *Rubber-tyre roller.*

Photo: M. Raynes, formerly Pulse Australia

4 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Photo 2: *Lentil ridges rolled after sowing.*

Photo: M. Raynes, formerly Pulse Australia

5.1.5 Benefits

The ideal outcome of rolling lentil is that the resulting flat soil surface will allow the harvester to operate at near-ground level, picking up the short crop and harvesting pods close to the ground. A flat surface reduces harvest losses, harvester wear and contamination in the grain sample.

Rolling may not necessarily flatten all the standing stubble present. However, after summer or harvest rains, cereal stubble and in particularly barley stubble, tends to be more brittle and does not stand as well after rolling. Some of the lentil crop growth and erectness benefits of standing stubble may therefore be lost. The use of some disc drills at sowing, sown into paddocks with standing stubble, may eliminate the need to roll lentil crops.[5]

Extra care is required for narrow-point and press-wheel tillage systems as standard rolling may result in the soil ridges being completely level to the roller, as the roller will tend to ride on the ridges and put less pressure on the plant rows.

5.1.6 When not to roll

Rolling is not usually necessary with disc tillage systems as these systems generally provide a flat harvesting surface. On some soil types the clods or ridges naturally flatten with rainfall during the season.

5 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

Plant and growth physiology

Key points

- **The lentil plant is hypogeal, meaning the cotyledons of the germinating seed remain below the ground and inside the seed coat.**
- **Lentil germination requires a minimum soil temperature of 5°C.**
- **The lentil plant is a slender, semi-erect, bushy annual with compound leaves with a tendril at each tip.**
- **Lentil roots are highly sensitive to saline, boron and sodic soils.**
- **Flowering begins on the lowest branches, gradually moving up the plant and continuing until near maturity.**
- **Lentil has an indeterminate growth habit, meaning it is possible to find flowers, immature pods and mature pods on a plant at the same time.**

6.1 Introduction

The lentil plant experiences hypogeal emergence, like field pea (Figure 1), which means the cotyledons of the germinating seed remain below the ground and inside the seed coat. Seedlings with hypogeal emergence are less likely to be killed by frost, wind erosion or insect attack. This is because new stems can develop from buds at nodes at, or below, ground level. Their growth may, however, be slowed considerably.

The lentil plant is a slender, semi-erect, bushy annual with compound leaves (four to seven pairs of leaflets), similar to vetch leaves, with a tendril at each tip. Plants can have single stems or many branches, depending upon the population in the paddock. The many stems of a lentil plant originate from near the ground and are better supported when the crop is sown inter-row, which means between the rows of last season's cereal stubble.

Plants normally range from 30–50 cm in height. Plants generally grow taller when the growing season temperatures are cool, and there is good moisture and soil fertility. Despite their relatively short plant height, many crops lodge late in spring due to their weak stems, particularly if well grown with high crop biomass and high yields.

Flowering begins on the lowest branches, gradually moving up the plant and continuing until harvest. Flowers can be white, lilac or pale blue in colour and are self-pollinated. Lentil plants flower profusely over a short period and set many pods, with each pod containing one or two seeds depending on the growing season conditions. **Due to its indeterminate growth habit it is possible to find flowers, immature pods and mature pods on a plant at the same time.** This means that crop desiccation may be required, as an aid to harvest, in order to create more even maturity.

Seeds are small in comparison with other pulses and are a characteristic lens shape.[1]

1 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

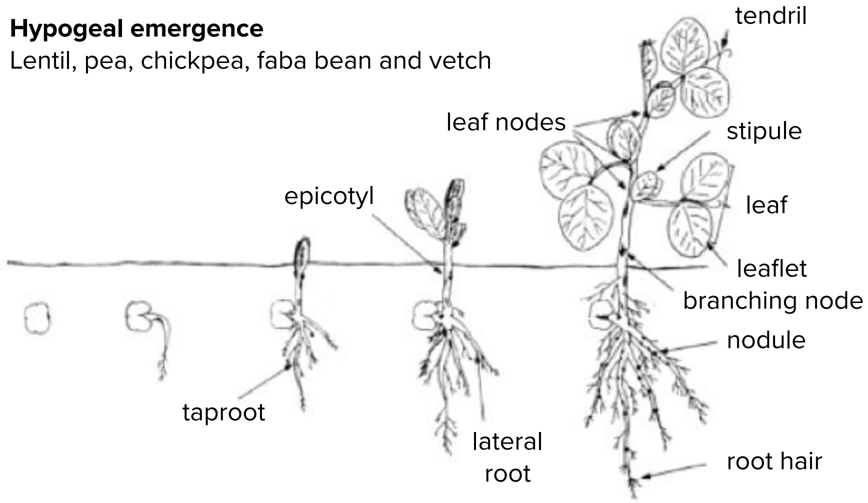

Figure 1: *Seedling development of lentil.*

Source: Best Management Guide –Lentil Production: Southern Region, (2015), Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

6.2 Stages of growth

Uniform growth stage descriptions have been developed for the lentil plant (Table 1). These descriptions are universally applicable to all growing environments and divergent cultivars.[2]

Table 1: Growth stages of a lentil plant.

Development phase	Growth stage (GS)	Description
Germination and emergence	VE	Seedling emergence, cotyledonary node visible
Vegetative	V1 V2 V3 V4 V5 NV	First simple leaf has unfolded at the first node Second simple leaf has unfolded at the second node First bifoliate leaf has unfolded at the third node Second bifoliate leaf has unfolded at the fourth node First multifoliate leaf has unfolded at the fifth node Nth multifoliate leaf has unfolded at the nth node
Reproductive Flowering in lentil is indeterminate, occurring from axillary buds on the main stem and branches. It proceeds acropetally from lower to higher nodes.	R1 R2 R3 R4 R5 R6	Early bloom, one open flower at any node Full bloom, flower open or has opened on nodes 10–13 of the basal Primary branch Early pod, pod on nodes 10–13 of the basal primary branch visible Flat pod, pod on nodes 10–13 has reached its full length and is largely flat Early seed, seed in any single pod on nodes 10–13 fill the pod cavity Full seed, seed on nodes 10–13 fill the pod cavities
Physiological maturity	R7 R8	Leaves start yellowing and 50% of the pods have turned yellow 90% of pods on the plant are golden-brown

Source: Stages of Development in Lentil (1990), https://www.researchgate.net/publication/231803378_Stages_of_Development_in_Lentil

2 W Erskine, F Muehlbauer, R Short (1990) Stages of Development in Lentil. Exp. Agric. 26:297-302, https://www.researchgate.net/publication/231803378_Stages_of_Development_in_Lentil

6.2.1 Germination and emergence

Germination occurs with the root developing out of the seed first. This is followed by the shoot emerging upward towards the soil surface.

The shoot emerges through the soil with the first leaves pointing downwards. Upon reaching the soil surface the shoot extends upwards.

6.2.2 Vegetative

The vegetative stage is determined by counting the number of developed nodes on the main stem, above ground level.

Vegetative nodes are counted from the point at which the first true leaves are attached to the stem. The last node counted must have its leaves unfolded.

The node at which the first leaflet arises from the main stem above the soil is counted as vegetative node one (Figure 2). A node is counted as developed when leaves are unfolded and flattened out. Scale leaves at the base of the plant and close to the ground are not counted but are classified as 'true nodes'.

Leaves that develop above the 5th or 6th node are about 5 cm long with 9–15 leaflets.

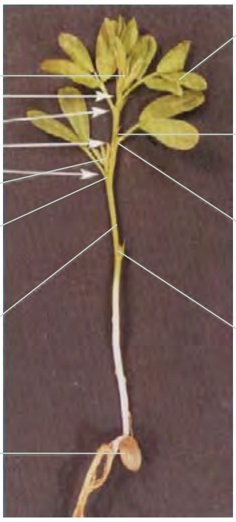

Figure 2: *Lentil early growth stages.*

Source: Image is modified from: Weeds in Winter Pulses (2004), CRC for Australian Weed Management, http://trove.nla.gov.au/work/11851108?selectedversion=NBD41255510

6.2.3 Reproductive

The reproductive stage begin when the plant begins to flower at any node. Flowering in lentil is indeterminate, occurring from axillary buds on the main stem and branches. It proceeds acropetally from lower to higher nodes.

Reproductive stages R1 and R2 are based on flowering, and R3 to R6 are based on pod and seed development.

6.2.4 Physiological Maturity

Physiological maturity is when the seed can develop no further dry matter (R7 and R8).

MORE INFORMATION

Cotyledtons

Cotyledons and first node are with the seed piece. Second and third nodes usually stay below the ground and act as axillary buds. The first true leaf actually is the third or fourth node. However, it is called the first vegetative node.

6.3 Crop development

6.3.1 Sowing to germination

Lentil germination requires a minimum soil temperature of 5°C, slightly warmer than that required for field pea.[3]

Under optimum moisture and temperature conditions, lentil seeds absorb water relatively quickly and germinate within a few days providing temperatures are above 0°C. Unlike lupin, lentil seedlings have hypogeal emergence, that is, their cotyledons (embryonic leaves) remain underground inside the seed coat whilst providing energy to the rapidly growing roots and shoots.

6.3.2 Germination to emergence

Emergence occurs 10–21 days after sowing, depending on soil moisture, temperature conditions and depth of sowing.

Depending on soil temperature, the number of days to emergence for lentil are:

- 5°C–7.2°C → 17–21 days;
- 7.2°C–10°C → 14–17 days; and
- 10°C–12.8°C → 10–14 days.

Growth of the shoot (plumule) produces an erect shoot and the first leaves are 'scales.' The first true leaves have a single pair of leaflets (i.e. two leaflets), and from the 5th to 8th node leaves have two or three pairs of leaflets. The development of multiple pairs of leaflets per leaf generally corresponds with development of the first flower bud.

Approximate times to reach leaf stages are:

- 1st node/leaf stage: usually 14 days (depending on soil temperature); and
- 2nd node/leaf stage and after: every 4–5 days.

6.3.3 Roots

Lentil has a slender taproot with a mass of lateral fibrous roots. Plant roots are important in the capture of moisture and inorganic nutrients, particularly on soils with low fertility or low water-holding capacity.

Positive associations have been reported between rate, and amount of, root surface development with grain yield.[4,5]

Lentil varieties, that are adapted to differing soil types, have either shallow, intermediate or deep root systems (Figure 3). Soil texture, depth, and whether the soil cracks or not, can determine which variety suits a particular soil.

3 K McKay (undated) Growing Peas and Lentils: Key Growth Stages. Unpublished, https://www.ag.ndsu.edu/NorthCentralREC/crop-production-extension/Pea%20Growth_Stages_Considerations.pdf

4 T Gahoonia, O Ali, A Sarker, M Rahman, W Erskine (2005) Root traits, nutrient uptake, multi-location grain yield and benefit-cost ratio of two lentil (Lens culinaris, Medikus) varieties. Plant and Soil, 272(1/2), 153-161, https://repository.uwa.edu.au/R/-?func=dbin-jump-full&object_id=18937&local_base=GEN01-INS01

5 A Sarker, W Erskine, M Singh (2005) Variation in shoot and root characteristics and their association with drought tolerance in lentil landraces. Genetic Resources and Crop Evolution 52(1): 89-97, http://link.springer.com/article/10.1007%2Fs10722-005-0289-x

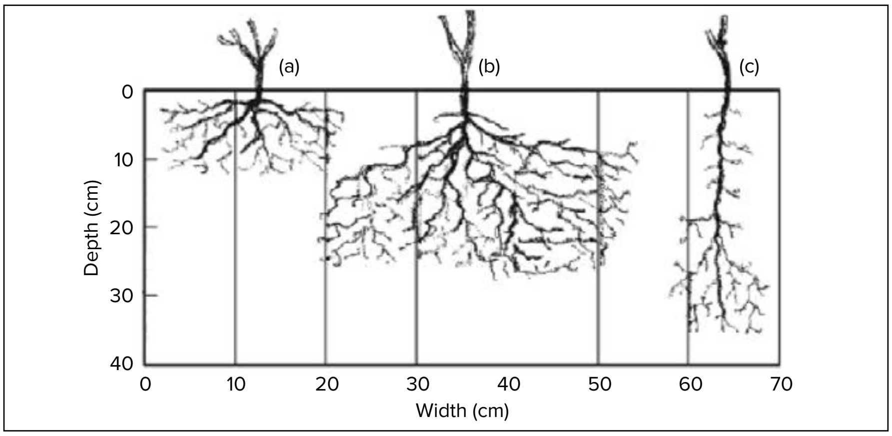

Figure 3: *Root systems in lentil.*

Source: The Lentil: Botany, Production and Uses. Centre for Legumes in Mediterranean Agriculture (2009), http://www.cabi.org/cabebooks/ebook/20093211138

The lentil varieties grown in Australia have profusely branched secondary roots that increase in size near the soil surface as the season develops. Their root systems are relatively strong, but do not penetrate to the same depths as cereal roots, especially when there are subsoil constraints.

Lentil roots are highly sensitive to saline, boron and sodic soils. Implications of this include limited root growth, root depth and moisture extraction capabilities. Yield can be severely reduced on wet, poorly drained soils, and root diseases will increase as well.

Lentil roots can 'leave' moisture at depth late in the season and this can contribute to their relatively lesser ability to withstand dry conditions. Root growth is most rapid before flowering and will continue until maturity under favourable conditions.

Lentil is susceptible to hard-pans, which are compacted layers of soil that physically restrict root growth. Lentil prefers deep, well-structured soils so that roots can penetrate deeply. Subsoil constraints, such as soil chloride in excess of about 800 milligrams per kilogram (mg/kg) soil in the top 60 cm will likely restrict root growth and water availability.

With chloride levels at over 1,000 mg/kg in the top 100 cm there is likely to be a significant negative relationship between yield and salt tolerance in lentil.

As well as their role in water and nutrient uptake, lentil roots develop symbiotic nodules with the rhizobium bacteria *Rhizobium leguminosarum*, which are capable of fixing atmospheric nitrogen. The plant provides carbohydrates for the bacteria in return for nitrogen 'fixed' inside the nodules (Photo 1).

MORE INFORMATION

For more information on soil types suited to lentil refer to Section 2: Paddock selection and preparation

Photo 1: *Nodulated roots.*

Photo: G. Cumming, formerly Pulse Australia

IN FOCUS

Root mass and penetration

Root growth of lentil is often most rapid until pod development, when seeds begin to fill. After, roots continue to grow at a much slower rate until close to crop maturity. The total root length beneath pulse crops is about 10 times smaller than in cereal crops. Root length density of pulse crops seldom exceeds 1 cm of root/cm^3 of soil, even in the surface layers. This restricted rooting density has consequences for the uptake of water by the lentil plant.[6]

Lentil roots do not produce as much biomass as chickpea or wheat plant roots.

MORE INFORMATION

The GRDC has produced fact sheets on nitrogen fixation and micronutrients. Please see: https://grdc.com.au/GRDC-FS-NFixation-Legumes

6 P Gregory (1988) Root growth of chickpea, faba bean, lentil, and pea and effects of water and salt stresses. In 'World crops: Cool season food legumes. Current Plant Science and Biotechnology in Agriculture Volume 5, 1988, pp 857-867, http://link.springer.com/chapter/10.1007/978-94-009-2764-3_68

6.3.4 Nodulation

Nodules might start appearing as early as 15 days after emergence. The taproot and lateral roots near the soil surface carry the small round or oblong shaped nodules, if the correct strain of rhizobia is present.

Nodulation by nitrogen-fixing bacteria begins at the 3rd and 4th node stage.

Peak nodule growth and development occurs at peak vegetative production, and starts to decline at the commencement of flowering, or later if adequate soil moisture is available.

Nodules eventually form slightly flattened, fan-like lobes and are nearly all confined to the top 30 cm of soil, with 90% being within 15 cm of the surface. When cut open, healthy nodules that are actively fixing nitrogen have a pink centre (Figure 5). Nitrogen fixation is highly sensitive to waterlogging so lentil needs well aerated soils.[7]

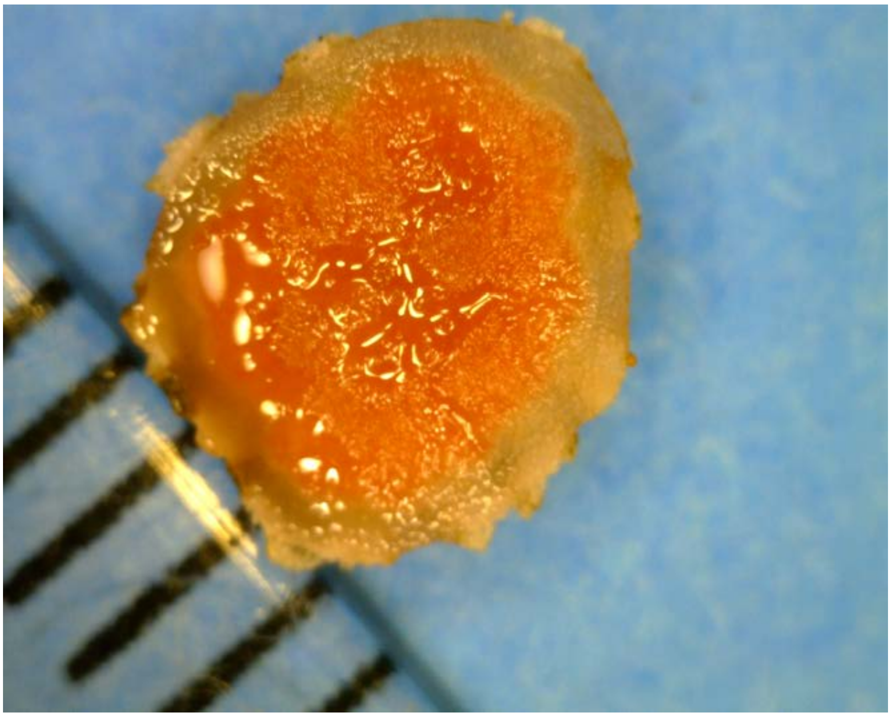

Photo 2: *Active nodules have a pink centre.*

Photo: G. Cumming, formerly Pulse Australia

7 AH Gibson (1971) Factors in the physical and biological environment affecting nodulation and nitrogen fixation by legumes. Plant and Soil. Aust J. Sci. 20 1087-1104, https://link.springer.com/article/10.1007/BF02661847

6.3.5 Nodes and leaves

The first node of the lentil plant is found below the soil surface, and sometimes the second is found below or at the ground surface. A scale or scale leaf will form at these nodes.

At the third and fourth nodes, a bifoliate leaf (two-leaflet compound leaf) will unfold.

From the fifth node on of the vegetative stages, a multifoliate leaf will unfold at each node. These multifoliate compound leaves will be made up of 9–15 leaflets.

Leaflets are not serrated. Unlike most other members of the *Lens* genus, lentil is without tendrils or rudimentary tendrils. Just prior to flowering, new leaves develop a short tendril at the leaf tip.

6.3.6 Stem and branches

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

Unlike lupin and some other pulses like chickpea, lentil does not have secondary or tertiary branches that develop from the main stem or branches.

Australian lentil varieties are indeterminate, which means vegetative growth continues initially after the plant switches to reproductive mode and flowering begins, but can terminate before moisture becomes limiting. Current Australian green lentil varieties are later maturing than red lentil varieties.

Plants normally range from 30–50 cm tall; the taller plants are a result of cool growing season temperatures, good moisture and good fertility. Plants can have single stems or many branches depending upon the population in the field.

Photo 3: *Lentil plant structure. Note basal branches, branch and then pod development as the plant grows. Note also leaves along the branch, with multiple leaflets on each leaf.*

Photo: Wayne Hawthorne, formerly Pulse Australia

Photo 4: *Lentil plant structure.*

Photo: Wayne Hawthorne, formerly Pulse Australia

6.3.7 Flowering and pod development

The beginning of the reproductive stage is marked by flowers opening at any node. In early maturing varieties, flowers will open at about the 10th to 11th nodes, while flowers of later-maturing varieties will open at the 13th or 14th nodes.[8]

Flowering begins on the lowest branches, gradually moving up the plant, and continuing until desiccation or harvest.

The node of the first flower, and the interval between successive nodes, vary depending on the month, season, variety and sowing time. Duration between nodes is particularly slow during vegetative and early reproductive stages during winter, but shorter during spring.

Each flower produces a short pod containing one or two lens-shaped seeds. Flowers can be white, lilac or pale blue in colour and are self-pollinated. At maturity, plants tend to lodge because of their weak stems.

Flowers are self-pollinated. Pods are less than 2.5 cm in length and contain one or two seeds. Most of the seed is produced on branches that form on the middle and lower nodes of the main stem, depending on variety and growing conditions.

If moisture and temperature conditions are favourable, additional crop growth, node production, flowering and, therefore, crop height occurs until flowering ceases. It is hot conditions (maximum temperatures >30°C) or lack of moisture that causes flowering and consequently, additional crop growth to cease.

If the crop is able to continue to grow taller as it flowers, it will use more soil water. Water-use efficiencies will decline under such circumstances.

8 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Photo 5: *Lentil flowers.*

Photo: M. Raynes, formerly Pulse Australia

Photo 6: *Lentil with poor podset.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 7: *Lentil with excellent podset.*

Photo: M. Raynes, formerly Pulse Australia

Photo 8: *Well-podded lentil plants showing their basal branching habit and multiple podding nodes.*

Photo: W. Hawthorne, formerly Pulse Australia

6.3.8 Maturity

Soon after the development of pods and seed filling, senescence (drying-off) of leaves begins. If there is plenty of soil moisture, and maximum temperatures are favourable for lentil growth, flowering and podding will continue on the upper nodes. However, as soil moisture is depleted, or if temperatures increase, flowering ceases and eventually the whole plant matures. Flowering can recommence if rain follows high temperatures. This is typical of pulse crops and annual plants in general.

In warmer environments, flowering might cease and plants start to ripen in response to high temperatures, even though there could be adequate soil moisture present.

Lentil is unlike chickpea, and cannot tolerate high temperatures even if there is adequate soil moisture. Chickpea is normally one of the last pulse crops to mature in Mediterranean-type environments.[9]

Green lentil varieties in Australia are generally later maturing than red lentil varieties, although both types have a range of maturities. These large green lentil varieties will only produce to their genetic potential for seed size if they are grown in a long, cool growing season.

As leaves begin to senesce, there is a rapid re-translocation of dry matter from leaves and stems into the seeds.

In southern Australia, lentil crops can reach maturity 180 to 220 days after sowing, depending on the sowing date, variety, and a range of environmental factors including rainfall and temperature. Lentil is ready to harvest when more than 90% of the pods lose their green colour. Stems may still show some 'green-ness', however, seeds are usually hard and rattle when the plant is shaken.

Windrowing, or desiccation, of lentil crops can commence when the majority of seeds are physiologically mature. This is assessed as being when at least 50% of the seeds in the pods present in the top third of the canopy are displaying some colour change (yellow-buff) and the remaining seeds are firm to touch and a deep green colour.

As an indicator this will coincide with 60% of the pods in the top third of the canopy appearing yellow-buff.

At this stage, at least 85% of the pods should be yellow to ripe, and the top pods should have turned from a dark green colour to a lighter green to yellow colour. Cotyledons of the top-most pods change from a green colour to yellow or red, depending on the lentil type. There is still yellow to green leaf present. Lowest pods start to turn light brown and have seeds with completely normal cotyledon colour for the variety.

Photo 9: *Lentil that has matured.*

Photo: W. Hawthorne, formerly Pulse Australia

9 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Photo 10: *Mature, well-podded lentil before their pods and stems dry for harvest.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 11: *A view from a harvester front of erect, well-podded lentil plants.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 12: *Mature lentils are a golden, light brown colour, and in this photo have been harvested (left). Note the erectness at harvest after being sown inter-row into standing cereal stubble.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 13: *This lentil grain is not yet considered physiologically mature. Note that the leaf colour has yellowed on the dry down, but pods have not yet started to dry down. Note also the small brown aborted pods in this crop.*

Photo: M. Raynes, formerly Pulse Australia

Photo 14: *Lentil pods starting to change colour from the tip as they commence to dry down towards maturity.*

Photo: M. Raynes, formerly Pulse Australia

Photo 15: *Lentil during pod-fill and before dry down.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 16: *Lentil during pod fill and starting to dry down.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 17: *Lentil drying down.*

Photo: W. Hawthorne, formerly Pulse Australia

Nutrition and fertiliser

Key points

- **Lentil nutrition requirements are similar to other pulses.**
- **Lentil is generally responsive to phosphorus and some trace elements (managnese and zinc in particular).**
- **Lentil can benefit from nitrogen at sowing if following a ‘nitrogen-hungry’ crop like cereal or canola.**
- **Symptoms of nutrient deficiency in lentil appear to be similar to the other pulses.**
- **Soil must be moist to allow roots to take up and transport nutrients.**
- **Soil pH influences the availability of most nutrients.**
- **Soil temperature must lie within a certain range for nutrient uptake to occur.**

7.1 Essential nutrients for plants

There are 16 nutrients that are essential for the healthy growth of all plants. They are classified as mineral nutrients and non-mineral nutrients.

Non-mineral nutrients are carbon (C), hydrogen (H) and oxygen (O). These nutrients are found in the atmosphere and water and used in the process of photosynthesis. The main product of photosynthesis is carbohydrate (as well as oxygen and water, to a lesser extent); it is carbohydrate that drives the growth and development of plants.

Mineral nutrients are absorbed by plants from the soil. Mineral nutrients can be classed as either macronutrients or micronutrients.

Table 1: The classification of mineral nutrients.

Macronutrients	Micronutrients
Nitrogen (N)	Boron (B)
Phosphorus (P)	Chlorine (Cl)
Potassium (K)	Copper (Cu)
Calcium (Ca)	Iron (Fe)
Magnesium (Mg)	Manganese (Mn)
Sulfur (S)	Molybdenum (Mo)
	Zinc (Zn)

Source: CSIRO Publishing, 2006, Australian Soil Fertility Manual

Five other elements are also essential to plant growth. These are sodium (Na), cobalt (Co), silicon (Si), nickel (Ni) and vanadium (Va). These nutrients are almost never found to be deficient in the soil; problems with these elements are generally due to toxicity and not deficiency.[1]

Macronutrients

Macronutrients are those elements that are needed in relatively large amounts. Nitrogen, phosphorus and potassium are classed as primary macronutrients and calcium, magnesium and sulfur are considered secondary macronutrients.

Macronutrients are used in the greatest quantity by plants and usually become deficient first.

High yields of crops for grain or forage will place greater demand on the availability of major nutrients such as phosphorus, potassium and sulfur. Nitrogen, phosphorus and, at times, sulfur are the main nutrients that are commonly lacking in Australian soils. Other nutrients can be lacking under certain conditions. Each crop type is different in its requirement for nutrients and may display different symptoms indicating this requirement.

Micronutrients

Micronutrients are those elements that plants need in small amounts such as iron, boron, manganese, zinc, copper, chlorine and molybdenum.

1 CSIRO Publishing (2006) Australian Soil Fertility Manual. CSIRO Publishing

A healthy plant

Healthy plants have a greater potential to ward off disease, pests, and environmental stresses leading to higher yields and improved grain quality.

Too little, too much, or the incorrect proportion of nutrients, can cause nutritional problems in lentil. If the condition is extreme, plants will show visible symptoms that can sometimes be identified. Visual diagnostic symptoms are readily obtained and provide an immediate evaluation of nutrient status. Visual symptoms do not develop until a major effect on yield, growth or development has occurred. Unfortunately, damage can be done before there is visual evidence.

7.2 Considerations when diagnosing nutrient disorders

There is limited nutritional information about lentil in Australia. However, lentil nutrition is like other pulses in that crop is generally is generally responsive to phosphorus and sulfur. It can require nitrogen at sowing if following a 'nitrogen hungry' crop like cereals or canola.

Symptoms of nutrient deficiency appear to be similar to the other pulses.[2]

Visual symptoms of nutrient disorders can assist in diagnosis. However, considerable yield loss can occur without there necessarily being any visual symptoms present.

The following points should be considered when diagnosing nutrient disorders:

- Visual symptoms on lentil may be caused by damage from herbicides, insects and pathogens. Damage may also be from physiological disorders arising from adverse environmental effects such as salinity, drought, cold, heat or high temperature stresses. Such symptoms can be indistinguishable from nutrient deficiency, although it should be obvious if environmental conditions are limiting (moisture stress).
- Factors that influence both nodulation and nitrogen fixation can result in symptoms of nitrogen deficiency.
- There can be differences between cultivars in the manifestation of symptoms.
- Visual symptoms in one pulse do not necessarily mean that it is the same in other pulses.

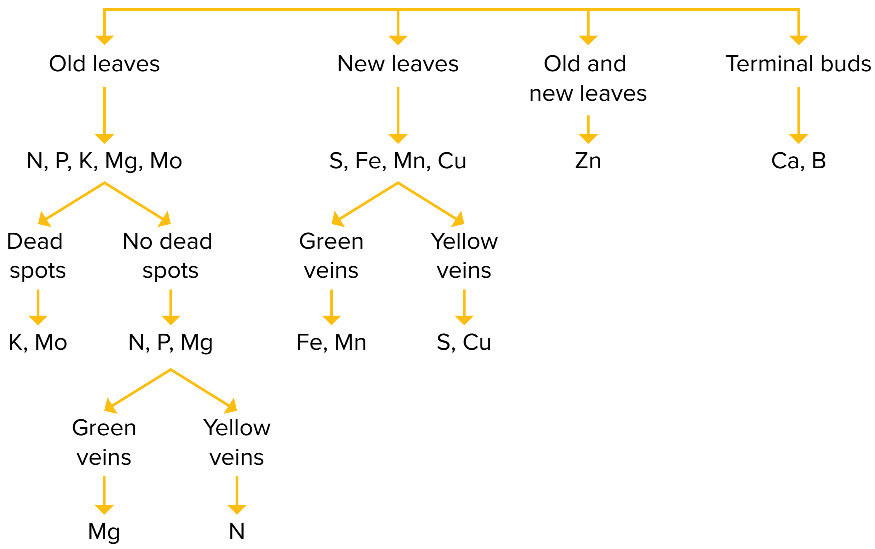

Figure 1: *Flow chart for the identification of deficiency symptoms.*[3]

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

3 T Reddy, G Reddi (1997) Mineral nutrition, manures and fertilizers. In Principles of Agronomy. pp. 204-256. Kalyani Publishers, Ludhiana, India,

Identifying nutrient deficiencies

To differentiate between nutrient deficiency symptoms that appear similar, the following should be undertaken:

- know what a healthy plant looks like in order to recognise symptoms of distress;
- the affected area of the crop needs to be identified and its appearance noted. For example, plants should be checked for discolouration (yellow, red, brown etc), death (necrotic), wilted or stunted etc.;
- the pattern of symptoms in the paddock needs to be identified (patches, scattered plants, crop perimeters);
- affected areas need to be assessed in relation to soil type (pH, colour, texture) or elevation; and
- individual plants need to be examined closely to identify detailed symptoms such as stunting, wilting and where the symptoms are appearing (whole plant, new leaves, old leaves, edge of leaf, veins etc.).

If more than one problem is present, typical visual symptoms may not occur. For example, water stress, disease or insect damage can 'mask' a nutrient deficiency.

If two nutrients are simultaneously deficient, symptoms may differ to when there is one nutrient deficiency alone.

Micronutrients are often used by plants to process other nutrients, or work together with other nutrients, so a deficiency of one may appear like another. For instance, molybdenum is required by pulses to complete the nitrogen fixation process.

Table 2 highlights symptoms of key nutrient deficiencies.

Table 2: Key to nutrient deficiencies in field pea that may be applicable to lentil.

Symptom	Old to middle leaves					Middle to new leaves					New leaves to terminal shoots						
Deficiency	**N**	**P**	**K**	**Mg**	**Zn**	**N**	**Zn**	**Ca**	**Mn**	**B**	**S**	**Mg**	**Mn**	**Fe**	**Cu**	**Ca**	**B**
Chlorosis (yellowing)																	
Complete											x			x			
Mottled	x	x		x			x	x	x				x				
Interveinal										x			x				
Cresent form								x									
Nercosis (tissue death)																	
Complete			x		x												x
Distinct areas (including spotting)	x		x	x			x				x	x	x				
Margins		x	x		x	x				x							x
Tips		x			x	x		x			x		x	x	x		x
Pigmentation within necrotic (yellow) or chlorotic (dead) areas																	
Opaque														x			
Light brown					x	x					x		x				
Brown		x						x									
Pink			x	x			x	x				x		x			
Malformation of leaflets																	
Rolling in of margin			x	x									x	x			
Wilting					x	x									x		
Twisting		x						x								x	
Puckering													x		x		
Malformation of leaves																	
Cupping							x										
Rosetting							x										x
Tendril distortion					x							x	x				x
Internode shortening		x					x										x
Stem lesions							x										x
Petiole collapse																x	
Root distortion								x		x						x	x

Source: Symptoms of nutrient deficiencies, (1991), Soil Science and Plant Nutrition, School of Agriculture, University of Western Australia, http://trove.nla.gov.au/work/20308916

7.3 Soil and plant tissue testing

Soil or plant tissue tests provide information on nutrients that are present and the level of concentration. They also show critical nutrient levels required for that crop type and whether the plant will or will not respond to that nutrient.

Pulse crops can have different requirements for critical nutrients levels, meaning test results for one crop are not necessary correct for another crop type.[4]

Plant tissue testing can be used to diagnose a deficiency or monitor the general health of the pulse crop.

Tissue tests are useful for identifying what is causing plant symptoms being expressed by plants but not readily identified. This is important because by the time noticeable symptoms appear in a crop, the yield potential can be markedly reduced. Technology is enabling quicker analysis and results reporting, which enables foliar or soil-applied remedies to be applied in a timely manner for a quick crop response.

Plant tissue tests are very useful when fine-tuning nutrient requirements, particularly when aiming to fully capitalise on available moisture. Diffuse Gradient Technology Phospohorus (DGT-P) is a relatively new method being tested for use with Australian soils, and mimics the action of the plant roots in access. However, there are no published DGT-P levels for lentil.

Most plant tissue tests diagnose the nutrient status of the plant at the time it is sampled. Results cannot reliably indicate the effect of a particular deficiency on grain yield.

MORE INFORMATION

For more about DGT-P, see: http://soilquality.org.au/factsheets/dgt-phosphorus

Table 3: Adequate levels for various soil test results.

Nutrient		Test used	
Phosphorus			
	Colwell P*	**Olsen P***	
Sand	20–30	10–15	
Loam	25–35	12–17	
Clay	35–45	17–23	
Potassium			
	Bi-carb**	**Skene****	**Exchangeable K**
Sand	50	50–100	Not applicable
Other soils	100	-	0.25 me/100g
Sandy loam	-	-	-
- Faba bean	100–120	-	-
- Field pea	70–80	-	-
- Lupin	30–40	-	-
- Canola	40	-	-
- Cereals	30	-	-
Sulfur***			
	KCl		
Low	5 ppm		
Adequate	8 ppm		

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Notes: *Colwell P or Olsen P are measured in mg/kg. , **Potassium Bi-carb and Skene are mg/kg or exchangeable K as milliequivalents per 100g of soil (meq/100g). ***For Sulphur The Kcl test reports in mg/kg (in this case ppm = mg/kg)

MORE INFORMATION

Refer to: *Lentils: The Ute Guide* for detailed descriptions and images of nutrient deficiencies. Available from the GRDC book shop on the GRDC website: https://grdc.com.au/Resources/Apps

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

MORE INFORMATION

See Section 3: Pre-planting for more information on inoculation.

MORE INFORMATION

See Section 6: Plant growth and physiology

7.4 Nitrogen (N)

Nitrogen is essential for plant growth as it is a part of every living cell. Plants require large amounts of nitrogen for normal growth and development.

Lentil should not normally need nitrogen fertiliser if the plant has achieved effective nodulation.[5]

Lentil seed should be inoculated with the correct strain of rhizobia, particularly when:

- lentil has not been grown in a paddock for five or more years; or
- the soil pH is less than 5.7.

Lentil does take up residual soil nitrates (nitrogen not used by the preceding crops). This, therefore, reduces the potential for nitrogen losses by leaching. Leaching is the loss of nitrogen due to it being washed down with water into the soil profile below the plant root zone meaning it is unable to be accessed by the plant. Thus, in some countries where it is important, growing lentil can have a positive impact on groundwater quality due to reduced leaching.[6]

Deficiency symptoms

The first sign of nitrogen deficiency in lentil is the appearance of overall 'paleness' of the plant. This will occur even before a general reduction in plant growth. There may be a 'cupping' of the middle to new leaves. With time a mottled chlorosis of old leaves slowly develops with little sign of necrosis (plant death).

If, based on visual plant symptoms, nitrogen deficiency is suspected, the next step is to check the nodules of the plant. Nodules should be healthy and plentiful.

Photo 1: *Nitrogen deficiency (left) relative to a well-nodulated plant (right).*

Photo: ICARDA

5 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

6 R Mahler (2005) Northern Idaho Fertilizer Guide: Lentils. University of Idaho, CIS1083, http://www.cals.uidaho.edu/edcomm/pdf/CIS/CIS1083.pdf

Photo 2: *In nitrogen deficiency the plant shows signs of stunting, yellowing and poor growth.*

Photo: C. Toker

Photo 3: *In nitrogen deficiency the plant shows signs of stunting, yellowing and poor growth.*

Photo: W. Hawthorne, formerly Pulse Australia

Some situations where nitrogen fertiliser may warrant consideration include:

- when recommended inoculation procedures have not occurred; and
- late sowing or low fertility situations where rapid early growth is critical for achieving adequate height and sufficient biomass to support a reasonable grain yield.

Table 4 shows the harvest index for lentil. Harvest index is the yield of a crop versus the total amount of biomass produced. Harvest index varies with crop types and is a factor that is targeted in plant breeding programs. The table highlights that for one tonne per hectare of lentil biomass, 33kg/ha of nitrogen will be removed in grain, and, overall, the total crop nitrogen requirement is 80 kg/ha.

Table 4: Harvest index and nitrogen requirements for lentil.

Total plant dry matter (t/ha)	Total shoot dry matter yield (t/ha)	Grain yield (t/ha) 40% HI*	Total crop nitrogen requirement (2.3% N) kg/ha	Nitrogen removal in grain (kg/ha)
1.75	1.25	0.5	40	17
3.50	2.50	1.0	80	33
5.25	3.75	1.5	120	40
7.00	5.00	2.0	160	66
8.75	6.25	2.5	200	83
10.50	7.50	3.0	240	100

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Application

The use of starter nitrogen (e.g. daimmonium phosphate, or DAP), banded with the seed (i.e. sown with seed, but without touching the seed) when sowing pulse crops has the potential to reduce establishment and nodulation if high rates are used. Hence, caution needs to be taken with rates of application.

7.5 Phosphorus (P)

Phosphorus is essential for many growth processes in plants. Soil phosphorus levels influence the rate of nodule growth. The higher the phosphorus level the greater the nodule growth. Adequate phosphorus is essential for seed germination, root development and in the ripening process of grain (and seed).

Deficiency symptoms

Phosphorus deficiency is usually denoted by a stunted plant: small leaf size and leaf colour.

Symptoms of phosphorus deficiency may take time to develop due to the initial reserves of phosphorus in the seeds still supporting the plant. When symptoms do start to appear, they may sometimes appear similar to that of a plant with adequate levels of phosphorus.

Visual symptoms appear first on the oldest leaves as a mildly mottled chlorosis over much of the leaf. These symptoms might be confused with either nitrogen or sulfur deficiency. However, the middle and new leaves remain a healthy green, meaning the plant overall does not appear pale.

As symptoms on old leaves develop, round purple spots may appear within areas of dark green in an otherwise mildly chlorotic leaf.

MORE INFORMATION

Further information on arbuscular mycorrhiza can be found at: https://grdc.com.au/resources-and-publications/groundcover/ground-cover-supplements/gcs96/phosphorus-uptake-and-mycorrhizal-colonisation-what-is-the-link

It is important to note that lentil is deemed medium in its responsiveness to phosphorus fertiliser. However, zinc status must be adequate to achieve a response to phosphorus.[7]

Arbuscular mycorrhiza (AM) is a fungi involved in a symbiotic relationship with plant roots. AM assists plants in taking up nutrients such as phosphorus, zinc and copper from both the soil and fertiliser. In Australia, there is little recognition of the need for AM in lentil.[8]

Lentil requirements

Phosphorus requirements can be established with a soil test and appropriate rates of required fertiliser determined (Table 5).

Table 5: Phosphorus fertiliser rates for lentil.

Soil test P (0–12 inches/30.5 cm)[1]			Application rate[2]	
NaOAc (ppm)	Bray I (ppm)	$NaHCO_3$ (ppm)	P_2O_5 (kg/ha)	P (kg/ha)
0 to 2	0 to 20	0 to 8	56	25
2 to 3	20 to 30	8 to 10	34	15
3 to 4	30 to 40	10 to 12	11	6
over 4	over 40	over 12	0	0

1. Soil test P can be determined by three different procedures: sodium acetate (NaOAc), Bray I method or sodium bicarbonate ($NaHCO_3$). Sodium bicarbonate should not be used on soils with pH values less than 6.2.

2. P_2O_5 x 0.44 = P, or P x 2.29 = P_2O_5

Source: Northern Idaho Fertilizer Guide: Lentils (2005), University of Idaho, http://www.cals.uidaho.edu/edcomm/pdf/CIS/CIS1083.pdf

Application

Lentil has a reasonably high phosphorus requirement.

Phosphorus can be incorporated into the seedbed by whatever method is most convenient for the grower. Acceptable methods include:

- broadcast (scatter) and plough-down or disc-in;
- band (direct placement around 2.5 cm below the seed); and
- drill (sow) with seed (without allowing direct contact with the seed if fertiliser contains nutrients other than phosphorus).

Germinating lentil is extremely sensitive to salts in fertilisers containing nitrogen, potassium and sulfur. If heavy phosphorus applications are required to correct nutrient deficiencies, fertiliser (containing salts) should be applied before or during seedbed preparation to prevent potential damage to the lentil seedling.[9]

Starter fertilisers (phosphorus and nitrogen) have been recorded as most effective when soils are cold. This results in root growth being stimulated by a readily available supply of phosphorus. Banding fertiliser improves efficiency of phosphorus uptake. Consequently, if applying phosphorus in a band, the recommended rate of fertiliser can be reduced by 10–15%.[10]

Changes in sowing techniques to narrow sowing points or disc seeders with minimal soil disturbance, and wider row spacing has increased the concentration of fertiliser near the seed. This, in turn, increases the risk of toxicity.

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

8 A Smith, S Smith, M Manjarrez (2012) Phosphorus uptake and mycorrhizal colonisation: what is the link? Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-96-Supplement-Soil-Biology-Initiative/Phosphorus-uptake-and-mycorrhizal-colonisation-what-is-the-link

9 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

10 R Mahler (2005) Northern Idaho Fertilizer Guide: Lentils. University of Idaho, CIS1083, http://www.cals.uidaho.edu/edcomm/pdf/CIS/CIS1083.pdf

7.6 Potassium (K)

Potassium is one of the three primary macronutrients. It is required by plants in greater quantities than phosphorus.[11]

Deficiency symptoms

When suffering from potassium deficiency, older leaflets of the plant show symptoms first. Initially growth is stunted compared with other parts of the paddock. Margins and tips of leaflets lose their green colour and become yellow-green. Reddish pigmentation is also seen on some leaflets. These leaflets often drop from the plant.

Symptoms progress up the plant when deficiency persists. Necrotic patches may develop on leaflets. Stems of some plants may also develop reddish-brown anthocyanin pigmentation (blue, violet or red pigment found in plants). Older leaves may show slight curling and then a distinct browning of leaf margins before eventually dying.[12]

Lentil requirements

Lentil appears to be similar to other pulses, like field pea and especially lupin, that are less susceptible to potassium deficiency compared with faba bean, which is quite susceptible.

Potassium fertilisers on lentil may be warranted on occasional circumstances; however, it should be determined with a soil test (Table 6). Fertiliser responses are likely where soil test levels, using the ammonium acetate test, fall below critical levels (<70 parts per million).[13]

Table 6: Potassium fertiliser rates for lentil.[14]

Soil test K (0–30cm)[1] (ppm)	Application rate[2]	
	K_2O (kg/ha)	K (kg/ha)
0–50	75	63
50–75	45	38
>75	0	0

1 Sodium acetate-extractable K in the 0–30 cm depth.
2 K_2O x 0.83 = K, or K x 1.20 = K_2O

Application

Potassium can be incorporated into the seedbed by whatever method is most convenient for the grower. Acceptable methods include:

- broadcast (scatter) and plough-down or disc-in;
- band (direct placement around 2.5 cm below the seed); and
- drill (sow) with seed (without allowing direct contact with the seed if fertiliser contains salt-based nutrients other than phosphorus. Lentil seedlings are extremely sensitive to salts).

If heavy potassium applications are required to correct nutrient deficiencies, fertiliser should be applied post-emergent, otherwise before or during seedbed preparation.

11 CSIRO Publishing (2006) Australian Soil Fertility Manual. CSIRO Publishing
12 J Lamb, A Poddar (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook
13 R Mahler (2005) Northern Idaho Fertilizer Guide: Lentils. University of Idaho, CIS1083, http://www.cals.uidaho.edu/edcomm/pdf/CIS/CIS1083.pdf
14 R Mahler (2005) Northern Idaho Fertilizer Guide: Lentils. University of Idaho, CIS1083, http://www.cals.uidaho.edu/edcomm/pdf/CIS/CIS1083.pdf

7.7 Calcium, magnesium and sulfur

Calcium, magnesium and sulfur are secondary macronutrients. They are as important to plant growth as the primary macronutrients.

Plants usually require less of these nutrients as fertiliser. Nutrient deficiencies of these three elements can depress plant growth as much as the primary macronutrients.[15]

Calcium (Ca)

Calcium function is mainly in the leaves of the plant and as part of the cell walls. Calcium is important for root development and in developing growing points.

Calcium does not move freely from older to younger tissue, resulting in younger tissue always being lower in calcium content.

Deficiency symptoms

Deficiencies are first shown at the tips of young shoots and are usually denoted by reduced plant height. In pulses, there is a broad yellowing of the leaves between the veins at the centre of the base of leaflets.[16] Also plant roots are less numerous, less branched, and the root tips are thickened.

Magnesium (Mg)

Magnesium serves many functions in the plant. Magnesium is actively involved in photosynthesis. Magnesium and nitrogen are the only nutrients that are constituents of chlorophyll.[17]

Deficiency symptoms

Magnesium is generally deficient in acid and sodic soils. Deficiency can occur in sandy and sandy loam soils.

In lentil, magnesium deficiency first appears on young leaves as a chlorosis (loss of chlorophyll meaning loss of green colour). This chlorosis can extend down the sides of the leaflets. The symptom on leaflets is yellow to yellow-green with a green area remaining around the central leaf vein.

Prevalence of magnesium deficiency results in light brown necrotic areas developing on the leaf tips or margins of the plant. The basal leaves usually remain green in severely affected plants. There is no evidence of anthocyanin pigmentation (blue, violet or red pigment) on magnesium deficient plants.

Application

To enhance crop yields in a magnesium deficient scenario, magnesium oxide (MgO) can be applied.[18]

Sulfur (S)

Sulfur is present in proteins, in some oils, and as sulphates. Without adequate sulfur, the lentil plant is unable to 'fix' enough atmospheric nitrogen to meet its needs.

Some forms of sulfur will acidify the soil (reduce soil pH). Superphosphate is acidic whereas gypsum (calcium sulfate) does not affect soil pH. Lighter, sandier soils, compared to heavier clays, will be more affected by sulfur due to less buffering capacity.[19]

15 CSIRO Publishing (2006) Australian Soil Fertility Manual. CSIRO Publishing
16 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia
17 CSIRO Publishing (2006) Australian Soil Fertility Manual. CSIRO Publishing
18 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia
19 CSIRO Publishing (2006) Australian Soil Fertility Manual. CSIRO Publishing

Deficiency symptoms

Symptoms of sulfur-deficient plants can resemble those of nitrogen deficiency. Chlorosis (yellowing) on sulfur-deficient plants firstly affects the leaves near the top of the plant, while leaves near the base remain green.

With increased severity of sulfur deficiency, chlorosis extends over the entire plant. The pattern of chlorosis development enables the differentiation of sulfur deficiency compared to nitrogen deficiency. Some leaflets become completely yellow, wither and drop from the plant. Reddish-brown pigmentation can appear on the stems and leaves and the plants are slender and small.

Certain soil types are prone to sulfur deficiency, for example some basaltic, black earths. On these soils with marginal sulfur levels, deficiency is most likely to occur in double-crop situations where levels of available sulfur have become depleted to very low levels.[20]

Lentil requirements

The need for sulfur is closely related to the amount of nitrogen available to the plant. This is because both nutrients are constituents of proteins and associated with the formation of chlorophyll.[21]

Table 7: Sulfur fertiliser requirements of lentil.

Soil test S (0–12 inches/30.5 cm)		S application rate
(ppm SO_4-S)	(ppm S)	(kg/ha)
0–10	0–4	17
>10	>4	0

Source: Northern Idaho Fertilizer Guide: Lentils (2005), University of Idaho, http://www.cals.uidaho.edu/edcomm/pdf/CIS/CIS1083.pdf

Application

Soil sampling to a depth of 60 centimetres is the suggested procedure when soil testing for sulfur.

Where soil phosphate levels are adequate, an application of a low rate of gypsum is a cost-effective, long-term method of correcting sulfur deficiency.[22]

Granular sulfur fertiliser should be avoided on lentil as this form of sulfur becomes available too slowly for the plants' actual requirements.[23]

Granulated sulfate of ammonia is another effective option when low rates of nitrogen are also required by the plant.

20 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

21 CSIRO Publishing (2006) Australian Soil Fertility Manual. CSIRO Publishing

22 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

23 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

7.8 Boron

Boron is essential in the formation of new plant tissue: the growing points. It is also essential for effective nodulation and nitrogen fixation in pulses, and in satisfying rhizobial requirements.[24]

Toxicity symptoms

Boron toxicity occurs on many of the alkaline soils of the southern cropping areas. Lentil is very vulnerable to boron toxicity, particularly as a seedling.[25]

Shallow (0–10 cm) and deep (10–90 cm) soil tests provide a good indication as to the suitability of soils (paddocks) for growing lentil. Soil testing will also provide an indication as to the impact boron (in toxic levels) might have on plant growth and rooting depth.

The most characteristic symptom of boron toxicity in lentil is chlorosis (yellowing) of the tip and serrated margins of leaflets, and the tip of stipules on lower leaves. Older leaves are usually most affected. Light brown necrotic patches occur and later develop on yellow areas. The necrotic areas expand to one-third of leaflets and, if severe, some withering, necrosis (death) of leaf tips or margins occurs. Leaflets can separate. Anthocyanin pigmentation (blue, violet or red pigment) does not appear with boron toxicity.

All current varieties of lentil are rated as intolerant or moderately intolerant of the high levels of boron that are associated with soil acidity and alkaline soil.[26] These slight differences in intolerance can be of practical significance for variety performance in the field.

Photo 4: *Boron toxicity in lentil showing typical leaf tip symptoms.*

Photo: M. Raynes, formerly Pulse Australia

24 CSIRO Publishing (2006) Australian Soil Fertility Manual. CSIRO Publishing

25 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

26 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Photo 5: *Boron toxicity in lentil.*

Photo: W. Hawthorne, formerly Pulse Australia

Deficiency symptoms

Boron deficiency has a dramatic effect on the root system of lentil.

The first symptom on a boron-deficient plant is yellowing on the tip and margins of leaflets of young entire expanded leaves. This 'bronzing' effect is partially due to red-brown pigmentation on the upper surfaces of leaflet margins. The tips and margins of affected leaflets start to die and the terminal buds turn rusty brown in colour.

The young buds and leaflets die progressively from the tip. Thus, axillary bud development is enhanced. Plant roots are also stunted and thick, with dark tips like those occurring on calcium deficient plants. Roots become brown with lateral extremities showing shortening and thickening.

Deformed flowers are a common plant symptom of boron deficiency. Many plants may respond by reduced flowering and improper pollination as well as thickened, curled, wilted and chlorotic new growth.

Application

Lentil grown in some circumstances can respond to boron applications. **It is always critical to consider that, as lentil is very vulnerable to boron toxicity, a correct deficiency diagnosis must be made before considering boron applications.**

Soil-applied boron fertiliser should always be broadcast, never banded.[27]

27 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

7.9 Copper (Cu)

Both copper and zinc deficiencies have a major effect on flowering and seed production. When very deficient, plant growth will also be affected.

Copper and zinc both have an important role in legume nodulation and nitrogen fixation. Copper has a role in cell wall constituents of plants.

Lentil requirements

Lentil has a greater requirement for copper than chickpea. The critical concentration of copper in the youngest tissue of lentil is estimated as 4.6 mg copper per kilogram (2.6 mg cu/kg in chickpea).

Deficiency symptoms

Symptoms of copper deficiency may not appear until flowering, hence there may be little effect on vegetative growth.

Copper-deficiency symptoms appear on the younger leaves of the plant, whilst the rest of the plant remains a normal green colour. Wilting and rolling of the leaflet ends of fully opened leaves becomes apparent.

The leaflets on the top leaves of each stem are smaller than usual. Plants produce small leaves with fewer leaflets on the young shoots. In these circumstances, leaves usually wither and appear rust-brown in colour. Shoot elongation is also reduced due to insufficient development of the terminal growing point.

Flowering may be delayed in lentil, as it is in field pea. Flowers can appear quite normal; however, few pods and seeds form.

7.10 Iron (Fe)

Iron is a catalyst in the formation of chlorophyll, and also acts as an oxygen carrier in the plant[28].

Iron is strongly immobile in plants.

Iron deficiency is observed occasionally on alkaline, high pH soils. It is usually associated with a waterlogging event, following irrigation or heavy rainfall.[29]

Deficiency symptoms

Iron deficiency can be confused with manganese and magnesium deficiency. Lentil appears more prone to iron deficiency compared to faba and broad beans.

Due to iron being immobile, symptoms appear first on younger leaves at the top of the plant. These leaves become chlorotic (even bright yellow) over the entire leaf. The deficiency can spread to older leaves and new growth can cease. Stems become slender and shortened.

If the deficiency becomes more severe leaflets can wither and die; withering occurs from the leaf tip back towards the base.

Yellowing between leaf veins can progress to completely yellow plants (Photo 7). Contrast in colour between old and new leaves is much stronger with iron deficiency compared with that of manganese deficiency.

Iron chlorosis can be transient, with deficiency symptoms largely disappearing at a time coinciding with increases in soil temperature and day length during reproductive growth.

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28 CSIRO Publishing 2006

29 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Iron deficiency symptoms tend to be very transient. An iron deficient lentil crop can achieve a rapid recovery once the soil begins to dry out.[30]

Application

Sulfate of ammonia improves absorption of iron and so should be considered in fertiliser applications to overcome iron deficiency.

Lentil varieties can exhibit a marked difference in sensitivity to iron chlorosis; this can be overcome through plant breeding. Most current lentil varieties are considered tolerant to all but extreme situations.

Photo 6: *Lentil suffering from waterlogging, not to be confused with iron deficiency.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 7: *Iron deficiency in lentil.*

Photo: ICARDA

30 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Photo 8: *Iron deficiency in lentil.*

Photo: W. Hawthorne, formerly Pulse Australia

7.11 Manganese (Mn)

Manganese promotes germination and accelerates maturity of the plant. Furthermore, the presence of manganese increases the availability of phosphorus and calcium.[31]

Toxicity symptoms

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

Symptoms appear on new leaves first and then develop in mid and older leaves. This is the opposite to toxicities such as phosphorus.

Small purple spots appear from the margins on young leaves (Photo 9) and in slightly older leaves take on a reddish colouration (Photo 11).

Photo 9: *Manganese toxicity.*

Photo: ICARDA

31 CSIRO Publishing (2006) Australian Soil Fertility Manual. CSIRO Publishing

Photo 10: *Manganese toxicity.*

Photo: ICARDA

Deficiency symptoms

Manganese deficiency is usually associated with drier, fluffy soil conditions; for example, rolled areas or wheel tracks in a paddock may appear healthy whilst the remainder might show manganese deficiency.

Manganese deficiency has been observed occasionally on alkaline, high pH soils.

Manganese-deficient plants are a lighter green colour on younger expanded leaves. Very small spots can develop later on both the surface of leaflets and the stipules of these leaves. Spots are generally found between the leaflet veins on the leaf surface.

Manganese deficient plants often lose many of their leaflets. In some circumstances, symptoms can extend to the middle leaves. Colour ranges from browning on tops of leaves and new growth, to necrosis over much of the leaf.

Deficiency later in the growing season can lead to seeds being discoloured, split, deformed, or having a brown spot or cavity in the centre.

Application

Manganese fertiliser can be applied at sowing on the seed, or as a foliar application later.

7.12 Molybdenum (Mo)

Molybdenum is required by rhizobia in root nodules and also for growth of the plant, particularly under acid soil conditions.

Molybdenum is often deficient in acid soils. Lentil grown on acid soils can respond to molybdenum fertiliser applications as it is present in the soil in only small amounts.

Deficiency symptoms

Due to its role in nitrogen fixation, molybdenum deficiency causes symptoms of nitrogen deficiency.

Leaves of nitrogen-deficient plants are lighter yellow than those of molybdenum-deficient plants. Symptoms start with chlorotic interveinal mottling of older leaves. Leaves, flowers and pods are reduced, as well as biomass and yield.

In severe deficiency conditions, molybdenum causes leaf wilting and disorders. In addition to growth depression, there are fewer and smaller flowers, and many fail to open or mature. Again, this leads to lower grain yield.

Molybdenum-deficient plants may contain high nitrogen levels. The presence of high nitrogen in a chlorotic, apparently nitrogen-deficient plant, is thus evidence for molybdenum deficiency.

Application

Soil testing to assess the molybdenum status of the soil is currently not commercially available. However, molybdenum can easily be applied to fertiliser (Mo Super) or as a liquid when planting the crop. It should not be applied to seed.

Molybdenum can be applied as a liquid (to soil or foliage), granular fertiliser inclusion, or as a seed treatment on lentil. When determining the rate of application soil pH needs to be considered. The history of the number of times lentil has been grown in that particular paddock also needs to be considered.

When applying molybdenum as a seed dressing, consideration needs to be given to rates, as higher rates can cause nitrogen-fixing bacteria to die.

7.13 Zinc (Zn)

Both zinc and copper are important in nodulation and nitrogen fixation in pulses.

Deficiencies in these two micronutrients have a major effect on flowering and seed production. When extremely deficient, plant growth can be affected.

On 'black' soils with a pH 8 or greater, zinc deficiencies can be caused by high phosphorus rates.[32]

Deficiency symptoms

Zinc deficiency appears as a reduction in inter-nodal growth and results in a rosette growth habit. The younger leaves of zinc-deficient plants initially become pale green in colour. Pigmentation (reddish-brown) takes place on the margins of upper surfaces of leaflets and on the lower portions of the stems.

Plants are small. The areas between veins turn yellow, becoming yellower on the lowest leaves. Maturity can be delayed.

Lentil requirements

There is a lack of Australian research on zinc responses in lentil. Lentil is considered to have a relatively medium demand for zinc. Lentil is efficient at extracting zinc from the soil as long as the phosphorus status adequate.

32 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Zinc fertiliser recommendations for lentil are conservatively based on a general recommendation for all crops:

- <0.8 mg/kg on alkaline soils; and
- <0.3 mg/kg on acid soils.[33]

Application

Zinc can be applied in numerous ways:

- incorporated into the soil prior to sowing;
- as a seed treatment;
- as a fertiliser at sowing; and
- as a foliar spray.

Severe zinc deficiency can be corrected for a period of 5–8 years with a soil application of zinc sulfate monohydrate. This fertiliser should be incorporated into the soil 3–4 months prior to sowing.

As zinc is not mobile in the soil, fertiliser application must result in even distribution over the soil surface, after which it can be thoroughly cultivated into the topsoil.

In the first year after application, this form of zinc may not be not fully effective; a foliar zinc spray may be required.

Seed treatments

Zinc seed treatments may be a cost-effective option in situations where soil phosphorus levels are adequate but zinc levels are likely to be deficient.

Fertilisers applied at sowing

A range of phosphate-based fertilisers either contain, or can be blended with, a zinc additive which can then be applied at sowing.

Foliar zinc sprays

Foliar application of zinc is relatively common as this method often fits in with herbicide or early fungicide applications.

33 W Lindsay, W Norwell (1978) Development of a DTPA soil test for zinc, iron, manganese and copper. Proceedings from the Soil Science Society of America 42: 421-428, https://dl.sciencesocieties.org/publications/sssaj/abstracts/42/3/SS0420030421

Photo 11: *Zinc-deficient lentil.*

Photo: ICARDA

7.14 Lime

Lime is used to reduce acidity in soil (raise pH) and provide calcium.

If lentil is grown on acidic soils, lime applications may be necessary as lentil yield can be reduced on soils with a pH 5.4 or lower. A key limiting factor is poor nodulation on low pH soils that, consequently, limits lentil production. In some areas, growing lentil on low pH acidic soils may not be considered economical.[34]

7.15 Cobalt (Co)

Cobalt is essential for growth of the rhizobium and hence nodulation of pulses and fixation of atmospheric nitrogen. Cobalt is also important in animal nutrition.

Soil testing for cobalt is not commercially available. Consequently, the decision to apply cobalt fertiliser needs to be based on paddock history and soil pH.

Cobalt fertiliser is applied before or at sowing. It can be applied as a liquid to soil or as a granular inclusion in fertiliser.

7.16 Soil pH and toxicities

Soil pH influences the availability of most nutrients. Occasionally some nutrients are made so available that they inhibit plant growth. For example, on some acid soils, aluminium and manganese levels may restrict plant growth, usually by restricting the rhizobia, and hence, the plants ability to nodulate.

34 R Mahler (2005) Northern Idaho Fertilizer Guide: Lentils. University of Idaho, CIS1083, http://www.cals.uidaho.edu/edcomm/pdf/CIS/CIS1083.pdf

Table 8: 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

* Lentil and lupin are not usually grown on high boron soils

Source: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

Aluminium (Al)

Aluminium toxicity can develop in lentil that is well nodulated but grown on soils of low pH.

There are no visual symptoms of aluminium toxicity in lentil other than delayed germination and plants appearing miniature and dark green. Roots are extremely stunted with many laterals appearing dead. Symptoms may be confused with phosphorus deficiency.

Salinity

Delays in germination occur with increasing levels of salinity in lentil (and chickpea). After germination, the first signs of salinity damage, due to excess ion accumulation in saline conditions, are necrosis of the outer margins and yellowing of the older leaves.

Salinity intensifies anthocyanin pigmentation (blue, violet or red pigment) in leaves and stems in red lentil and desi chickpea; while leaves and stems of green lentil and Kabuli chickpea appear yellow. Leaves die and separate due to accumulation of ions. Salinity also reduces flower production and pod-setting.

Lentil varieties differ in their tolerance to salinity. Nipper⊕ is the only variety that shows any salt tolerance. All other varieties are intolerant.

7.17 Determining fertiliser requirements

Prior to the planting of lentil, fertiliser requirements for that paddock must be determined. Specifically, this refers to the types of fertiliser required and the recommended rate(s).

Fertiliser required is a combination of knowing:

- the current nutritional status of the soil; and
- the nutrient removal by the crop.

Current nutritional status of the soil

Soil types vary in terms of nutritional status.

Different soil types may have different nutrient reserves which vary in availability during the growing season, or are unavailable due to the soil's pH. This is often the case with micronutrients; in this case, foliar sprays can be used to correct any deficiencies.

Important factors that contribute to determining the current nutritional status of the soil include:

- a soil test;
- paddock history;
- soil type; and
- personal or local experience.

Plant tissue tests are also helpful in identifying the nutritional status of the plant (which is based on the nutritional status of the soil) once the crop is growing. These tests can assist in fine-tuning nutrient requirements later in the growing season.

Nutrient removal by crops

When grain is harvested from the paddock, nutrients are removed in the grain (Table 9). If, over time, more nutrients are removed (via grain) than are replaced (via fertiliser) then the fertility of the paddock will decline.[35]

Table 9: Nutrients removed by 1 tonne of grain.

Grain	Kilograms (kg)					Grams (g)			
	N	P	K	S	Ca	Mg	Cu	Zn	Mn
Pulses									
Chickpea (desi)	33	3.2	9	2.0	1.6	1.4	7	34	34
Chickpea (kabuli)	36	3.4	9	2.0	1.0	1.2	8	33	22
Faba bean	41	4.0	10	1.5	1.3	1.2	10	28	30
Lentil	40	3.9	8	1.8	0.7	0.9	7	28	14
Lupin (sweet)	53	3.0	8	2.3	2.2	1.6	5	35	18
Lupin (white)	60	3.6	10	2.4	2.0	1.4	5	30	60
Field pea	38	3.4	9	1.8	0.9	1.3	5	35	14
Cereals									
Wheat	23	3.0	4	1.5	0.4	1.2	5	20	40
Barley	20	2.7	5	1.5	0.3	1.1	3	14	11
Oat	17	3.0	5	1.6	0.5	1.1	3	17	40

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Actual values for nutrient removal via grain may vary by 30% or sometimes more. This is due to differences in soil fertility, varieties and seasons. For example, phosphorus per tonne removed by lentil grain can vary from 2.7 kg on low fertility soils to 5.1 kg on high fertility soils.

To prevent this, fertiliser inputs must be matched to expected yields and the nutritional status of the soil. The higher the expected yield, the higher the fertiliser input, particularly for the major nutrients, phosphorus, potassium and sulfur.

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

7.18 Nutrient budgeting

Nutrient budgeting is a simple way to calculate the balance between nutrient removal (via grain) and nutrient input (via fertiliser).

Table 10 shows an example of nutrient budgeting. The values used for nutrients removed are taken from Table 9.

Table 10: An example of nutrient budgeting.

Year	Crop	Yield (t/ha)	Nutrients removed (kg/ha)			
			N	P	K	S
2009	Faba bean	2.2	90	8.8	22	3.3
2010	Wheat	3.8	87	11.4	15	5.7
2011	Barley	4.2	84	11.3	21	6.3
2012	Chickpea	1.8	59	5.8	16	3.6
		Total	320	37.3	74	18.9
Year	**Fertiliser**	**Rate**	**Nutrients applied (kg/ha)**			
			N	**P**	**K**	**S**
2009	0 : 20 : 0	50	0	10	0	1
2010	18 : 20 : 0	70	12.6	14	0	1
2011	18 : 20 : 0	70	12.6	14	0	1
	Urea	60	27.6	0	0	0
2012	0 : 16 : 0 : 20	80	0	12.8	0	16
		Total	52.8	50.8	0	19
Balance			**–267.2**	**+13.5**	**–74**	**0**

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

From Table 9, a 2 t/ha crop of lentil will, on average, remove approximately 7.8 kg/ha of phosphorus. This then is the minimum amount of phosphorus that needs to be replaced. Higher quantities may be needed to build up soil fertility or overcome soil fixation of phosphorus.

As can be seen from Table 10, a simple nutrient budget, interpretation is required to establish the true situation:

Nitrogen: the nitrogen deficit of 267 kg needs to be countered by any nitrogen fixation that occurred.

This may have been 50 kg/ha per pulse crop, meaning the deficit might be more along the lines of 217 kg/ha (267 minus 50 kg/ha). Regardless, it still shows that the nitrogen status of the soil is decreasing and nitrogen fertiliser needs to be applied to reduce this deficit.

Estimating nitrogen fixation is not an easy process. One rule is: 20 kg of nitrogen is fixed for every tonne of plant dry matter at flowering.[36]

Phosphorus: Table 10 shows a surplus of 13 kg of phosphorus. This surplus will be used by the soil in building phosphorus levels, hence increasing soil fertility.

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

Potassium: Australian soils generally have adequate levels of potassium. Therefore, reducing the level of potassium without replacing it with fertiliser is accepted practice. However, some Australian cropping soils (usually white sandy soils) do show a positive response to potassium; fertiliser application should at least be considered to replace the potassium used by the crop.[37]

Sulfur: The sulfur applied as fertiliser matches sulfur removed by the crop.

Other nutrients, such as zinc and copper, should also be included in a nutrient-balancing exercise.

Nutrient budgeting is a useful tool; however, it must be considered in conjunction with other nutrient management tools such as soil and tissue testing, soil type, soil fixation and potential yields.

As phosphorus is the basis of soil fertility and hence crop yields, all fertiliser regimes are based initially on the phosphorus requirement. Table 11 shows various fertilisers and the rates required to meet phosphorus requirements.

Table 11: Fertiliser application rate ready reckoner (all rates are read as kg/ha).

Phosphorus	Some of the fertilisers used on pulses														
	Superphosphate														
	Single 8.6% P		Gold Phos 10 18% P		Triple 20% P		6 : 16 : 0 : 10 Legume Special			10 : 22 : 0 MAP		18 : 20 : 0 DAP		0 : 15 : 0 : 7 Grain Legume Super	
	fert	S	fert	S	fert	S	fert	N	S	fert	N	fert	N	fert	S
10	116	13	50	5	45	0.7	62	4	6	46	5	50	9	69	5
12	140	15	67	7	60	0.9	75	4	8	55	6	60	11	83	6
14	163	18	78	8	70	1.1	87	5	9	64	6	70	13	97	7
16	186	20	89	9	80	1.2	99	6	10	73	7	80	14	110	8
18	209	23	100	10	90	1.4	112	6	11	82	8	90	16	124	9
20	223	25	111	11	100	1.5	124	7	12	91	9	100	18	138	10
22	256	28	122	12	110	1.7	137	8	14	100	10	110	20	152	11
24	279	31	133	13	120	1.8	149	8	15	110	11	120	22	166	12

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Growers should always consult an agronomist when determining fertiliser applications for lentil.

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

7.19 Nutrition requirements of lentil

Table 12: Critical nutrient levels for lentil at flowering.

Nutrient	Plant part	Critical range*
Phosphorus (%)	YML**	0.3
Potassium (%)	YML	1.8
Sulfur (%)	YML	0.2
Boron (mg/kg)	YML	20
Copper (mg/ka)	YML	3
Zinc (mg/kg)	YML	20

* Any nutrient level below the critical range will be deficient; any level above will be adequate. ** YML = youngest mature.

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Fertiliser recommendations for lentil, as with most pulses, tend to be very generic. Some say this is often based more on convenience and availability, rather than meeting the specific nutrient requirements of the crop.[38] Fertiliser recommendations need to be more prescriptive, and should consider:

- soil type;
- rotation;
- yield potential of the crop;
- plant configuration (row spacing, type of opener and risk of 'seed burn');
- soil analysis results; and
- effectiveness of inoculation techniques.

MORE INFORMATION

A GRDC Fact Sheet on care with fertiliser and seed placement can be found at: www.grdc.com.au/GRDC-FS-FertiliserToxicity

Fertiliser toxicity

All pulses can be affected by fertiliser toxicity which, essentially, is the application of nutrients at a higher level than is required by the plant.

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

38 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

7.20 Keys for successful uptake of nutrients by lentil

IN FOCUS

Both macronutrients and micronutrients are taken up (absorbed) by roots and require certain soil conditions 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.
- Soil pH influences the availability of most nutrients and must be within a range (6 to 8 in $CaCl_2$) for nutrients to be released from soil particles. On acid soils, aluminium and manganese levels can increase and may restrict plant growth, usually by restricting the rhizobia and so the plants' ability to nodulate.
- Soil temperature must lie within a certain range for nutrient uptake to occur. Cold conditions can induce deficiencies such as zinc or phosphorus.

The optimum range of temperature, pH and moisture can vary for different pulse crops. Thus, nutrients may be physically present in the soil, but not available to those plants. Knowledge of a soil nutrient status (soil test), pH, texture, history and moisture status are all very useful for predicting potential nutrient deficiencies. Tissue tests, later on, help to confirm the level of individual nutrients in the plant.[39]

39 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Weed control

Key points

- **Weeds cost Australian grain growers $3.3 billion each year.**
- **An integrated weed management system includes both herbicide and non-herbicide options.**
- **Lentil is similar to lupin and chickpea in terms of its poor ability to compete with weeds in the paddock**
- **Grass weeds are easier to control in broadleaf crops. Broadleaf weeds are easier to control in cereal crops.**
- **Large advanced weeds, not controlled prior to or during sowing, are the most difficult, and often impossible, to control with in-crop herbicides.**
- **The broadleaf weed risk always needs to be assessed prior to sowing lentil.**
- **Crops with weed burdens should be harvested first and the chaff removed.**
- **Conventional lentil varieties are sensitive to sulfonylurea residues and the imidazolinones.**
- **Seek advice before spraying recently released lentil varieties as they may differ in their tolerance to herbicides.**
- **PBA Herald XT$^{\phi}$ and PBA Hurricane XT$^{\phi}$ are NOT Clearfield™ varieties. These 'XT' lentil varieties have tolerance to imidazolinone residues.**
- **The risk of herbicide damage needs to be weighed against potential yield loss from weed competition.**
- **Herbicide resistance has developed because of repeated, and often uninterrupted, use of herbicides with the same mode of action.**
- **Herbicide labels must be followed carefully for information on both crop and weed growth stages, and the best conditions for spraying.**

8.1 Introduction

The problem with weeds

Weeds affect the yield and management of broadacre crops across all seasons and can sometimes affect the price received for grain.[1]

Weeds may:

- lower crop yields by competing for soil moisture, nutrients, space and light;
- carry diseases and viruses that can infect crops;
- impede harvest;
- contaminate grain; and
- restrict cropping options due to limited herbicide options in pulse crops.[2]

Weed management aims to reduce the overall number of weeds competing with the crop and, in some cases, target particular 'hard to manage' weeds such as herbicide-resistant ryegrass. Crop rotations should consider crops that provide opportunities for weed control required in each paddock. Crop rotation should also allow for rotation of herbicide groups to minimise the build-up of herbicide resistance.

Planting a pulse crop as a break crop between cereals provides an ideal opportunity to target and control grass weeds.

Identifying weeds

The Grains Research and Development Corporation (GRDC) has developed an application (app) to assist in the identification of the most common weeds found in paddocks throughout Australia.

The app is called 'Weed ID: The Ute Guide.' Where possible, photos are shown for each stage of the weed's life cycle, from seed and seedling through to mature and flowering plants. Weeds are categorised by plant type, and results for each can be refined by state and lifecycle and whether they are native, currently flowering, or have a distinctive smell.

The app allows users to search, identify and compare photos of weeds in their own paddock to weeds in the app.

MORE INFORMATION

For more on PBA varieties see: https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

1 W Hawthorne (2015) Residual Herbicides and Weed Control. Pulse Australia, http://www.pulseaus.com.au/pdf/Residual%20Herbicides%20and%20Weed%20Control.pdf

2 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

MORE INFORMATION

For more information, go to: https://grdc.com.au/apps

Go to "Appendix 1 – Common weed names" for a list of all common weeds.

Figure 1: *Weed ID: The Ute Guide app.*

Source: GRDC (iTunes)

Impact and cost of weeds

Weeds cost Australian grain growers $3.3 billion each year. That is $2.6 billion in control costs and another $745 million in reduced yield. The cost to southern growers ranges from $105 per hectare (ha) in the low rainfall zones, up to $184/ha in the medium to high rainfall zones.

Reducing the cost of weed management is one of the grains industry's largest challenges as good weed control is vital for successful and profitable crop production.

Weed management is a challenge because weeds are constantly evolving, with changes in weed types and their characteristics, such as herbicide resistance. The use of a variety of management techniques to overcome weed problems is increasing. This includes crop-topping, double-knockdowns (two spray applications using different herbicide groups to kill all weeds) and burning of narrow windrows.

Grasses are the most costly weeds in the southern region (Table 1). Brome grass has increased in importance since the previous rankings were determined in 2000.[3]

Table 1: Problem weeds in the southern region.

Source: Impact of weeds on Australian grain production - The cost of weeds to Australian grain growers and the adoption of weed

Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss
1	Ryegrass	3,419,170	Ryegrass	155,332	Ryegrass	$38.9 million
2	Wild oats	1,252,299	Wild oats	87,855	Wild oats	$21.7 million
3	Brome grass	1,122,207	Brome grass	86,683	Brome grass	$21.0 million
4	Wild mustard	822,497	Wild radish	37,169	Wild radish	$10.4 million
5	Wild radish	739,339	Wild mustard	15,711	Vetches	$4.9 million
6	Wild turnip	586,488	Vetches	11,517	Wild mustard	$3.8 million

3 R Llewellyn, D Ronning, M Clarke, A Mayfield, S Walker and J Ouzman (2016) Impact of weeds on Australian grain production - The cost of weeds to Australian grain growers and the adoption of weed management and tillage practices. Grains Research and Development Corporation, https://grdc.com.au/ImpactOfWeeds

MORE INFORMATION

Agriculture Victoria
General grains information is available on Twitter @VicGovGrains

Australia wide
The GRDC has a GrowNotes Alert for the latest weed, pest and disease issues in the users area. The GrowNotes Alert is delivered via App, SMS, voice, email, social media or web portal (or a combination of preferred methods). Subscription to the GrowNotes Alert is on the GRDC website. https://grdc.com.au/resources-and-publications/grownotes/alerts

Alert services for weeds

Growers can subscribe to newsletters that provide local weed updates. The services listed are all free.

8.2 Integrated weed management (IWM)

An integrated weed management (IWM) system combining all available methods is the key to successful control of weeds. IWM includes both herbicide and non-herbicide options (Table 2).

Table 2: Weed control options for integrated weed management.

	Herbicide	Non-herbicide
Crop phase	• Use knockdown herbicides before sowing • Use selective herbicides before and/or after sowing to ensure weeds do not set seed • Avoid high-resistance-risk herbicides • Crop-topping • Delay sowing to get maximum weed control before sowing • Brown manure crops	• Rotate crops • Rotate varieties • Grow a dense and competitive crop • Use cultivation • Green manure crops • Cut crops for hay/silage • Burn stubbles/windrows • Delay sowing • Collect weed seeds at harvest and remove/burn • Destroy weed seeds harvested (Harrington seed destructor)
Pasture phase	• Spray-topping; • Winter cleaning; and • Use selective herbicides and ensure escapee weeds do not set seed.	• Good pasture competition; • Cut for hay / silage; • Cultivated fallow; and • Grazing.

Source: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

Strategy – paddock choice and crop rotation

A well-managed rotation in each paddock, which alternates broadleaf crops with cereal crops and may also include pastures, is a very useful technique for controlling weeds. For example, **grass weeds are more easily and cheaply controlled chemically in broadleaf crops, whereas broadleaf weeds are much easier to control in cereal crops.** Good crop rotation management can substantially reduce the cost of controlling weeds with chemicals.

Pulses grown in rotation with cereal crops offer opportunities to easily control grass weeds with selective herbicides that cannot be used when the paddock is sown to cereal. An effective kill of grass weeds in pulse crops reduces root disease carryover and provides a 'break crop' benefit in following cereal crops. Grass-selective herbicides can control most grass weeds in pulses, along with volunteer cereals.

Metribuzin alone, and in mixtures with trifluralin in lentil, can be used to control some other grasses that are not readily controlled by selective grass herbicides.[4]

4 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Good agronomic practice

Some crops and varieties are more competitive against weeds than others. Of the pulses, lentil is similar to lupin and chickpea in terms of its poor ability to compete with weeds in the paddock. Faba bean and field pea are rated as having a medium competitive ability.[5]

Good agronomic practice results in a more competitive crop. Using weed-free seed (preferably registered or certified), sowing on time, optimal plant populations and adequate nutrition all contribute to good weed control.

All weeds growing in a paddock should be controlled before the crop emerges. **Large, advanced weeds not controlled prior to or during sowing are the most difficult, and often impossible, to control with in-crop herbicides.**[6]

Pre-plant weed control

Tillage is a valuable method for killing weeds and preparing seedbeds. There are varying combinations of mechanical and chemical weed control to manage fallows or stubbles.

Knockdown herbicides are generally used instead of cultivation for fallow commencement, as well as for pre-sowing weed control in autumn. Knockdown herbicides benefit soil structure and provide more timely and effective weed control. However, the risk of herbicide resistance must be understood and managed.

Cultivation can spread grass weed seeds such as ryegrass, wild oat and brome grass, through the soil profile and prolong their seedbank dormancy. For these weeds a light cultivation (1–3 cm deep) in autumn can encourage germination and assist in depleting the seedbank. This can be combined with delayed sowing; however, yield penalties may apply.[7]

In-crop weed control

A wide range of pre-emergent and early post-emergent herbicides are available for grass weed control in lentil. With broadleaf weeds, post-emergent options are very limited.

Weeds should be removed from crops early, and certainly no later than six weeks after sowing, to minimise yield losses. Yield responses depend on weed species, weed, and crop density and seasonal conditions.

The growth stage of the weed and the crop are vital factors to consider to successfully use post-emergent herbicides. The growth stages of lentil are detailed in Section 6: Plant Growth and Physiology.

Herbicide labels must be followed carefully for information on both crop and weed growth stages, and the best conditions for spraying.

The risk of crop damage from herbicide application should be balanced against the potential yield loss from weed competition. In heavy weed infestations, some crop damage can be tolerated, as it is easily offset by the yield loss avoided by reducing weed competition.

MORE INFORMATION

For more information go to the GRDC Webpage: Integrated weed management manual: https://grdc.com.au/weedlinks

5 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

6 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

7 Grains Research and Development Corporation (2012) Cropping with Herbicide resistance. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

MORE INFORMATION

For more information go to:

Managing weeds at harvest: https://grdc.com.au/resources-and-publications/iwmhub/section-6-stopping-weed-seed-set

Weedsmart webpage: Capturing weed seeds at harvest http://www.weedsmart.org.au/10-point-plan/capture-weed-seeds-at-harvest/

AHRI Webpage: Rules of thumb for weed seeds http://ahri.uwa.edu.au/rules-of-thumb/

Harvest the time to get on top of resistant weeds: https://youtu.be/uURyKaaq-_I

Harvest weed-seed control for the high-rainfall zone https://youtu.be/RrvQQYqSmdE

Managing weeds at harvest

Managing weeds at harvest is an effective way to reduce carryover of problem weeds, particularly those with herbicide resistance.

Most southern Australian cropping weeds have seed that does not shatter before harvest. This major biological weakness provides the potential to remove the weed seed from the paddock at harvest.[8]

Research by the Australian Herbicide Resistance Initiative (2014) (AHRI) found that ryegrass, wild radish, brome grass and wild oats all retained at least 75% of weed seeds at the first opportunity to harvest wheat. As lentil can be harvested before wheat this presents an excellent opportunity to reduce the weed seed carryover.

These same weeds will shed 0.8–1.5% of their seeds each day that harvest is delayed. To improve control of problem weeds, **crops with weed burdens should be harvested first and the chaff removed.**[9]

Options for removing weed seeds in chaff include:

- remove the weed-laden chaff via baling;
- tow a chaff cart and burn the heaps;
- concentrate the chaff into narrow windrows for burning;
- pulverise the chaff to crush and destroy the weed seeds (with the Harrington Seed Destructor) before they exit the harvester; and
- in controlled-traffic farming, chaff can be funnelled and confined onto tramlines. This contains the weeds in a hostile environment separate from the crop.

Reducing the seedbank

A weakness of weeds in southern Australian is that, for many, their seed does not remain viable in the soil for very long, and seedbanks decline rapidly if not replenished each year.

Control methods for weed seed at harvest can lower a very large seedbank of more than 1,000 seeds/m^2 to 100 seeds/m^2 in only four years (e.g. annual ryegrass).[10] The level of reductions varies between weed species.

In paddocks with low **ryegrass** burdens, harvest weed seed methods reduced ryegrass emergence by as much as 90%. Paddocks with high ryegrass burdens (>2,000 seeds/m^2) were less responsive, with 30–40% reduction in ryegrass emergence. This means that harvest weed seed management takes longer to lower ryegrass populations in highly infested paddocks where the residual seedbank is still being exhausted.

Trials in South Australia and New South Wales show that narrow windrow burning and the use of a chaff cart are as effective at removing ryegrass seed as the Harrington Seed Destructor and at a similar cost.[11]

8 Grains Research and Development Corporation (2013) Ground Cover Supplement Issue 104 - Herbicide Resistance Supplement. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

9 Australian Herbicide Resistance Initiative (2014) Rules of thumb. Australian Herbicide Resistance Initiative, http://ahri.uwa.edu.au/rules-of-thumb/

10 Grains Research and Development Corporation (2016) Weed ID: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/app

11 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

Alternatives to harvesting the crop

Operations such as **cutting hay or silage** or **green or brown manuring** provide an opportunity for improved weed control when compared with harvesting crops for grain. These techniques are particularly valuable where herbicide-resistant weeds are a problem. When timed well they can prevent almost all seedset.[12]

Additional benefits of **manuring** include boosting soil nitrogen and conserving soil moisture to benefit yield in subsequent years.[13]

Green manuring uses cultivation and brown manuring uses chemical control to stop the growth of both crop and weed.

While green and brown manuring cost money without providing an income, the benefits for subsequent years can make it worthwhile. Manuring is usually suited to longer-seasoned forage crops and crop-topping to earlier-maturing grain crops. If income is important, crop-topping and grain harvest may be a more economically viable option even though yield may be reduced by topping.[14]

8.3 Managing weeds in lentil

Weed control strategy

The weed control strategy for growing a successful lentil crop depends on substantially reducing the viable weed seedbank in the soil before the crop emerges as post-emergence weed control options are limited.

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

Broadleaf weeds need to be heavily targeted in the preceding crop and/or fallow. **The broadleaf weed risk always needs to be assessed prior to sowing lentil.** This should be based on:

- grower's experience;
- the previous crop and weeds, and herbicides used; and
- an assessment of winter weeds germinating in the paddock prior to planting.

Paddocks with a severe broadleaf or grass weed problem that cannot be controlled in-crop should be avoided.

Lentil can be relatively slow to emerge, but has rapid early growth, even during the colder winter months. As a consequence it competes poorly with early weeds. Even moderate weed infestations can cause large yield losses and harvest problems.

Lentil can mature too late in some extended seasons for weed seedset control, so crop-topping may either have to be delayed or conducted before physiological maturity, risking yield and quality losses.

The risk with or inability to crop-top to prevent weed seed set is one of the main reasons growers give for not growing lentil in southern Australia. Broadleaf weed control options post-emergence are available, but can be damaging or limited in the weed spectrum they control in lentil. Although a common reason for not growing conventional lentil, new herbicide-tolerant varieties (PBA Hurricane XT⏀ and PBA Herald XT⏀) are offering more and safer options.

In general, options for broadleaf weed control with selective herbicides in lentil are limited, compared to the treatments available for use in other pulse crops and cereal crops.

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12 A Glover, I Trevethan, L Watson, M Peoples, T Swan (2013) Break crops in cropping systems: impacts on income, nitrogen and weeds 2012. Riverine Plains, pp. 38-41, http://www.farmtrials.com.au/trial/16519

13 Grains Research and Development Corporation (2013) Manuring of Pulse Crops. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2013/09/Manuring-of-Pulse-Crops

14 E Armstrong (2015) Weigh up the risks, benefits of pulse harvest. Ground Cover Supplement, Issue 155: Profitable pulses and pastures, GRDC, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Weigh-up-the-risks-benefits-of-pulse-harvest

Specific issues

Special attention is required for the following weed issues in lentil:

- Crop-topping cannot always be conducted at the optimum stage for preventing ryegrass seedset and be safe for the lentil plant.
- Late germination of weeds (ryegrass and brome grass) can safely be prevented by crop-topping in earlier-maturing pulses.
- Early-maturing varieties (PBA Bolt⁽ᶦ⁾ PBA Blitz⁽ᶦ⁾ and PBA Flash⁽ᶦ⁾) are safer to crop-top than later-maturing varieties (Nugget). This is because crop-topping may not be timely or fully effective in the later-maturing lentil varieties without affecting yield and quality or efficacy of preventing seedset of ryegrass.
- Lentil can initially be a poor competitor with weeds across southern Australia because of slow germination, small plant structure and an extended period before ground is covered at canopy closure.
- Lentil is often sown early or into dry soil, which limits the opportunity for ‘knockdown’ weed control before sowing and increases the reliance on herbicides and low weed numbers for in-crop weed control.

Problem weeds in lentil, that require special attention or are difficult to fully control include:

- annual ryegrass that is resistant to Group A products (‘dims’ and ‘fops’), particularly where high rates of clethodim are required;
- annual ryegrass that is resistant to trifluralin;
- snail medic and other medics;
- wild radish – there are no fully safe treatments available post-emergence in conventional lentil varieties, and germinations occur over an extended period; and
- hoary cress, soursob and tares.

Positives for weed control when growing lentil include the following.

- Availability of herbicide-tolerant (XT) varieties like PBA Hurricane XT⁽ᶦ⁾ and PBA Herald XT⁽ᶦ⁾. These XT varieties have increased herbicide options for broadleaf weeds and improved crop safety to Group B herbicides applied in-crop or as residues (herbicides with APVMA registration or permits are the only ones able to be applied in this crop).
- Delayed sowing is possible in higher rainfall areas, or with early maturing varieties. This enhances the opportunity for knockdown weed control before sowing.
- Lentil can be grown in wider rows in a stubble system that might allow inter-row herbicide application with shielded sprayers.
- If sowing into dry soil, there can be a delay of 14–21 days before lentil emerges after germinating rains, depending on soil temperatures and depth of sowing. In the right circumstances, this might allow a non-selective knockdown herbicide application to kill emerged weeds prior to lentil emergence.[15]

Weed competition in lentils

Preventing increases in resistant ryegrass numbers during the lentil phase of rotations is essential for maximum crop yield and sustainable cropping systems in southern Australia. Preventing weed seedset is the aim of most lentil growers. Lentil is a poor early competitor against ryegrass and other weeds, but has a relatively low plant population. Hence, low numbers of weeds can grow without necessarily inhibiting early development of lentil. If weeds are present, they can affect yield and become a problem by setting seed later in the season, often necessitating desiccation to enable harvest.

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Yield loss in lentil due to weed presence occurs, but has not often been documented in research trials. Medic can be very damaging to lentil yields. Good control of medic can also lead to damaged lentil.[16]

Impact of weed seedset and carryover to subsequent years may be more significant than yield loss per se, especially where weeds like ryegrass or late broadleaf weeds are present and not controlled. As well, weed seeds can affect grain quality and influence quality grades obtainable at delivery. This is particularly a problem with wild vetch seed contamination, which can be very hard to clean out of some varieties.

Photo 1: *Broadleaf weed contaminants in lentil.*

Photo: M. Raynes, formerly Pulse Australia

Photo 2: *Grass weeds in lentil.*

Photo: W. Hawthorne, formerly Pulse Australia

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MORE INFORMATION

For more information on XT lentil varieties read the GRDC *GroundCover*™ article: 'Effective weed management is critical for successful pulse production and system sustainability'. https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Weed-control-benefits-whole-system

A GRDC video on pulse herbicide tolerance is at: https://www.youtube.com/watch?v=j7JEfzclUfg

MORE INFORMATION

For more information go to the APVMA (https://apvma.gov.au/node/612) and Pulse Australia (http://www.pulseaus.com.au/growing-pulses/crop-protection-products) websites.

IMI-tolerant lentil varieties

Due to lentil's poor competitive nature, breeding in Australia has focused on developing variety types more tolerant to herbicides.

The first two varieties with specific herbicide tolerances have been released: PBA Herald XT⍉ in 2012 and PBA Hurricane XT⍉ in 2014.

Photo 3: *IMI damage to a conventional lentil variety (left) compared to an IMI-tolerant (XT) variety. PBA Herald XT⍉ (right).*

Photo: W. Hawthorne, formerly Pulse Australia

These varieties have tolerance to imazethapyr ('IMI'). The minor-use permit (14369) for imazethapyr use is for these XT lentil varieties only. (This permit expires on August 31 2017. At least one product – Gemfarm imazethapyr 700wg – is now registered for use in PBA Herald XT⍉ and PBA Hurricane XT⍉.) These XT varieties allow a lentil crop to be grown without the risk of yield loss from herbicide damage. Weed control now be achieved on weeds that may, otherwise, have been difficult to control.

Even with improved tolerances, product registrations, product label rates, plant-back periods and directions for use in lentil must still be adhered to in XT varieties.

There are no registrations for use of other IMI or sulfonylurea products in XT lentil.

The use of imazethapyr increase options for managing particularly difficult to control weeds, such as bifora and bedstraw. Bifora and bedstraw are both "declared weeds" in South Australia and are significant weed threats to that state's primary production industries. Bifora to is spreading to Victoria's lentil areas and is becoming a bigger issue. However, bedstraw is a problem weed for Victorian growers.

Imazethapyr also provides better and safer options (pre-emergent and post emergent) in XT lentil varieties including management of two other important broadleaf weeds, Indian hedge mustard and wireweed.

In addition, the weed spectrum controlled with pre-emergent application of imazethapyr covers a broad range of the important broadleaf weeds (bifora, bedstraw, capeweed, deadnettle, Indian hedge mustard, turnip weed, wild radish and wireweed). Prickly lettuce is developing resistance to Group B herbicides and IMIs are regarded as 'weak' in controlling this weed. Also, IMIs are not very effective in cotrolling capeweed. IMIs are effective in controlling brassica weeds.

Another difficult to control "declared weed" in South Australia and the Wimmera region of Victoria is muskweed (*Myagrum perfoliatum*). This weed is also a "declared weed" in South Australia. Limited trials have shown imazethapyr has strong activity on this weed, showing promise for further work in this area.[17]Lentil herbicide tolerance (NVT South Australia).

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Table 3: Lentil herbicide tolerance (NVT South Australia).

Herbicide		Broadstrike®	Brodal Options®	Boxer Gold®	Diuron	Dual Gold®*	Lexone®	Lexone®*	Simazine*	Simazine*	Simazine + Diuron500*	Status®*	Terbyne®*	Terbyne®
		Flumetsulam	Diflufenican	Prosulfocarb + S-metolochlor	Diuron	S-metolochlor	Metribuzin	Metribuzin	Simazine	Simazine	Simazine + Diuron	Clethodim	Terbuthylazine	Terbuthylazine
Variety	Years tested	1994–2015	1994–2015	2015	1996–2015	1997–2000	1994–2015	2005–2008	2004–2015	2001-2004	1992-2002	2014	2009–2013	2014–2015
PBA Ace⍉	2012–2014	N (1/3)	✓(3)	-	✓(3)	-	30 -35 (2/3)	-	21 -35 (2/3)	-	-	✓(1)	N (2/2)	10 (1/1)
PBA Blitz⍉	2010–2012	10-13 (2/3)	✓(3)	-	N (1/3)	-	10 (1/3)	-	N (3/3)	-	-	-	N (3/3)	-
PBA Bolt	2013–2015	14 (1/3)	✓(3)	✓(1)	✓(3)	-	12 (1/3)	-	28 (1/3)	-	-	✓(1)	29 (1/1)	✓(2)
Boomer	2005–2009	7-19 (2/5)	7-11 (2/4)	-	✓(5)	-	19 (1/5)	34 (1/4)	✓(5)	-	-	-	N (1/1)	-
PBA Bounty⍉	2009–2011	12 (2/3)	9 (1/3)	-	N (1/3)	-	N (2/3)	-	9 (1/3)	-	-	-	11 (1/3)	-
Cassab	1999–2001	N (1/3)	7 (1/3)	-	N (2/3)	8 (1/2)	N (2/3)	-	-	✓(1)	N (1/3)	-	-	-
Cobber	1994–2002	10 (1/4)	22 (1/4)	-	N (1/2)	✓(1)	12 (1/4)	-	-	-	-	-	-	-
Digger	1994–2001	8-18 (2/7)	15-23 (2/7)	-	N (3/5)	N (2/3)	32 (1/7)	-	-	✓(1)	6 (1/3)	-	-	-
PBA Flash⍉	2006–2013	10-14 (3/8)	N (3/8)	-	N (1/8)	-	N (5/8)	42 (1/3)	42 (1/8)	-	-	-	26 (1/5)	-
PBA Greenfield⍉	2014–2015	N (1/2)	N (1/2)	✓(2)	✓(2)	-	✓(2)	-	✓(2)	-	-	-	-	✓(2)
PBA Giant⍉	2014–2015	✓(2)	✓(2)	✓(2)	✓(2)	-	✓(2)	-	✓(2)	-	-	-	-	✓(2)
PBA Herald XT⍉	2012–2014	✓(3)	✓(3)	-	✓(3)	-	13 - 21 (3/3)	-	13-39 (3/3)	-	-	✓(1)	N (2/2)	✓(1)
PBA Hurricane XT⍉	2013–2015	✓(3)	✓(3)	✓(1)	✓(3)	-	N (1/3)	-	10-33 (2/3)	-	-	✓(1)	N (1/3)	✓(2)
PBA Jumbo2⍉	2014–2015	✓(2)	N (1/2)	13 (1/1)	✓(2)	-	30 (1/2)	-	8-25 (1/2)	-	-	✓(1)	-	N (1/2)
PBA Jumbo	2011–2012	12 (1/2)	✓(2)	-	✓(2)	-	N (2/2)	-	N (2/2)	-	-	-	N (1/2)	-
Nipper⍉	2004–2015	8-20 (5/12)	7 (1/12)	✓(1)	N (3/12)	-	10-25 (7/12)	26-52 (3/4)	13-64 (4/12)	N (1/2)	✓(1)	✓(1)	21-40 (2/5)	✓(2)
Northfield	1994–2004	10-25 (3/9)	16-24 (3/9)	-	14 (1/7)	21 (1/2)	17-19 (2/9)	14 (1/1)	✓(1)	N (2/3)	12 (1/4)	-	-	-
Nugget	1999–2005	6-20 (3/6)	11 (1/6)	-	N (1/6)	N (1/2)	6 (1/6)	✓(2)	✓(2)	7 (1/3)	15 (1/4)	-	-	-
Rates (product/ha)		20 g	150 mL	2.5 L	1 kg	500 mL	280 g	180 g	1 kg	1.2 L	500 mL + 500 mL	1 L	1 kg	1 kg
Crop stage at spraying		6 weeks	6 weeks	IBS	PSPE	PSPE	PSPE	3 node	PSPE	6 weeks	PSPE	3 node	PSPE	IBS

– Not tested or insufficient data ✓(z) No significant yield reductions at recommended rates or higher than recommended rates in (z) trials
N (w/z) narrow margin, significant yield reductions at higher than recommended rate, but not at recommended rate, significant event ocurring w years out of z years tested. E.g. (2/5) = tested for 5 years, 2 years returning a significant yield loss
x% (w/z) yield reduction (warning) significant yield reduction at recommended rate in 1 trial only in z years of testing
x-y% (w/z) yield reductions (warning) significant yield reductions at recommended rate in w years out of z years tested

* Denotes an off-label use. This use is not endorsed by this data and no responsibility will be taken for its interpretation.

Always follow label recommendations. All pesticide applications must accord with the currently registered label for that particular pesticide, crop, pest and region. Any research regarding pesticides or their use reported in this website does not constitute a recommendation for that particular use by the authors, the author's organisations or ACAS.

It must be emphasised that crop tolerance and yield responses to herbicides are strongly influenced by seasonal conditions.

Source:: National Variety Trials: Herbicide Tolerance (2016) Grains Researchand Development Corporation http://www.nvtonline.com.au/herbicide-tolerance/

How XT varieties were developed

XT lentils were developed via mutation using ethyl methane sulfonate (EMS), similar to how the current Clearfield™ wheat, canola, barley and other varieties were developed and which are now commercialised internationally. The varieties are not genetically modified.[18]

PBA Herald XT⦶ and PBA Hurricane XT⦶ are NOT Clearfield™ varieties.

As there is limited information available on levels of tolerance of lentil to imidazolinones, comparisons are made with field pea. The levels of tolerance of PBA Herald XT⦶ to the range of imidazolinones indicates that PBA Herald XT⦶ has much better tolerance to imidazolinone herbicides than current field pea varieties. Crop damage is less likely using the allowable rates of imazethapyr, which are those currently recommended for field pea.

Avoiding overuse of 'IMI' chemistry

In Canada, within four years of IMI-tolerant (Clearfield™) lentil being available, herbicide resistance to its chemistry became a major issue.[19]

Although the release of IMI-tolerant (XT) lentil varieties in Australia is being heralded as a major breakthrough in controlling problem weeds, it must be managed carefully to ensure the initial advantage is not lost through overuse of IMI chemistry in the rotation.

Australia already has IMI-tolerant varieties of canola, wheat and barley. All have tolerance to IMI residues from the previous crop. Other pulses such as field pea and faba bean have IMI products registered or under permit for use.

Using an IMI product in each of these crops in a sequence would quickly lead to resistance developing in targeted weeds. To avoid resistance developing, at least one or more of these IMI-tolerant crops must be grown in the rotation without the IMI being used on it.

For example, an XT lentil can be grown because of its tolerance to IMI residues rather than use an IMI product on the actual crop. Alternatively, an IMI-tolerant cereal may be grown and a non-IMI product used so that the IMI product can be used on the XT lentil.

Current herbicide products for conventional and XT lentil varieties

Not all herbicide products registered and commonly used in other pulses are registered for use in lentil. Examples of products not registered for use in lentil include simazine and triallate.

Herbicide options for conventional lentil varieties include:

- pre-sowing (metribuzin, cyanazine, terbuthylazine, trifluralin);
- post-sowing pre-emergent (diuron, metribuzin, trifluralin); and
- post-emergent (diflufenican, flumetsulam).

Under adverse conditions, most post-sowing pre-emergent herbicides are capable of causing damage to lentil. Adverse conditions include:

- varying soil types;
- unevenness in a paddock; and
- instances of heavy rainfall after sowing resulting in herbicide being washed into furrows.

These scenarios can all pose difficulties in determining the balance between applying herbicide rates for adequate weed control while minimising crop damage.

Registered products available for post-emergent applications can cause crop damage and yield reduction in some circumstances in currently grown conventional

18 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

19 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

MORE INFORMATION

See Variety Management Packages (VMPs) at:

http://www.pulseaus.com.au/growing-pulses/crop-protection-products

www.nvtonline.com.au/herbicide-tolerance

MORE INFORMATION

For more information on the development of herbicide tolerance in lentil click on the link to go to GRDC Groundcover TV Episode 16: Pulse Herbicide Tolerance. https://grdc.com.au/Media-Centre/GroundCover-TV/2015/05/Episode-16-May-2015

lentil varieties. Some varieties are more sensitive than others (Tables 4 and 5). This information is advised on the herbicide labels.

Research trials conducted by the South Australian Research and Development Institute (SARDI) on alkaline soils over seven years (1994–2010) have shown yield losses of up to 25% in trials using flumetsulam and up to 24% yield loss in trials using diflufenican. Of the five post-emergent products registered for lentil these two herbicides have caused the most instances of crop damage and yield loss (Tables 4 and 5).[20]

Delayed sowing is an option to enable several weed kills before sowing. However, the method used can limit crop yield potential in lower rainfall areas, and in seasons when drier springs occur. Lentil crops, being very short, require more care and specialised harvesting equipment to harvest efficiently, and delayed sowing can result in very short crops, which are more difficult to harvest.

Controlling many broadleaf weeds in lentil crops can be difficult to achieve. These broadleaf weeds include: bedstraw, bifora, clovers, medics, tares, vetches, wild radish and self-sown pulses.

Note that most general damage in conventional varieties seems to occur with flumetsulam. Damage from other herbicides is more specific to individual varieties, like Boomer and Northfield to diflufenican or Nipper⁽ᵇ⁾ and Northfield to metribuzin. Quite a few varieties have a narrow safety margin against diuron and/or metribuzin.

Severe seasonal effects on herbicide activity occur, so work is ongoing to validate findings under differing seasonal conditions.

20 Grains Research and Development Corporation (2016) National Variety Trials: Herbicide Tolerance. Grains Research and Development Corporation, http://www.nvtonline.com.au/herbicide-tolerance/

MORE INFORMATION

A GRDC Booklet on spraying 'Spray application manual' is at https://grdc.com.au/GrowNotesSprayApplication

And a GRDC webinar on spray application in summer fallows is at: https://youtu.be/kDuz6ADMjA0

MORE INFORMATION

APVMA webpage: Registration database https://portal.apvma.gov.au/pubcris

APVMA webpage: Permits database https://portal.apvma.gov.au/permits

APVMA app: Permit app for iOS: http://apvma.gov.au/node/10831#iphone_app

Pulse Australia webpage: Permits for pulses http://www.pulseaus.com.au/growing-pulses/crop-protection-products

Grain Producers booklet: Safely managing risks with crop inputs and grain on farm http://grainsguide.grainproducers.com.au/

8.4 Using herbicides

Herbicides that are registered for use in lentil can be found using the **Australian Pesticide and Veterinary Medicines Authority (APVMA) database**. An **ios app** is also available. Seek the advice of your local agronomist or reseller.

It is important to ensure information on the registration status of herbicides is current. Specifically, this refers to rates of application, warnings related to withholding periods, occupational health and safety, residues, and off-target effects.

Herbicides must only be used if they are legally registered for the particular use in the particular crop at the listed label rates. Using products off-label risks reduced efficacy, exceeding Maximum Residue Limits (MRLs) and litigation.

The product label and Safety Data Sheet (SDS) must always be read prior to using herbicides.

Residue limits in any crop are at risk of being exceeded or breached where pesticides are applied:

- at rates higher than the maximum specified;
- more frequently than the maximum number of times specified per crop;
- within the specified withholding period; and
- where they are not registered for the particular crop.

The National Residue Survey (NRS) is part of an Australian Government and industry strategy to minimise chemical residues and environmental contaminants in Australian food products. NRS programs support primary producers and commodity marketers by confirming Australia's status as a producer of clean food and facilitating access to key domestic and export markets. The compliance rate for pulses in 2013- 14 was 99.5%.[21]

Getting best results from herbicides

Successful results from herbicide application depend heavily on numerous interacting factors.

Annual weeds compete with cereals and broadleaf crops mainly when the crops are in their earlier stages of growth. Weeds should be removed no later than six weeks after sowing to minimise losses. Early post-emergence control nearly always results in higher yields than treatments applied after branching in broadleaf crops.[22]

Points to remember for the successful use of herbicides:

- Plan the operation. Check paddock sizes, tank capacities, water availability and supply.
- Do not spray outside the recommended crop growth stages as damage may result.
- Carefully check crop and weed growth stages before deciding upon a specific post-emergent herbicide.
- Read the label. Check to make sure the chemical will do the job. Note any mixing instructions, especially when tank mixing two chemicals.
- Follow the recommendations on the label.

Conditions inhibiting plant cell growth, such as stress from drought, waterlogging, poor nutrition, high or low temperatures, low light intensity, disease or insect attack, or a previous herbicide application, are not conducive to maximum herbicide uptake and translocation.

- Use good quality water, preferably from a rainwater tank. Water quality is very important.
- Hard, dirty or muddy water can reduce the effectiveness of some herbicides.

21 National Residue Survey (2014) Residue results for 2013-14. Australian Government, Department of Agriculture and Water Resources, http://www.agriculture.gov.au/ag-farm-food/food/nrs/nrs-results-publications/plant-product-monitoring-2013-14

22 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

MORE INFORMATION

For more on herbicide use efficiency go to the GRDC website: *New technology for improved herbicide use efficiency* https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/new-technology-for-improved-herbicide-use-efficiency

- Use good equipment checked frequently for performance and output.
- Use sufficient water to ensure a thorough, uniform coverage regardless of the method of application.
- Check boom height with spray pattern operation for full coverage of the target.
- Check accuracy of boom-width-marking equipment.
- Check wind speed.
- A light breeze helps herbicide penetration into crops.
- Do not spray when wind is strong (>10–15 km/h).
- Do not spray if rain is imminent or when heavy dew or frost is presesnt.
- Calculate the amount of herbicide required for each paddock and tank load. Add surfactant where recommended.
- Select the appropriate nozzle type for the application.
- Beware of compromising nozzle types when tank mixing herbicides with fungicides or insecticides.
- Be aware of spray conditions to avoid potential spray drift onto sensitive crops and pastures, roadways, dams, trees, watercourses or public places.

Seek advice before spraying recently released lentil varieties as they may differ in their tolerance to herbicides. Information on herbicide tolerance is available on the variety management package for the variety.

Keep appropriate spray records for each spray operation.

Current minor-use permits (MUP)

Some products may be available under permit, with conditions attached, until enough data is generated for full registration. In other cases, a temporary permit may be granted when there is a particular seasonal issue, for example, in 2010 and 2016 when fungicide availability became an issue across pulse crops.

Pulse Australia holds several minor-use permits on behalf of the pulse industry and is actively involved in the pursuit of new permits and label registrations to meet industry needs.

There are new permits available in 2017. These permits are in addition to those already issued.

- PER84309 azoxystrobin / cyproconozole (asochyta in chickpea/lentil)
- PER84407 Prosaro (TM) (ascochyta in chickpea/lentil)
- PER84408 Boscalid (Botrytis grey mould in chickpea / lentil)

Please note these are only valid until 30 November 2017. A full list of permits can be found on the Pulse Australia website (http://www.pulseaus.com.au/growing-pulses/crop-protection-products).

8.5 Herbicide performance

Characteristics that determine herbicide performance and activity are:

- herbicide uptake: how and where the chemical is taken up by the plant.
- herbicide solubility: how readily it dissolves or leaches in soil water.
- herbicide adsorption: how much is lost by binding to the soil.
- herbicide persistence: how long it will last in the soil, affected by:
  - volatilisation: loss to the atmosphere.
  - leaching potential: how much is lost below the root zone.
  - decomposition by light: loss of product by decomposition.

Understanding these factors will assist in ensuring more effective herbicide use.

For best performance, pre-sowing and pre-emergence herbicides should be placed within the top 5–7 centimetres of soil. They must enter the germinating weed seedling in order to kill it. These herbicides can be mixed in by cultivation, rainfall, or sprinkler irrigation, depending on the herbicide. They are also used in incorporation by sowing (IBS) systems where they are applied to the soil surface and covered during the sowing operation.

Poor herbicide efficacy can occur under dry conditions at application. Some soil-active herbicides (terbuthylazine or simazine) can damage lentil where wetter conditions favour greater activity and leaching. Figure 2 illustrates how herbicides are broken down.

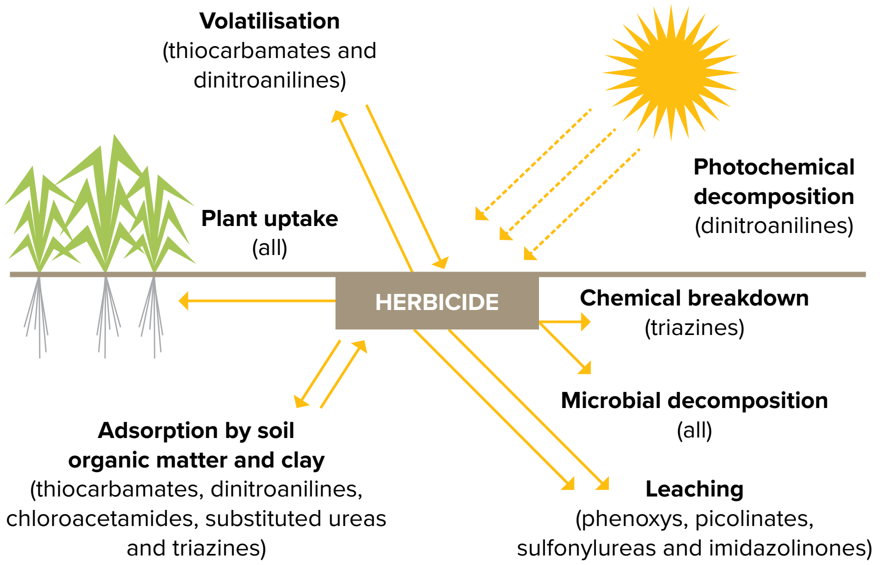

Figure 2: *Fate of applied herbicides in soil, plant and sunlight.*

Source: Understanding stubble & soil binding of pre-emergent herbicides used for ryegrass control in winter crops (2013), GRDC, https://grdc.com.au/__data/assets/pdf_file/0016/151090/interactions-of-herbicides-with-soil-and-crop-residue-webinar-slides.pdf.pdf

8.6 Herbicide types

Knockdown herbicides

The most important part of the pulse weed-control strategy is to control the majority of weeds before sowing, either by cultivation or with knockdown herbicides such as glyphosate (Group M) and/or Spray Seed® (Group L).

A technique used with varying success by growers has been to sow lentil and then use a knockdown herbicide tank-mixed with a pre-emergent herbicide to control germinating weeds just before the crop has time to emerge. Lentil crops may take up to 21 days to emerge under cool, drying soil conditions. Under favourable warm, moist soil conditions it is important to be aware that lentil may emerge in as little as 7–10 days. If considering this option, lentil should be sown deeper (6–8 cm) and paddocks checked carefully for the emergence of lentil immediately before spraying. Done well, this can be an effective weed-control option.[23]

Double-knockdown is the sequential application of two different weed-control tactics where the second tactic controls survivors from the first.[24] A common technique is to apply glyphosate (Group M), followed 2–10 days later by paraquat/diquat (Group L). Non-chemical options such as burning or grazing may also be used.[25]

MORE INFORMATION

GRDC Update paper: 'Optimising the impact of glyphosate'. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/optimising-the-impact-of-glyphosate

GRDC video: Double-knock timing. https://www.youtube.com/watch?v=tNNRziB3MKc

GRDC video: IWM: Double Knock Applications – Double Knock Strategies for Resistant Weed Populations https://youtu.be/bL0sbdQAYK0

GRDC Video: Double knock applications – a grower's experience https://youtu.be/pElEGsQDzBg

23 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

24 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

25 Grains Research and Development Corporation (2012) Cropping with Herbicide resistance. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

Pre-sowing herbicides

The resistance status of the weeds present, particularly ryegrass, must be known to determine which products and mixtures can be used pre-sowing.

Incorporation by sowing is generally considered safer on the crop than post-sowing pre-emergence (PSPE) with most herbicides used in modern no-till sowing systems. There is, however, little herbicide protection within the sowing row, and there is potential for crop damage if soil is thrown or washed back into the sowing furrow.

Trifluralin, pendimethalin, cyanazine, terbuthylazine and some diuron brands are registered for use on lentil.

Triallate and simazine are NOT registered for use in lentil.

Most of the above herbicides require or benefit from mechanical incorporation by sowing, and are often used in mixtures.

Post-sowing pre-emergent herbicides

Pre-emergent herbicides are essential because there are limited post-emergent options for broadleaf weed control in lentil.

Pre-emergent herbicides offer the following advantages:

- alternative modes of action to post-emergent and knockdown herbicides;
- many are very effective on hard-to-kill weeds, such as annual ryegrass and barley grass;
- herbicide resistance to pre-emergent herbicides is low in some varieties or some areas;
- pre-emergent herbicides control weeds early in crop life and potentially over several germinations, maximising crop yield potential;
- they suit a no-till sowing system with knife points and press-wheels and/or disc seeders, as well as conventional tillage systems; and
- can be cost-effective.

These pre-emergent herbicides are primarily absorbed through the roots, but there may also be some foliar absorption.

When applied to soil, best control is achieved when the soil is flat and relatively free of clods and trash. While most pre-emergent herbicides are suitable for use in high stubble load paddocks, product labels will suggest adequate control with 50% groundcover.

Sufficient rainfall (20–30 mm) to wet the soil through the weed root zone is necessary within 2–3 weeks of application. Best weed control is often achieved from a post-sowing application because rainfall provides the best incorporation (moisture or rainfall is still required to activate pre-sowing herbicide applications).

Mechanical incorporation is less uniform and so weed control may be less effective. If applied pre-sowing and sown with minimal disturbance, incorporation will essentially be by rainfall after application. Weed control in the sowing row may be less effective because a certain amount of herbicide will be removed from the crop row through the sowing operation.

The residual activity of a pre-emergent herbicide controls the first few flushes of germinating weeds while the crop is too small to compete. As a result, pre-emergent herbicides are often excellent at protecting the crop from early weed competition.[26]

Pre-emergent herbicides will not adequately control large weed populations by themselves. They need to be used in conjunction with paddock selection, crop rotation and pre-sowing weed control.

In no-till sowing systems, incorporation by sowing (IBS) is generally considered safer on the crop than post-sowing pre-emergent (PSPE). This is because there is

26 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

no herbicide over the sowing row, that can get washed down into the root zone. Movement of soil, after incorporation by sowing or post-sowing pre-emergent spraying, can move and concentrate herbicide over the seed row, thus increasing the risk of damage.[27]

To avoid PSPE damage deep sowing is recommended. The herbicide should be applied to moist soil, not dry, and not apply if there is heavy rain forecast. The soil surface should be level to limit the possibility of herbicide concentrating in the furrow. Lower herbicide rates are recommended on lighter soils.[28]

Post-emergent herbicides

Selective post-emergent herbicides give high levels of control (often >98%) when applied under recommended conditions on susceptible populations. When used early in crop development the yield benefit provides significant economic returns.[29]

Application of post-emergent herbicides to stressed crops and weeds can result in reduced levels of weed control and increased crop damage.

Stress from waterlogging, frost or dry conditions results because crops cannot produce sufficient levels of the enzymes that normally break down the herbicide.[30]

Only two broadleaf herbicides are currently registered for post-emergence use in conventional lentil varieties.

Flumetsulam and diflufenican are registered products available for post-emergent applications. However, they can cause crop damage and yield reduction in conventional lentil varieties.

Some varieties are more sensitive than others and this is advised on these herbicide labels. Yield losses of up to 25% using flumetsulam and up to 24% yield loss using diflufenican have been recorded. Of the herbicide products registered for lentil these two post-emergent herbicides have caused the most instances of crop damage and yield loss (Tables 4 and 5).

Directed sprays in-crop

With the shift to cropping lentil on wide rows, weeds will have more time to become established between the rows but there are also more opportunities to use inter-row spraying. This can be combined with banding of fertiliser during sowing to favour the crop over the weed.[31]

Shielded sprayers

Shielded sprayers are becoming increasingly more common in or around the cotton-growing areas, as they provide very cheap grass and broadleaf weed control with glyphosate.

Lentil has little tolerance to glyphosate during the vegetative stage, so caution is required as the basal branches may not be fully erect and could be sprayed during this process. Basal branches contribute a large proportion of the total lentil yield.

Issues that need to be considered include:

- selection and operation of spray shields (speed, nozzle type etc.);
- height of the crop (small lentil plants are more susceptible); and
- variety can also be important. Upright types such as PBA Bolt⍉ are more suited to this technique than the more prostrate or lodging types like PBA Jumbo⍉.

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27 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

28 B Haskins, G Brooke, A Schipp (2011) Weed control in winter crops 2012. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops

29 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

30 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

31 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

MORE INFORMATION

For more information:

GRDC booklet: *Soil behaviour of pre-emergent herbicides in Australian farming systems.* https://grdc.com.au/resources-and-publications/all-publications/publications/2015/08/soilbehaviourpreemergentherbicides

GRDC Videos: Pre-emergent herbicide application. https://www.youtube.com/watch?v=s63GYYyflzw

Weed wiping

Weed wiping (or 'wick' wiping) is done by wiping herbicide (usually glyphosate) onto the weeds that stand above the crop canopy, without affecting the crop itself. It is being successfully used in lentil to prevent weed seedset of herbicide-resistant ryegrass and other tall weeds in the crop. Weeds must be taller than the lentil plants. Hence crop height and erectness need to be considerations in lentil variety choice for weed-wiping opportunities. Also, lentil sown into standing stubble needs to be taller than the standing cereal stubble to enable effective weed-wiping.

Paddocks with high levels of herbicide-resistant ryegrass should be avoided when choosing paddocks to grow lentils because of the poor relative competitiveness of lentils. However, where weed numbers are manageable and because lentils are short in height, there is an opportunity for weed-wiping to prevent the taller ryegrass plants from setting seed.

Photo 4: *A weed wiper can be useful to prevent seedset of tall weeds in lentil, and help dry those weeds for easier and earlier harvest management.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 5: *Crop damage from using a weed wiper that has either been set too low or has bounced through excessive speed.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 6: *Use of a weed wiper to prevent weed seedset in lentil may be limited if the standing stubble is cut too tall at harvest or the lentil grows short through lack of moisture or variety choice.*

Photo: W. Hawthorne, formerly Pulse Australia

8.7 Herbicide residues

Pulse types differ in their sensitivity to residual herbicides.[32] It is important to check each herbicide and pulse crop variety prior to use for sensitivity to residues. This is because of new XT lentils and different pulse crop sensitivities (see Photos 9 to 20).

Group B:

- **Unless it is an XT variety (herbicide-tolerant), lentil is sensitive to sulfonylurea residues and the imidazolinones.**
- Lentil should not immediately follow after beans or field pea if IMIs or sulfonamides were used in that crop.
- Lentil and chickpea are most vulnerable to sulfonylurea residues, with field pea, faba and broad bean the least. Residues persist longer in high pH soil.
- Lentil, faba and broad bean, and lupin are more sensitive to sulfonamide residues particularly on shallow duplex soils where breakdown is slower.
- At low pH (<6.5) faba and broad bean are more sensitive to Monza® residues (sulfonylurea) than lentil, chickpea, lupin and field pea. All are sensitive at higher pH (>6.5).

Group I:

- All pulses are vulnerable to pyridine residues (Lontrel®). Lontrel® is more likely to persist in stubble retention systems.
- 'Spikes' (dicamba) added to knockdown sprays may persist under dry conditions and can reduce pulse crop establishment. Dicamba plant-backs start after 15mm of rain. **Lentil and faba bean are not listed on label.**
- Picloram and aminopyralid applied to previous summer fallows are more likely to persist and damage crops under dry conditions.

32 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016, NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

Group C:

- Triazine and diuron herbicides applied in-crop can potentially cause crop damage in some circumstances.

All residual herbicides require moist soil to break down. Where dry conditions have persisted between herbicide application and sowing there will be a higher risk of residual herbicide damage.

Some of the newer broadleaf herbicides used in cereals now have plant-back for lentil.

8.8 Herbicide damage

The risk of herbicide damage needs to be weighed against potential yield loss from weed competition. In heavy weed infestations some herbicide crop damage can be tolerated as this is more than offset by the yield loss avoided by removing competing weeds. Weeds at harvest can also lead to harvest and marketability problems.

If herbicide is applied to dry soils, the risk of movement and crop damage is increased greatly after rainfall, particularly if the soil is left ridged and herbicide washes into the seed row. Incorporation by sowing (IBS) may be more appropriate in dry conditions, or, alternatively, a split application to minimise risk. Post-sowing pre-emergent (PSPE) herbicides should be applied to moist soil regardless of the sowing time.

Herbicides move more readily in soils with low organic matter, more sand, silt or gravel. Herbicide movement is much less in soils with higher organic matter and higher clay contents. Damage from leaching is also greater where herbicides are applied to dry, cloddy soils, than to soils which have been rolled and which are moist from rainfall prior to the herbicide application.

Herbicide damage can result from:

- residues in the soil;
- drift from outside the crop (see also Section 4.6);
- leaching within soil profile;
- pre and post-emergent herbicides applied to the crop; and
- spray tank contamination.

Damage from pre and post-emergent herbicides can be minimised by careful application and by understanding the tolerance of lentil varieties.

Timing of rolling can also influence herbicide damage. Rolling immediately after post sowing pre emergence spraying (PSPE) or incorporation by sowing spraying (IBS) can 'push' more herbicide in the seed row, increasing the risk of damage. This risk is increased on lighter-textured soils where there is more soil movement during rolling.

Plants weakened by herbicide injury are more susceptible to diseases. The most common problems come from residual herbicides applied to prior cereal crops. However, non-residual herbicides have also been implicated.[33]

33 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016, NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

Table 3: The relative leaching potential of some soil-active herbicides (1 = the least leaching).

Chemical	Example of product	Leaching index
Pendimenthalin	Stomp®	1
Trifluralin	Treflan®	1
Diuron	Diuron	2
Prometryn	Prometryn	3–4
Simazine	Simazine	5
S-metalochlor	Dual Gold®	6
Terbuthylazine	Terbyne®	8*
Atrazine	Atrazine	10
Metribuzin	Sencore®	14

*Estimated

Source: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

Metribuzin leaches at almost three times the rate of simazine and seven times the rate of diuron.

The relative tolerance of the crop type and variety will also affect crop damage from these herbicides. For example, lupin is more tolerant to simazine than other pulses.

Symptoms of herbicide damage

Pulses have narrow crop safety margins to most registered herbicides. They can be severely damaged by some herbicides. This might be due to soil residues from previous applications, contaminants in spray equipment, spray drift onto the crop or by incorrect use of the herbicide.

Symptoms of crop injury from herbicides do not always mean a grain yield loss will occur. Recognition of crop injury symptoms allows the cause of the injury to be identified and possibly prevented in future crops. The type of injury depends on how the herbicide works in the plant, the site on the plant, and seasonal conditions.

Herbicide injury may be very obvious (for example scorched leaves) or it may be subtler (for example 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.

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.

Taking some general precautions can help to reduce the likelihood of crop damage with residual herbicide use:

- do not apply if rain is imminent;
- maintain up to 8 cm soil coverage;
- avoid leaving a furrow or depression above the seed that could allow water (and chemical) to concentrate around the seed/seedling; and
- avoid leaving an exposed, open slot over the seed with disc openers and avoid a cloddy, rough tilth with tyned openers.

MORE INFORMATION

App: Lentil: The Ute Guide
https://grdc.com.au/Resources/Apps

App: Herbicide Injury: The Ute Guide
http://www.uteguides.net.au/UteGuides

Photo 7: *Group C. Crops grown on lighter soils are more prone to metribuzin damage.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 8: *Group C. High rates of simazine can damage lentil. Lower leaves turn brown and die back from the edge.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 9: *Group C. Herbicide damage affecting emergence and survival of seedlings.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 10: *Simazine damage on one row where shallower sown, or deeper sowing, furrow remained.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 11: *Group C. Triazine injury (front) on sandier soil, causing stunted growth.*

Photo: A. Mayfield, via Grain Legume Handbook

Photo 12: *Group I. Bean seedlings affected by Lontrel® residue in soil.*

Photo: W. Hawthorne, formerly Pulse Australia

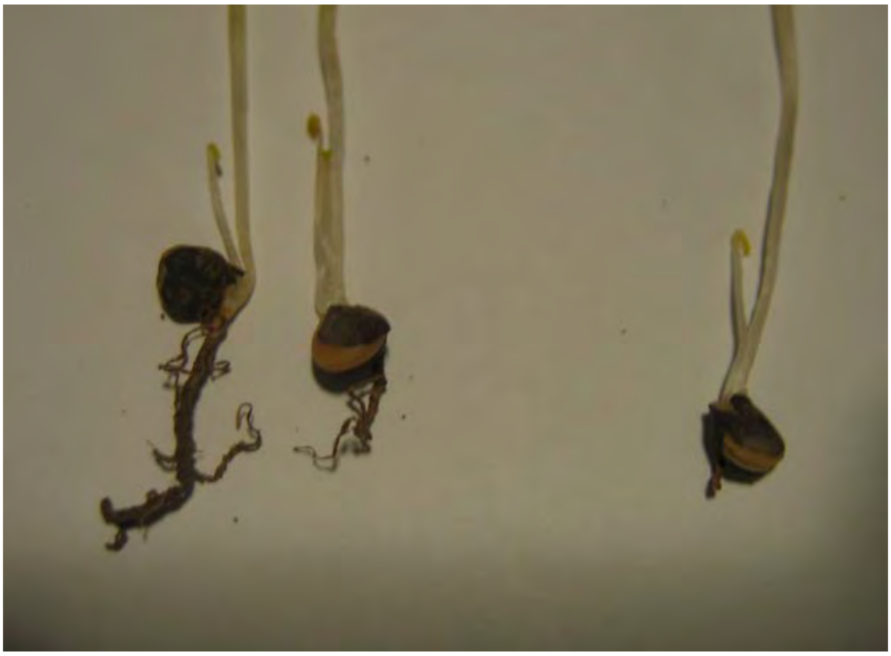

Photo 13: *Group D. Trifluralin injury (left) causing stunted growth. It can also cause development of multiple growing points.*

Photo: I Koch, J&D Southwoods

Photo 14: *Group B. Damage caused by Broadstrike®.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 15: *Group B. Broadstrike® damage.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 16: *Group I. 2,4-D spray drift causing narrow leaves with crinkled edges.*

Photo: Canadian Phytopathological Society via SasPulse Growers Handbook

Photo 17: *Group I. Damage from Lontrel® drift.*

Photo: T. Bray, formerly Pulse Australia

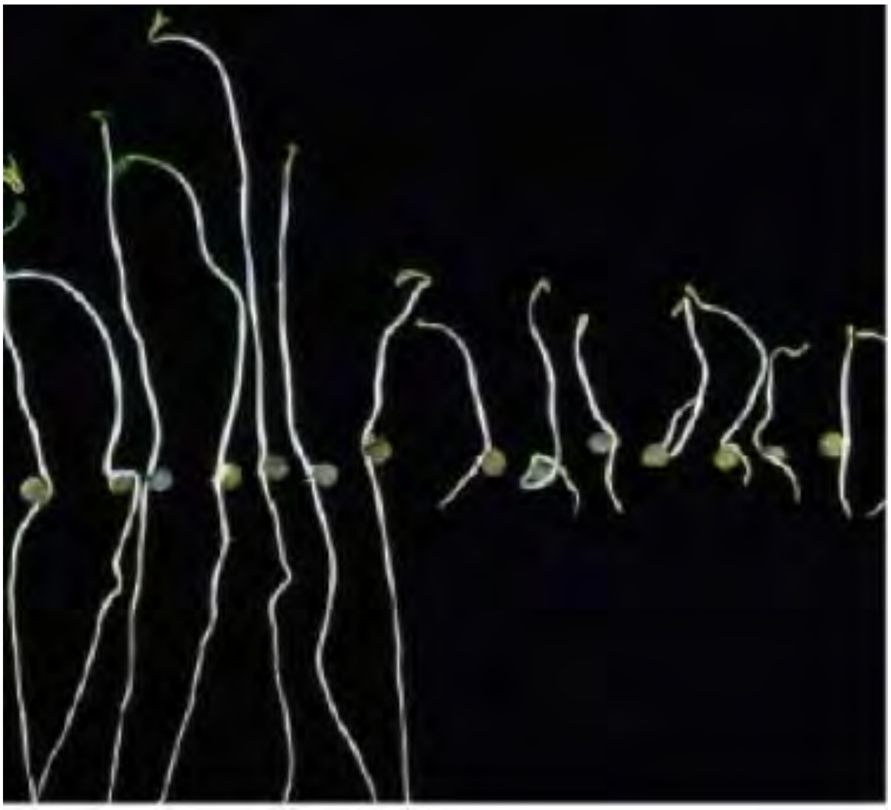

Photo 18: *Pre-harvest glyphosate damage (R) after a 7-day germination test.*

Photo: Canadian Phytopathological Society, via SasPulse Growers Handbook

8.9 Herbicide resistance

Heavy reliance on the very effective grass and/or broadleaf herbicides since the 1980s has seen herbicide resistance across southern Australia develop in a range of cropping weeds.

In 2014 there were 39 weed species in Australia with resistance to one or more herbicide modes of action.

Herbicide resistance is one of the biggest agronomic threats to the sustainability of Australia's cropping systems. Although it need not spell the end of profitable cropping.

It does mean that over-reliance on herbicides with the same mode of action should be avoided.

Delaying the onset of and/or reducing the impact of herbicide-resistant weed populations requires the implementation of a wide range of weed control strategies, that will in turn help sustain profitable grain production. Resistance can be managed through good crop rotation, rotating herbicide groups, and by combining both chemical and non-chemical methods of weed control.[34]

Evolution

Herbicide resistance evolves following the intensive use of herbicides for weed control.

In any weed population there are likely to be a small number of individuals that are naturally resistant to herbicides due to genetic diversity, even before the herbicides are used. When herbicide is used, these individual weeds survive and set seed, whereas the majority of susceptible plants are killed. Continued use of one herbicide, or herbicide group, will eventually result in a significant fraction of the weed population with resistance.

There are four main factors that influence the evolution of resistance:

1. The intensity of selection pressure.

This refers to how many weeds are killed by the herbicide. It is good practice to use label rates of herbicides to control weeds, as this will lead to the highest and most consistent levels of weed control. Failure to control weeds adequately will lead to increases in weed populations and put pressure on all herbicides used.

2. The frequency of use of one herbicide or mode-of-action group.

For most weeds and herbicides, the number of years of herbicide use is a good measure of selection intensity. The more often herbicide is applied the higher the selection pressure and the higher the risk of herbicide resistance developing.

3. The frequency of resistance present in untreated populations.

If the frequency of resistant genes in a population is relatively high, such as with Group B herbicides, resistance will occur quickly. If the frequency is low, such as with Group M herbicides, resistance will occur more slowly.

4. The biology and density of the weed.

Weed species that produce large numbers of seed, and have a short seedbank life in the soil, will evolve resistance faster than weed species with long seedbank lives. Weed species with greater genetic diversity are more likely to evolve resistance. Resistance is also more likely to be detected in larger weed populations.[35]

34 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

35 CropLife Australia Resistance Management Review Group and industry researchers (2016) Herbicide Resistance Management Strategies. CropLife Australia, https://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/

MORE INFORMATION

For up-to-date herbicide mode-of-action groups go to Croplife: https://www.croplife.org.au/resistance-strategy/2016-herbicide-moa-table

Current impact on weed management

The confirmed resistance (in 2014) of 39 grass and broadleaf weed species is to 11 distinctly different herbicide chemical groups. This significantly reduces herbicide options for grain growers. Cases of multiple resistance have also been commonly reported where, for example, annual ryegrass proves resistant to two or more chemical groups.[36]

Mode of action

Mode of action is important

The main reason resistance has developed is because of the repeated and often uninterrupted use of herbicides with the same mode of action.

Selection of resistant strains can occur in as little as three to four years if no attention is paid to resistance management.

Mode-of-action labelling in Australia

All herbicides sold in Australia are grouped by mode of action. The mode of action is indicated by a letter code on the product label. The mode-of-action labelling is based on the resistance risk of each group of herbicides.

Groupings of herbicides have changed over the years to improve the accuracy and completeness of the modes of action. Ultimately, this enables informed decisions to be made about herbicide rotation and resistance management.

Grouping by mode of action and ranked by resistance risk

All herbicide labels now carry the mode-of-action group clearly displayed (see below). This enables users to better understand the mode-of-action grouping and resistance risk by reference to the mode of action chart.

GROUP	G	HERBICIDE

HIGH RESISTANCE RISK herbicides

Group A (mostly targeted at annual ryegrass and wild oats); and

Group B (broadleaf and grass weeds).

Specific guidelines are written for use of these products in winter cropping systems.

MODERATE RESISTANCE RISK herbicides

Group C (annual ryegrass, wild radish and silver grass);

Group D (annual ryegrass and fumitory);

Group F (wild radish);

Group I (wild radish and Indian hedge mustard);

Group J (serrated tussock and giant Parramatta grass);

Group L (annual ryegrass, barley grass, silver grass, square weed and capeweed);

Group M (annual ryegrass, barnyard grass, fleabane, liverseed grass and windmill grass);

Group Q (annual ryegrass); and

Group Z (wild oats and winter grass).

36 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

MORE INFORMATION

For information on the development of tolerance in lentil to Group C herbicides click on the link to go to GRDC Groundcover TV Episode 16: Pulse Herbicide Tolerance. https://grdc.com.au/Media-Centre/GroundCover-TV/2015/05/Episode-16-May-2015

MORE INFORMATION

Click on the link to watch GRDC GroundCover™ TV Episode 19 to learn more about glyphosate resistance in feathertop Rhodes grass https://grdc.com.au/Media-Centre/GroundCover-TV/2016/04/Episode-19-May-2016/Yk95mS_hvhM

A GRDC video on glyphosate-resistant weeds is at: https://youtu.be/Ke8klYNQzl8

Group K

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

NO GUIDELINES

Group E

Group G

Group H

Group N

Group O

Group P

Group R

There are no recorded cases of weeds resistant to members of these groups in Australia.

Herbicide-resistant weeds

Herbicide-resistant weeds include annual ryegrass, wild oats, Indian hedge mustard, milk thistle, wild radish, wild turnip and prickly lettuce as well as barley grass and capeweed.[37]

Glyphosate (Group M)

Continued reliance on glyphosate is leading to increased resistance. The potential inability to use glyphosate due to resistant weeds will increase the cost of weed management. Glyphosate-resistant weeds have a lower fitness and are more vulnerable to IWM techniques. Controlling weeds using IWM is more costly, but has long-term benefits in delaying resistance development and reducing weed seedbanks.[38]

Resistance mainly occurs in situations where glyphosate has been used as the main weed control tactic, no other effective herbicides are used, and few other weed management practices are employed. These include chemical fallows, fence lines, irrigation channels, vineyards and roadsides.

In 2014, glyphosate resistance was present in annual ryegrass, awnless barnyard grass, liverseed grass, brome grass, red brome grass, windmill grass, flaxleaf fleabane, milk/sow thistle and wild radish.[39]

In 2016 feathertop Rhodes grass was the latest weed species to have confirmed populations of glyphosate resistance. Resistant populations have been found in South Australia and the weed has spread into the western region as well.

Growers are encouraged to use paraquat for crop-topping in pulses rather than rely on glyphosate, which is frequently used for topping in other crops. However, paraquat resistance is also increasing so weeds should be tested before planning a management strategy.

37 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

38 C Preston (2014) UA00104 - Understanding and management of weed resistance to glyphosate. Grains Research and Development Corporation, http://finalreports.grdc.com.au/UA00104

39 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

Paraquat (Group L)

In 2014, paraquat-resistant weeds included capeweed, northern barley grass, barley grass, annual ryegrass, small square weed and silvergrass.[40]

Ryegrass that is resistant to both glyphosate and paraquat has been found in South Australia.[41]

IN FOCUS

Other herbicides

Annual ryegrass in Australia is now resistant to eight different herbicide groups.[42] The major herbicides are Group A (>20,000 sites in Australia), Group B (>20,000 sites) and Group D (>5,000 sites). Resistance to trifluralin (Group D) and the 'dims' (Group A) is increasing in southern Australia.[43]

Clethodim (Group A) resistance is a major issue in pulse production.[44] Clethodim is the last Group A herbicide that provides effective control of herbicide-resistant ryegrass.[45] A clethodim/butroxydim mix controls many populations of ryegrass that are resistant to clethodim or butroxydim.[46]

In wild oats frequency of resistance to all of the Group A herbicides is common (fops, dims and dens).[47]

40 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

41 Grains Research and Development Corporation (2012) Cropping with Herbicide resistance. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

42 CropLife Australia (2016) Herbicide resistant weeds, CropLife Australia, http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistant-weeds-list/

43 G Brooke, C McMaster (2016) Weed control in winter crops 2016. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops

44 C Preston, P Boutsalis, S Kleemann, R Saini and G Gill (2015) Managing resistant ryegrass in break crops and new herbicides for resistant ryegrass. Grains Research and Development Corporation, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Managing-resistant-ryegrass-in-break-crops-and-new-herbicides-for-resistant-ryegrass

45 Grains Research and Development Corporation (2013) Ground Cover Issue 102 - Emerging Issues with Diseases Weeds and Pests Supplements. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102

46 G Gill, P Boutsalis, C Prestong (2016) How can I best control herbicide resistant annual ryegrass in canola. Grains Research and Development Corporation, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/How-can-I-best-control-herbicide-resistant-annual-ryegrass-in-canola-crops

47 G Brooke, C McMaster (2016) Weed control in winter crops 2016. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops

MORE INFORMATION

For more information, see:

WeedSmart: www.weedsmart.org.au

Australian Herbicide Resistance Initiative: www.ahri.uwa.edu.au

Australian Glyphosate Sustainability Working Group: http://glyphosateresistance.org.au

MORE INFORMATION

Ryegrass Integrated Management (RIM) is a decision-support tool to evaluate the long-term profitability of strategic and tactical ryegrass control methods. It allows growers/ users to test ideas to reduce ryegrass populations while improving profitability.

For more information go to: http://ahri.uwa.edu.au/research/rim

Preventing herbicide resistance

Weedsmart (http://www.weedsmart.org.au/10-point-plan/) lists 10 ways to weed out herbicide resistance:

1. Act now to stop weeds from setting seed.
2. Capture weed seeds at harvest.
3. Rotate crops and herbicide modes of action.
4. Test for resistance to establish a clear picture of paddock-by-paddock status.
5. Never cut the rate.
6. Don't automatically reach for glyphosate.
7. Carefully manage spray events.
8. Plant clean seed into clean paddocks with clean borders.
9. Use the double-knock technique.
10. Employ crop competitiveness to combat weeds.

WEED smart every weed every seed every farm every year

Annual ryegrass

Annual ryegrass has higher levels of resistance than any other weed. Preventing ryegrass from setting seed and removing weed seeds at harvest before they fall to the ground is the top priority.[48]

The recommendation is to aim for three years with no weed seedset.

Techniques to manage resistant ryegrass include:

- know your resistance status. What herbicides is the ryegrass resistant to?
- use crop rotation to access different treatment options;
- use double-knockdowns before sowing;
- consider crop-topping even if yield will be reduced;
- consider green or brown manuring or cutting for hay;
- capture and destroy weed seeds at harvest; and
- control ryegrass in non-crop areas such as fence lines, channel banks.[49]

48 Grains Research and Development Corporation (2012) Cropping with Herbicide resistance. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

49 L Pearce (2015) Herbicide resistance management, a local, in-field perspective. Grains Research and Development Corporation, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Herbicide-resistance-management-a-local-infield-perspective

MORE INFORMATION

For more information on herbicide resistance:

CropLife webpage: Herbicide mode of action table http://www.croplife.org.au/resistance-strategy/2016-herbicide-moa-table

CropLife webpage: Herbicide resistant weeds in Australia http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistant-weeds-list

GRDC fact sheet: Herbicide resistance https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

CropLife Booklet: Herbicide resistance management strategies http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/

WeedSmart 10 Point Plan http://www.weedsmart.org.au/10-point-plan/

Australian Glyphosate Sustainability Working Group http://www.glyphosateresistance.org.au

Weedsmart to estimate paddock risk (app) (iOS only) https://grdc.com.au/apps

AHRI decision support tool: Ryegrass Integrated Management (RIM) http://ahri.uwa.edu.au/research/rim

GRDC Update Paper: Herbicide resistance management, a local, in-field perspective https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Herbicide-resistance-management-a-local-infield-perspective

Monitoring for herbicide resistance

Monitoring of weed populations before and after any spraying is an important management tool:

- Keep accurate records.
- Monitor weed populations and record results of herbicide used.
- If herbicide resistance is suspected, prevent weed seedset.
- If a herbicide does not work, find out why.
- Check that weed survival is not due to spraying error.
- Conduct paddock tests to confirm herbicide failure and what herbicides are still effective.
- Have a herbicide-resistance test carried out on seed from suspected plants, testing for resistance to other herbicide groups.
- Do not introduce or spread resistant weeds in contaminated grain or hay.

Following weed removal or suppression, regular monitoring is required to assess the effectiveness of weed management and the expected situation afterwards. Without monitoring, the impact of a management program or how it might be modified in the future is not understood. Effective weed management begins with monitoring weeds to assess current or potential threats to crop production, and to determine the best methods and timing of control measures.

Regular monitoring and recording details of each paddock allows:

- the identification of critical stages of crop and weed development for timely cultivation or other intervention;
- the identification of weed species and composition, which helps determine the best short and long-term management strategies; and
- detection of new, invasive or aggressive weed species, whilst the infestation is still localised and possible to eradicate.

Thorough monitoring allows for assessment of critical aspects of the weed–crop interaction, such as:

- weed seed germination and seedling emergence;
- weed growth sufficient to affect crops if left unchecked;
- weed density, height, and cover relative to crop height, cover, and stage of growth;
- weed impacts on crops. This includes harbouring pests, pathogens, or beneficial organisms. It also includes modifying microclimate, air circulation, or soil conditions. Lastly, direct competition for light, nutrients, and moisture can be assessed;
- flowering, seedset, or vegetative reproduction in weeds; and
- efficacy of cultivations and other weed management practices.

Herbicide-resistance testing

There are two types of commercial tests for herbicide resistance:[50]

Seed testing is suitable for pre and post-emergent herbicides and takes four to five months. This requires 3,000 seeds of each weed, which is approximately one cup of annual ryegrass seed or six cups of wild radish pods.

The **quick test** for post-emergent herbicides only uses live plant seedlings and results are available within six weeks. This requires 50 plants (or 20 large tillering plants) for each herbicide tested.

50 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

There are two testing services in the southern region:

Plant Science Consulting offers both seed testing and the quick test.

22 Linley Avenue, Prospect, SA 5082.
Ph: 0400 66 44 60
Email: info@plantscienceconsulting.com.au
http://www.plantscienceconsulting.com.au

Charles Sturt University offers the seed test only.

Herbicide Resistance Testing,
School of Agricultural and Wine Sciences,
Charles Sturt University,
Locked Bag 588, Wagga Wagga, NSW, 2678.
Ph: John Broster 02 6933 4001 or 0427 296 641
Email: jbroster@csu.edu.au
https://www.csu.edu.au/weedresearchgroup/herbicide-resistance

8.10 Water quality for herbicide application[51]

Clean, good quality water is important when mixing and spraying herbicides. Poor quality water can reduce the effectiveness of some herbicides and damage spray equipment.

Effects of water quality

Water quality will vary with the source of the water (rain-fed tank, dam, river, bore or aquifer) and the season (heavy rain or drought). There are several characteristics of water quality that affect chemical performance.

Turbid or muddy water

Dirty water has very small soil particles (clay and silt) suspended in it. These soil particles can absorb and bind the chemical's active ingredient and reduce its effectiveness. This applies especially to glyphosate, paraquat and diquat.

Dirt can also block nozzles, lines and filters and reduce the sprayer's overall performance and life. As a guide, **water is considered dirty when it is difficult to see a 10-cent coin in the bottom of a household bucket of water**.

Water hardness

Water is termed hard when it has a high percentage of calcium and magnesium. Hard water won't lather with soap and can cause some chemicals to precipitate. Susceptible chemicals often have agents added to overcome this problem.

Formulations of 2,4-DB are particularly sensitive to hard water (>250 ppm $CaCO_3$ equivalent). Other herbicides such as glyphosate, 2,4-D amine and MCPA amine, Lontrel™ and Tigrex® can also be affected.[52]

Hard water can affect the balance of the surfactant system and affect properties such as wetting, emulsification and dispersion. Very hard water can reduce the efficiency of agents used to clear dirty water. Also, some agents used to clear turbid water can increase hardness.

Hardness can be ameliorated with ammonium sulfate.

51 G Brooke, C McMaster (2016) Weed control in winter crops 2016. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops

52 G Brooke, C McMaster (2016) Weed control in winter crops 2016. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops

Water pH

pH is a measure of acidity and alkalinity scaled on a range between 1 and 14. A pH of 7 is neutral, less than 7 acid and more than 7 alkaline. Most natural waters have a pH of 6.5–8.

In highly alkaline water (pH>8) many chemicals undergo a process called alkaline hydrolysis. This process causes the breakdown of the active ingredient into other compounds, which can reduce the effectiveness of the pesticide over time (some insecticides are particularly sensitive). This is one reason why **spray mixes should not be left in spray tanks overnight**.

Very acidic water can also affect the stability and physical properties of some chemical formulations.

Dissolved salts

The total amount of mineral salts dissolved in water is usually measured by the electrical conductivity (EC) of the water.

The EC of bores and dams depends largely on the salt levels in the rock and soil that surrounds them. During a drought the salinity of water increases.

Very salty water can cause blockages in equipment and is more resistant to pH changes.

There are general limits for spraying water with regard to salt, pH and hardness.

Organic matter

Water containing organic matter, such as leaves or algae, can block nozzles, lines and filters. Algae can also react with some chemicals, reducing their effectiveness.

Temperature

Very hot or cold water can affect the performance of some chemicals.

Improving water quality

Water needs to be tested to see whether it will affect chemical performance. There are commercial products available to reduce pH (Primabuf® BB5, LI700, Hotup®, ammonium sulfate), soften hard water and clear dirty water. To reduce the effects of very salty water, water may need to be mixed from several sources.

The effect of water quality on some herbicides is summarised in Table 5.

Table 4: Herbicide tolerances to water qualities.

Hebicide	Water quality				
	Muddy	Saline	Hard	Alkaline (pH>8)	Acidic (pH<5)
2,4-DB			X	NR	
2,4-D or MCPA amine	✓	✓	X	NR	
2,4-D or MCPA ester	✓	test	test	✓	✓
Associate®	✓	✓	✓	Marginal	X
Brodal®		✓	✓	X	
Dicamba	✓	✓	NR	NR	
Diuron	✓	test	✓	✓	
Diuron + 2,4-D amine	✓	test	X	NR	
Diuron + MCPA amine	✓	test	X	NR	
Fusilade® Forte	✓	✓	✓	NR	X
Tackle®	✓	✓	✓	marginal	X
Glyphosate	X	✓	X		✓
Gramoxone®	X	✓	✓	✓	✓
Logran®B-Power	✓	✓	✓	marginal	X
Lontrel™ Advanced	✓	✓	X	X	
Simazine	✓	X	✓	NR	
Spray.Seed®	X	✓	✓	✓	✓
Elantra® Xtreme®	✓	✓	✓	✓	✓
Tigrex®	✓	X	X	NR	
Trifluralin		✓	✓	✓	✓
Verdict™	✓	✓	✓	NR	✓

√= OK X = Do not use NR = Not recommended but use quickly if there is no alternative test = Mix herbicides and water in proportion and observe any instability marginal = Not ideal, but acceptable.

Source: Weed control in winter crops 2017, (2017), NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops

8.11 Tips for tank-mixing herbicides

Tank-mixing herbicide is a common practice to improve weed control and broaden the weed spectrum. There may also be some advantages in helping avoid herbicide-resistance problems.

Many tank mixes are included on registered herbicide labels. Where herbicides are registered for a particular use, they may be tank-mixed, provided they are compatible and label mixing instructions are followed.

Note that some herbicides, although physically compatible, can be antagonistic to weed control. This information is usually outlined on herbicide labels under 'Compatibility'.

The order that herbicides are mixed is also important and the following mixing sequence is usually followed:

1. Water conditioning agents.
2. Water dispersible granules and dry flowable products (including those in water-soluble bags).
3. Wettable powders.
4. Flowables or suspension concentrates.
5. Emulsifiable concentrates.
6. Water-soluble concentrates.
7. Surfactants and oils.
8. Soluble fertilisers.

8.12 Adjuvants

An adjuvant is any additive to a herbicide which is intended to improve the effectiveness of the herbicide.

Adjuvants can result in a dramatic improvement in grass weed control when using Group A herbicides. This is primarily through improved leaf coverage and absorption through the leaf cuticle.

Herbicide label directions and recommendations should always be followed when selecting a suitable adjuvant. Generalisations should not be made, as what works best with one chemical may not necessarily work best with other Group A herbicides. The herbicide label will state the required adjuvant to use.

Using adjuvants, surfactants and oils with herbicides

There are many products which have been developed to assist herbicides, firstly, to contact the weed target and, secondly, to remain and penetrate the weed leaf.

Adjuvants can be classified as follows:

- surfactants;
- crop oils;
- penetrants;
- acidifying/buffering agents; and
- compatibility agents.[53]

53 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Surfactants

These adjuvants increase the spread of droplets, or the wetting of waxy or hairy leaf surfaces.

Surfactants consist of three different types:

1. Non-ionic. These are the most commonly used agricultural surfactants. They are non-reactive (no electrical charge). They remain on the leaf once dry and allow 're-wetting' after rain, permitting additional herbicide uptake.
2. Anionic. These adjuvants have a negative charge and are not often used with herbicides.
3. Cationic. Cationic adjuvants have a positive charge, such as many domestic detergents, and are rarely used with herbicides.

Crop oils

Most crop oils contain emulsifiers that allows them to mix with water. Some crop oils contain various levels of surfactants.

The benefits of crop oils are:

- reduced rain-fast periods;
- more uniform droplet size (less chance of drift);
- less spray evaporation; and
- better penetration of herbicide into waxy leaves.

Oils can be divided into three main groups:

1. Mineral oils.

These products are usually a blend of mineral oil and non-ionic surfactant. Products such as Ad-Here® and D-C-Tron® have low levels of surfactant, whilst Uptake® and Supercharge® have higher levels. These products have lower potential of crop phytotoxicity as they are more refined.

2. Vegetable oils

These products are a blend of vegetable oils and non-ionic surfactant. Vegetable oils are sometimes called crop oil concentrates. Examples include Synertrol® and Codacide®. and

3. Esterified vegetable oils.

Esterified Vegetable oils. These oils are the more commonly used products and are produced by reacting vegetable oil with alcohol and then blending with a high level of non-ionic surfactant. The physical and chemical properties are quite different to that of vegetable oil. They have claims of superior wax-modifying characteristics and penetrating ability. They should be used strictly according to the label with selective herbicides. Hasten® and Kwickin® are examples of these products.

Penetrants

Penetrants are specific compounds that help dissolve waxy cuticles.

Acidifying/buffering agents

Acidifying/buffering agents make spray solutions more acidic by lowering the pH. Herbicides are most stable when the pH of the solution is between 6 and 7 (neutral or slightly acidic). Examples include LI-700 and Primabuff BB5.

Compatibility agents

Compatibility agents are materials that reduce the likelihood of antagonism from other agents in the spray solution. The most commonly used compatibility agent is ammonium sulfate. Compatibility agents are also used to neutralise the effect of hard water on amine formulations, such as glyphosate. Examples of these products are Liase®, and Liquid Boost®.

Other

Some adjuvants combine a number of roles. For example, Hot-up® contains surfactant, a compatibility agent, and oil.

There are also a range of other adjuvants which are added to herbicides during formulation that improve the efficacy, increase crop safety, or ease of herbicide use. These include thickeners, spreaders, stickers, anti-foamers and safeners.

Factors affecting adjuvant use

Crop safety

Addition of an adjuvant can reduce crop safety margins and, therefore increase crop damage. This is not an issue for fallow and pre-emergent herbicides.

Effectiveness or activity

Adjuvants are usually added to increase the effectiveness of herbicides. However, use of the wrong type or rate can reduce effectiveness, such as decreasing herbicide retention on leaves.

Water hardness

Hard water can lead to poor mixing of the chemical with water. This occurs particularly with emulsifiable concentrates. High levels of calcium and magnesium ions bind with the amine formulations causing them to be less soluble and, therefore, less effective.

Water temperature

Low water temperature can lead to 'gelling' in the spray tank. High concentration herbicides might not mix and surfactants might perform ineffectively.

8.13 Spraying Issues

Spray drift

All herbicides are capable of drifting from neighbouring paddocks.

Pulses are particularly vulnerable to damage from phenoxy herbicides (Group I). Phenoxy herbicides are more prone to drift as a vapour, both during or after application.

Spray drift can occur when herbicides are applied nearby in very windy or still conditions, especially where there is an inversion layer of air on a cool morning, late afternoon or evening.

Chemical users have a moral and legal responsibility to prevent herbicides from drifting and contaminating or damaging neighbouring paddocks and sensitive areas.

Contamination of spray equipment

The importance of cleaning and decontaminating spray equipment for the application of herbicide is critical.

Traces of sulfonylurea herbicides (such as chlorsulfuron, metsulfuron or triasulfuron) and Group G carfentrazone in spray equipment can cause severe damage to lentil and other legumes when activated by grass-control herbicides and/or adjuvants.[54]

Product labels should always be referred to for specific product recommendations on decontamination.

54 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Minimising damage from pre and post-emergent herbicides

Herbicide damage does not always result in reduced grain yield. Damage may be very obvious, such as scorched leaves, or it may be subtle, such as poor establishment or delayed maturity. Symptoms can be easily confused with symptoms produced by other causes, such as frost, disease or nutrition.

The risk of crop damage from a herbicide should be balanced against the potential yield loss from weed competition. In heavy weed infestations some herbicide crop damage can be tolerated. This is because some damage is easily offset by the yield loss avoided by removing competing weeds.

Some precautions for using pre-emergent residual herbicides can reduce the likelihood of crop damage:

- do not apply if rain is imminent;
- plant seed up to 8 cm deep;
- avoid leaving a furrow or depression above the seed that could allow water (and chemical) to concentrate around the seed/seedling;
- avoid leaving an exposed, open slot over the seed with disc openers; and
- avoid a cloddy, rough tilth with tyned openers.

If herbicide is applied to dry soils, the risk of movement and crop damage is increased greatly after rainfall. This is particularly so if the soil is left ridged and herbicide washes into the seed row. Incorporation by sowing (IBS) may be more appropriate in dry conditions or, alternatively, a split application will also minimise risk.

Metribuzin leaches at almost three times the rate of simazine and seven times the rate of diuron. The relative tolerance of the crop type and variety will also alter the level of crop damage from these herbicides.[55]

Some spray oils used with post-emergent selective grass herbicides can cause minor leaf spotting and/or burning, which should not be confused with disease symptoms.

Advice from an experienced agronomist should always be sought for specific details on soil-active herbicides and the risk of crop damage in any particular situation.

8.14 Selective sprayer technology

As a result of an increase in the use of no-till cropping and the incidence of summer weeds many growers have adopted a spray fallow system which has predominantly used glyphosate over summer to remove weeds and conserve moisture for the next crop.

To reduce the risk of glyphosate resistance developing in fallow weeds some growers are using weed-detecting technology to detect individual weeds that have survived the glyphosate application and spraying these with an alternative knockdown herbicide.

The key to successful resistance management is killing the last few individuals, but this becomes rather difficult on large-scale properties. Left uncontrolled, these last few weeds result in significant seed production and a resetting of the weed seedbank.

The introduction of weed-detecting technology is timely as it is well suited to detecting patches of weeds across large areas.

The technology uses optical sensors to turn on spray nozzles only when green weeds are detected, greatly reducing total herbicide use per hectare. The units have their own light source so can be used day or night.

55 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Rather than spray a blanket amount of the herbicide across a paddock, the weed-detecting technology enables the user to apply higher herbicide rates (per plant), which results in more effective weed control as well as saving on herbicide costs.

8.15 Exotic weeds of lentil

Branched broomrape (*Orobanche* spp)

Description and life cycle

Branched broomrape is a serious parasitic pest of lentil (and faba bean) in the Middle East.

Orobanche spp., commonly known as broomrape is a parasitic plant that attacks the roots of a considerable number of plant species. This includes a wide range of vegetables, pulses and pasture legumes.

Suitable hosts in Australia include lentil, faba bean, broad bean, chickpea, vetch, field pea, clover, cabbages, canola, capsicums, carrots, cauliflowers, celery, eggplant, lettuce, melons, potato, and tomato. Major crops attacked overseas include sunflowers and tobacco.

Orobanche spp. drains its hosts of nutrients, causing anything from 10–70% yield losses. Lentil and chickpea, for example, can suffer up to 50% yield loss with remaining seed being of poor quality.

Of the 20 or so *Orobanche* spp. worldwide, five are particularly weedy. These are *O. aegyptiaca, O. cernua var. cernua, O. crenata, O. cumana* and *O. ramosa.* Only three *Orobanche* spp. are known to be present in Australia. *O. cernua* var. *australiana* is a native that does not attack crops.

Lesser broomrape (*O. minor*) is a common minor weed. An infestation of *O. ramose*, or branched broomrape, has been found in South Australia. One *O. ramosa* plant can produce up to 500,000 seeds. As well as parasitising a range of pulse and vegetable crops, *O. ramosa* is the only broomrape to attack *Cannabis sativa*.

All O*robanche* spp. are Australian Quarantine Inspection Service (AQIS) prohibited imports. However, the seeds are very small, like dust, and could enter the country undetected.

The seeds can be spread in contaminated soil, on machinery, or by livestock. Even if these parasites become established in one location, Australian export markets could be affected as many of our trading partners prohibit *Orobanche* spp.

As *Orobanche* spp. has been identified as a major exotic threat and development of an emergency response is a priority.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

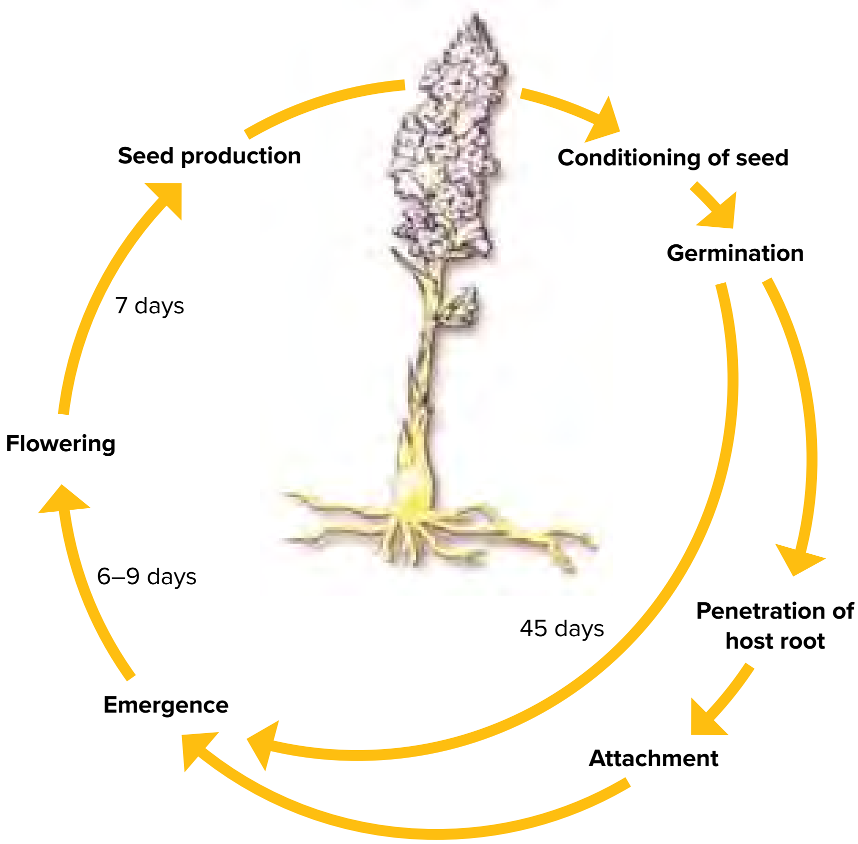

Figure 3: *Diagram of the life cycle of branched broomrape.*

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Photo 19: *Flowering branched broomrape.*

Photo: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Photo 20: *Branched broomrape setting seed on capeweed.*

Photo: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Flowers/seed head

Flowers: Pale blue, tubular and two-lipped. Lower lip three-lobed and upper lip shallowly two-lobed. An erect spike of flowers appears in spring and summer.

Description

Mature plants are about 20 cm tall with several branches from ground level. Stems have dense soft woolly hairs on the upper part. Leaves are reduced to a few brown scales to 8 mm long. The capsule is enclosed in persistent corolla. Seeds are pepper-like, up to 40,000 per plant.

Distinguishing features

Branched yellow-brown glandular-hairy stems; absence of green parts; blue flowers.

Dispersal

Spread by seed.

Confused with

Other species of *Orobanche* in Australia; see a specialist to confirm identification.

Surveillance

As symptoms may be characteristic of a number of seedling weeds of lentil, plant samples of unknown or suspicious looking weeds should be sent for diagnosis.

Entry potential

High. Entry through seed, debris or soil contamination.

Establishment and spread potential

High as has a fine, powder-like seed. Also spread by soil and debris to become problematic.

Economic impact

High. Yield and possible market losses could occur.

Overall risk

High

8.16 Legal considerations of herbicide use

Prior to making decisions on which herbicide to use the following must be done in relation to the proposed herbicide:

- registration status confirmed;
- rates of application and warnings related to withholding periods confirmed;
- all aspects of occupational health and safety (OH&S) considered; and
- residues and off-target effects obtained.

This information is available from state department chemical standards branches, chemical resellers, Australian Pesticides and Veterinary Medicines Authority (APVMA) and the pesticide manufacturer.

Registration

Users should be aware that all pesticides (including herbicides) undertake a process called registration. Registration is authorised (registered) by APVMA and states the pesticide is for use:

- against specific pests;
- at specific rates of product;
- in prescribed crops and situations; and
- where risk assessments have been evaluated that these uses are:
    - » effective (against the pest, at that rate, in that crop or situation);
    - » safe (in terms of residues not exceeding the prescribed MRL (Maximum Residue Limit); and
    - » not a trade risk.

Labels

A major outcome of the registration process is the approved product label, a legal document, that prescribes the pest and crop situation where a product can be legally used, and how.

SDS

Safety Data Sheets (SDSs) are also essential reading. These document the hazards posed by the product, and the necessary and legally enforceable, handling and storage safety protocols.

Permits

In some cases, a product may not be fully registered but is available under a permit with conditions attached. The permit often requires the generation of further data for eventual registration.

APVMA

The Australian Pesticides and Veterinary Medicines Authority is based in Canberra or Armidale. Details of product registrations and permits are available via APVMA's website (www.apvma.gov.au).

Always read the label

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

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

- applied at rates higher than the maximum specified;
- applied more frequently than the maximum number of times specified per crop;
- applied within the specified withholding period; and
- not registered for the crop in question.

8.17 Appendix 1 – Common weed names

Broadleaf weeds

Amaranth: *Amaranthus spp*

Amsinckia: *Amsincka spp*

Bathurst burr: *Xanthium spinosum*

Bedstraw: *Galium tricornutum*

Bifora: *Bifora testiculata*

Black bindweed: *Galium tricornutum*

Blackberry nightshade: *Solanum nigrum*

Bladder ketmia: *Hibiscus trionum*

Boggabri weed: *Amaranthus mitchelli*

Buchan weed: *Hirschfeldia incana*

Caltrop: *Tribulus terrestris*

Capeweed: *Arctotheca calendula*

Catsear: *Hypochaeris radicata*

Charlock: Sinapis arvensis

Chickweed: *Stellaria media*

Chinese lantern: *Physalis minima*

Cockspur (Maltese): *Centaurea melitensis*

Common cotula: *Cotula australis*

Crassula: *Crassula helmsii*

Deadnettle: *Lamium amplexicaule*

Dock: *Rumex* spp.

Fat hen: *Chenopodium album*

Fumitory – common: *Fumaria officinalis*

Fumitory – red: *Fumaria densiflora*

Fumitory – white: *Fumaria parviflora*

Geranium: *Erodium* spp.

Goose foot: *Chenopodium pumilio*

Goose berry (wild): *Physalis minima*

Hares ear: *Conringia orientalis*

Heliotrope (white): *Heliotropium europaeum*

Hexham scent: *Melilotus indicus*

Hoary cress: *Cardaria draba*

Hogweed: *Polygonum aviculare*

Horehound: *Marrubium vulgare*

Ice-plant: *Gasoul crystallinum*

Lesser loose strife: *Lythrum hyssopifoli*

Lesser swine cress: *Coronopus didymus*

Lettuce-prickly: *Lactuca serriola*

Medic: *Medicago* spp.

Melon camel/afghan: *Citrullus lanatus*

Melon paddy/prickly: *Cucumis myriocarpus*

Mintweed: *Salvia reflex*

Muskweed: *Myagrum perfoliatum*

Mustard – ball: *Neslia paniculata*

Mustard - Indian hedge: *Sisymbrium orientale*

New Zealand spinach: *Tetragonia tetragonoides*

Noogoora burr: *Xanthium occidentale*

Oxalis: *Oxalis* spp

Ox tongue: *Helminthotheca echioides*

Paterson's curse: *Echium plantagineum*

Peach vine: *Ipomea lonchophylla*

Pepercress: *Lepidium* spp

Pigweed: *Portulacca oleracea*

Poppy – rough: Papaver hybridum

Radish: *Raphanus raphanistrum*

Saffron thistle: *Carthamus lanatus*

Scotch thistle: *Onopordum acanthium*

Sheep weed: *Buglossoides arvensis*

Shepherd's purse: *Capsella bursa-pastoris*

Sorrel: *Rumex acetosella*

Soursob: *Oxalis pes-caprae*

Sowthistle: *Sonchus* spp

Speedwell - ivy leaf: *Veronica hederifolia*

Spear/black thistle: *Cirsium vulgare*

Spiny emex: *Emex* spp.

Storksbill: *Erodium* spp

Tares: *Vicia* spp.

Three corner jack: *Emex* spp.

Toadrush: *Juncus bufonius*

Treacle mustard: *Conringia orientalis*

Turnip - long fruited: *Brassica tournefortii*

Turnip - short fruited: *Rapistrum rugosum*

Variegated thistle: *Silybum marianum*

Ward's weed: *Carrichtera annua*

White ironweed: *Buglossoides arvensis*

Wild radish: *Raphanus raphanistrum*

Wild turnip: *Brassica tournefortii*

Wireweed: *Polygonum* spp.

Yellow Burr weed: *Amsinkia* spp.

Grasses

Barley grass: *Hordeum* spp.

Barnyard grass: *Enchinochloa crus-galli*

Brome grass: *Bromus* spp.

Canary grass: *Phalaris canariensis*

Johnson grass: *Sorghum halepense*

Liverseed grass: *Urochloa panicoides*

Paradoxa grass: *Phalaris paradoxa*

Phalaris: *Phalaris minor*

Prairie grass: *Bromus catharticus*

Annual Ryegrass *Lolium rigidum*

Sand fescue: *Vulpia fasciculata*

Silver grasses: *Vulpia bromoides*,

Storksbill: *Erodium* spp.

Summer grass: *Digitaria* spp.

Vulpia: *Vulpia bromoides*

Vulpia myuros

Wild oats: *Avena fatua*

Avena ludoviciana

Winter grass: *Poa annua*

Pest management

Key points

- **The key pests of lentil in southern Australia are Helicoverpa punctigera (native budworm), etiella, snails, slugs, aphids, redlegged earth mite and lucerne flea.**
- **Damage from pests such as budworm and etiella have marketability implications, as does contamination of the grain samples with snails.**
- **Integrated pest management (IPM) is an ecological approach aimed at significantly reducing use of pesticides while managing pest populations at an acceptable level.**
- **IPM involves planning, monitoring and recording, identification, assessing options, controlling/managing and reassessing.**
- **Monitoring for beneficial species is important.**
- **Exotic bruchids and leaf miners pose a biosecurity threat.**

9.1 Integrated pest management (IPM)

9.1.1 IPM definition

Integrated pest management (IPM) is an integrated approach to crop management to reduce chemical inputs and solve ecological problems. Although originally developed for agricultural insect pest management, IPM programs are now developed to encompass diseases, weeds and other pests that interfere with the management objectives of sites.

IPM is an ecological approach aimed at significantly reducing use of pesticides while managing pest populations at an acceptable level. IPM uses an array of complementary methods including mechanical and physical devices, as well as genetic, biological, cultural management and chemical management.[1] It uses strategies of prevention, observation and intervention. Benefits include the reduction in cost, contamination, residues and resistance to the pesticide.

9.1.2 Problems with pesticides

IPM does not mean abandoning pesticides – they are still the basis for pest control – but the impact on natural enemies is considered when selecting a pesticide. Regular monitoring needs to observe the pest and beneficial species dynamics. Beneficial species can provide control of most pests if they are present. By reducing the use of non-selective pesticides, the aim is to foster predators and parasites to stabilise pest populations and reduce the need to spray.

Overuse of pesticides can hasten pesticide resistance developing. It can also lead to a resurgence of pests, create new pests, potentially increase pesticide residues in grain and lead to off-target contamination including of wildlife reserves and waterways.

MORE INFORMATION

Please see the GRDC Integrated Pest Management Fact Sheet for more details, https://grdc.com.au/resources-and-publications/all-publications/bookshop/2009/12/integrated-pest-management-fact-sheet-national

9.1.3 IPM, organics and biological control

IPM is not the same as organic pest management, although many organic options are compatible with IPM.

IPM is sometimes confused with classic biological control. While they are not the same, IPM plays an important role in maximising the success of biological control by reducing the use of non-selective sprays and boosting the survival of biological control agents.[2]

Native remnant vegetation can support beneficial predatory insects. Pest-suppressive landscapes are those that have the right mix of habitats that support beneficial insects and allow them to move into crop fields, while discouraging the build-up of pest insect species.[3]

1 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

2 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

3 GRDC (2014) Pest suppressive landscapes: Pest management using native vegetation Fact Sheet, 4 pp., Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-PestSuppressiveLandscapes

MORE INFORMATION

A Fact Sheet on pest-suppressive landscapes can be found at www.grdc.com.au/GRDC-FS-PestSuppressiveLandscapes

9.1.4 Soft *v.* hard pesticides

The terms 'soft' and 'selective' are terms used to describe pesticides that kill target pests but have minimal impact on parasites and predators attacking these pests. Parasites and predators are often called 'beneficials'.

Pesticides that impact on beneficial species are termed 'hard', 'non-selective' or 'broad-spectrum'.

In practice, there are varying degrees of softness and many products may be hard on one group of beneficial species but relatively soft on another. (See Section 9.7)

Insecticides that are less toxic to beneficial insects should be used where possible.[4]

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.[5] Examples are nicotine, pyrethrum and insect juvenile hormone analogues. Further 'biology-based' or 'ecological' techniques are being evaluated.

9.1.5 IPM process

The process in managing insect pests to reduce damage in a profitable manner is:

1. Planning.
2. Monitoring and recording.
3. Identification.
4. Assessing options.
5. Controlling/managing.
6. Reassessing.[6]

Regular monitoring, with accurate pest identification, is the key to IPM. For insects, monitoring for beneficial organisms and predators is important too. Record-keeping is essential, as is knowledge of the behaviour and reproductive cycles of target pests. For more information on monitoring, see Section 9.1.7.

Use the information gathered from monitoring to decide what sort of control action (if any) is required. Make spray decisions based on a combination of economic threshold information and your experience. Insecticide resistance and area-wide management strategies may also affect spray recommendations.

If a control operation is required, ensure application occurs at the appropriate time of day. Record all spray details including rates, spray volume, pressure, nozzles, meteorological data (relative humidity, temperature, wind speed and direction, inversions and thermals) and time of day.

Assess crops after spraying and record data. Post-spray inspections are important in assessing whether the spray has been effective.[7]

4 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

5 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

6 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

7 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

9.1.6 IPM system

An IPM system is designed around some basic components:

1. Acceptable pest levels.
2. Preventative cultural practices.
3. Monitoring the crop.
4. Biological and environmental control.
5. Responsible chemical use.

Acceptable pest levels

Emphasis is on control, not eradication. IPM programs work to establish acceptable pest levels (action thresholds) and then apply controls if those thresholds are exceeded.

The most common threshold used is an economic threshold, which involves control at a density that will prevent the pest numbers from reaching an economically damaging population. The aim of pest management is to keep pest populations below the economic threshold.

Guideline thresholds based on research exist for some pests but most thresholds fluctuate depending upon a number of factors. Monitoring and sampling of crops is essential to determine these factors and their influence on where the threshold lies. Growers, who maintain a close watch on pest activity through regular crop inspections and thorough sampling, are best placed to decide if and when treatment is needed.

Preventative cultural practices

Use varieties best suited to local growing conditions and maintain healthy crops. Mechanical methods may be possible under some circumstances.

If lentil is the first crop in the rotation after a pasture phase, there can be a range of pests that occur naturally in pastures that can attack lentil seedlings. These include blue oat mite, wireworm and pasture cockchafer, which will often be present in the pasture phase. A long fallow (September–April) with clean cultivation and good weed control before the lentil crop can prevent these pests. Weedy fallows can provide resources and shelter for these pests as well as taking soil moisture that could be used by the crop later in the season.

Monitoring lentil crops

Regular observation is the key to IPM. Observation is broken into inspection and then identification. For insects, monitoring for beneficial organisms and predators is important too. Record-keeping is essential, as is a thorough knowledge of the behaviour and reproductive cycles of target pests.

Before sowing lentil, the paddocks should be checked for signs of insect presence. When stubble mulch covers soil in autumn there are several pests that are capable of feeding on organic matter and then transferring to emerging seedlings. Earwigs, slaters and Rutherglen bugs can all be present in stubble residues waiting to attack crops as they emerge.

Monitoring should start as the crop emerges, to check plant populations and for gaps from attack by insects such as earwigs, weevils or by slugs. These can leave large bare patches which may need resowing. As the crop grows there can be a range of herbivores and sucking pests that can feed on lentil, but as many varieties of lentil are capable of vigorous growth, the main threat is transfer of viruses.

Monitoring during the vegetative stages can be limited to weekly visual inspections looking for evidence of caterpillar or aphids in the crop. Beneficial species such as lady beetles, hoverflies and wasps are often seen during this phase and can be a good indicator to check for pest species.

As the canopy closes, monitor weekly to check for presence of pests, particularly aphids. Aphids will target stressed crops. They will move quickly from weeds or other crops and can build up overnight. Monitoring needs to occur several times a week if aphids are noticed. Many beneficial species such as lady beetles, hoverflies and wasps will follow the aphid colonies.

Once the crop is flowering, use of a beat-sheet or sweep net and a standardised protocol for each sample can be useful to give counts that can be compared with previous counts.

Recording results in a diary or on a spreadsheet will enable decisions to be made objectively rather than in an ad-hoc manner.

Monitor the degree days of an environment to determine when is the optimal time for a specific insect outbreak, particularly etiella.

Biological and environmental control

A range of organisms and environmental processes can provide control, with minimal crop damage, often at low cost. The main focus is on promoting beneficial organisms that target pests. (See Section 9.7)

There is a lag period between when a pest is present and when the beneficial species affect the pest population. Predators destroy their prey and leave little evidence of their actions, so these effects are often underestimated. Some biological control agents are very prolific, relatively predictable and able to keep the pests at low levels so they do not impact on crop production.

In broadacre crops the best strategy is to preserve and encourage these beneficial organisms that are naturally occurring. Grow a diverse range of plant species around the farm, preserving native habitat near crop paddocks and reduce the use of broad-spectrum insecticides.

Use biological insecticides, derived from naturally occurring microorganisms (*Bt*, Viva Gold®, entomopathogenic fungi and nematodes) and chemicals specific to pest species where possible.

Responsible chemical use

Synthetic pesticides are generally only used as required and often only at specific times in a pest's life cycle. Many newer pesticide groups are derived from plants or naturally occurring substances.

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

(Pirimicarb is not currently registered for use in lentil. However, emergency permits have previously existed.)

9.1.7 Monitoring methods

Scout crops thoroughly and regularly during 'at risk' periods using the most appropriate sampling method. Record insect counts and other relevant information using a consistent method to allow comparisons over time. Also monitor any nearby crops that may be harbouring aphids that could rapidly build up to then take flight into a neighbouring lentil crop.

Pest numbers alone may not always give an accurate assessment of damage being caused. Observing and monitoring crop damage may also assist in assessing any accumulating yield loss.[8]

Pest monitoring needs to be based on a realistic but effective system suited to individual needs.

8 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Sweep net monitoring

The easiest and quickest way to determine the number of grubs in a crop is to 'sweep' the crop with an insect sweep net. It is impossible to accurately determine numbers by simply looking in the crop. However, sweep-net sampling can underestimate the abundance of pest insects present in the crop.

Sweep netting works best for small pests found in the tops of small crops. It is less efficient in assessing larger pests such as pod-sucking bugs. Sweep netting can be used for flighty insects and is the easiest method for sampling crops with narrow row spacing. It is also useful in wet paddocks[9]

A standard sized net (380 mm in diameter) can be purchased from most chemical suppliers.

- Take 10 sweeps of the net through the crop canopy while walking slowly through the paddock. A standard sweep of the net needs to be about 2 m.
- Empty the contents into a tray or bucket and count the caterpillars of various sizes. It is important to look very carefully for small caterpillars as these have the most potential to cause damage.
- Repeat this process in at least 12 places throughout the paddock to obtain an average insect density.

Crop inspection

Sampling flowers and leaves in the crop can tell you much more than a sticky trap including:

- levels of non-flying juvenile stages (eggs, larvae, pupae);
- levels of non-flying adult pests (such as mites, snails); and
- early stages and extent of pest damage.

This information is much more powerful for assessing pest levels, accurately predicting trends and checking the effectiveness of control measures. It is essential for making decisions and following up on the results.

Depending on the pest, where it feeds, hides and breeds, you will need to check flowers, leaves, pods and stems. The pattern, frequency and level of sampling depend on the crop, pests of concern and beneficial insects of interest, and the time of year.

Weeds nearby will build up large numbers of pests in spring. Inspecting the weeds can keep you in touch with how the local pest pressure is building. Ideally, remove the weeds before the pest numbers build.[10]

9 DAF (2012) Insect monitoring techniques for field crops, Queensland Department of Agriculture and Fisheries, www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/insect-monitoring

10 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Yellow sticky traps or cards

Sticky traps are useful as a way of monitoring flying pests like thrips, whitefly and aphids. They attract these insects because of their colour. They are a useful way of sending samples away for identification of thrips species. However, they do not give a complete picture of pest dynamics in the crop. Adult insects may settle into the crop after flying in and juvenile non-flying stages may survive spray applications but will not show up on the traps.

Sticky traps should be changed or checked at least weekly. They need to be placed just above the growing tips of the plants to catch insects hovering above them and to avoid getting stuck and lost in the crop.[11]

Quadrats

Use quadrats to sample snails. (See Section 9.3.2)

Tiles, hessian bags and slug traps

Use either a tile, hessian bag or slug trap left in the paddock overnight to count snail or slug numbers. (See Section 9.3.2)

9.2 Identifying pests

9.2.1 Correct identification of insect species

It is important to be able to identify the various insects present in your crop, whether they are pest or beneficial species, and their growth stages.

Sending insect samples for diagnostics

SARDI Entomology Unit provides free insect diagnostic services for subscribers of PestFacts South Australia and western Victoria newsletter. For more details on how to package specimens, go to: www.pir.sa.gov.au/research/services/crop_diagnostics/insect_diagnostic_service

The NSW DPI will identify insects for a fee. Phone 1800 675 821 for more information.

Agriculture Victoria and cesar (University of Melbourne) do not offer a routine insect-identification service.[12]

11 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

12 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

MORE INFORMATION

For more information see: Insect ID: The Ute Guide app: https://grdc.com.au/resources-and-publications/app

9.2.2 Insect ID: The Ute Guide

While many resources are available, the primary insect-identification resource for grain growers is 'Insect ID: The Ute Guide', a digital guide for smart phones and tablets that is progressively updated as new information becomes available (Figure 1).

Insect ID is a comprehensive reference guide to insect pests commonly affecting broadacre crops and growers across Australia, and includes the beneficial insects that may help to control the pests.

Photos have been provided for multiple life-cycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored and other pests that they may be confused with.[13]

Not all insects found in field crops are listed in this app, so further advice may be required before making management decisions.

Figure 1: *Screenshots from the iOS edition of 'Insect ID: The Ute Guide' app.*

MORE INFORMATION

GrowNotes™ Alerts
https://grdc.com.au/grownotesalert

9.2.3 GrowNotes™ Alerts

GrowNotes™ Alerts is a free, early warning system that notifies you of any emerging disease, pest and weed threats specific to the user's chosen area. It provides real-time information from experts across Australia.

A GrowNotes™ Alert can be delivered via app, SMS, voice, email, social media or web portal (or a combination of preferred methods). The urgency with which they are delivered can help reduce the impact of weed, pest and disease costs. GrowNotes Alerts improve the relevance, reliability, speed and coverage of notifications on the incidence, prevalence and distribution of weed, pest and diseases.

13 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

9.3 Key pests of lentil

Lentil is most vulnerable to economic insect damage during establishment and between flowering and maturity.[14]

The key pests of lentil in southern Australia are *Helicoverpa punctigera* (native budworm), etiella, snails, slugs, aphids, redlegged earth mite (RLEM) and lucerne flea. Table 1 shows the timing of damaging effects of the key and other pests in lentil crops.

Table 1: Incidence of lentil crop pests.

Pest	Crop stage				
	Emergence/ seedling	Vegetative	Flowering	Podding	Grain-fill
RLEM	Damaging	Present			
Lucerne flea	Damaging	Present			
Cutworms	Damaging				
Slugs and snails*	Damaging	Damaging			
Aphids	Damaging	Present	Present		
Thrips	Present				
Loopers		Damaging			
Native budworm		Present	Damaging	Damaging	Damaging
Etiella			Damaging	Damaging	Present

*Snails may also cause grain contamination at harvest. Present = Present in crop but generally not damaging. Damaging = Crop susceptible to damage and loss.

Source: http://ipmguidelinesforgrains.com.au/crops/winter-pulses/lentils/

Lentil is useful as a rotation crop as it can suppress RLEM and blue oat mite populations if weeds are controlled. However, lentil crops will suffer if mite populations are high. RLEM populations have been found with high levels of resistance to two synthetic pyrethroids – bifenthrin and alpha-cypermethrin.

Lentil is tolerant of some foliar damage and can compensate by producing secondary shoots.[15]

9.3.1 *Helicoverpa* species: native budworm and corn earworm (*Helicoverpa punctigera* and *H. armigera*)

The larva of native budworm (*Helicoverpa punctigera*) is the main insect pest of lentil late in the season in southern Australia.

H. punctigera is not the same species *H. armigera*, which is commonly known as corn earworm or cotton bollworm.[16]

Helicoverpa spp. are commonly referred to as helicoverpa, heliothis, or 'helis'. It is technically more correct to refer to them as "*Helicoverpa* species" to distinguish them from true *Heliothis* spp.[17]

14 Queensland Government (2016) IPM Guidelines, website, http://ipmguidelinesforgrains.com.au/crops/winter-pulses/lentils/

15 http://ipmguidelinesforgrains.com.au/crops/winter-pulses/lentils/

16 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

17 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp

Distribution of *Helicoverpa* spp.

Most *Helicoverpa* in southern Australia from September to early November will be *H. punctigera*.[18] *H. punctigera* is native to Australia. It is more common in inland regions and southern Australia.[19]

H. punctigera (native budworm) breeds over winter in the arid inland regions of Queensland, South Australia, Western Australia and New South Wales on desert plants before migrating into southern agricultural areas in late winter or spring. They can migrate as far south as Tasmania.[20]

H. armigera is more problematic in summer crop irrigation areas. It occasionally occurs in significant numbers in Victorian crops.[21] Although summer pulses are at greatest risk from *H. armigera*, spring outbreaks are possible.

H. armigera is present in Europe, Asia, Africa and Australasia. While it is present in all Australian states, it is more common in the tropics and subtropics.[22] It is a major pest of chickpea and other pulses in northern Australia.

Pest status of *Helicoverpa* spp.

Helicoverpa spp. are major pests and can severely damage all crop stages and all plant parts of all summer and winter pulses. Both species of *Helicoverpa* may be found in lentil.

While significant numbers of *H. armigera* are rare in Victoria, it is still an important pest when it does occur in large numbers, as it may be resistant to many of the commonly used insecticides.[23]

MORE INFORMATION

For more information on insect identification, see: Insect ID: The Ute Guide: https://grdc.com.au/Resources/Ute-Guides/Insects/Butterflies-moths-larvae/North/Heliothis

Identification of *Helicoverpa* spp. eggs and larvae

The adult moths lay round eggs singly on the host plant. Eggs are pale cream or white when laid, 0.6 mm diameter, ribbed and globular. Fertile eggs develop a red or brown ring after one to two days and become brown or black before hatching.[24 25] They hatch two to five days after being laid.[26]

18 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

19 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

20 G McDonald (2015) Native budworm. 8 pp. Pest Notes Southern. CESAR and South Australian Research and Development Institute. http://www.pir.sa.gov.au/__data/assets/pdf_file/0005/274181/Native_Budworm.pdf

21 G McDonald (1995) Native budworm. Agnote Ag0417. Agriculture Victoria. June 1995. http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/native-budworm

22 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

23 G McDonald (1995) Native budworm. Agnote Ag0417. Agriculture Victoria. June 1995. http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/native-budworm

24 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

25 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

26 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/Resources-and-Publications/app

The two *Helicoverpa* species can be differentiated for eggs and small larvae with a Lepton™ test.[27]

Photo 1: *(From left) fresh white eggs of* Helicoverpa*, 1–2-day-old eggs showing brown ring and eggs close to hatching, showing black larval head.*

Photo: Northern Faba Bean GrowNotes™ (2014), Grains Research and Development Corporation, https://grdc.com.au/GrowNotes

Newly hatched larvae are pale with tiny dark spots and dark heads.

Medium larvae are usually brown and the darker spots become more obvious.

Medium larvae develop lines and bands running the length of the body in variable colours.[28]

Large larvae can reach 45 mm. Darker specimens are more common in high density populations. Large larvae vary from green, yellow, orange, pink and red-brown to black.[29] [30]

27 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/resources-and-publications/app

28 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/resources-and-publications/app

29 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

30 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Photo 2: *It is important to be able to identify the different larval instars of* Helicoverpa *spp.*[31] *The six larval instars and two eggs are shown.* Helicoverpa *spp. have four abdominal pro-legs.*[32] *Insecticides are more effective on smaller larvae.*[33]

Photo: Gabriella Caon, SARDI.

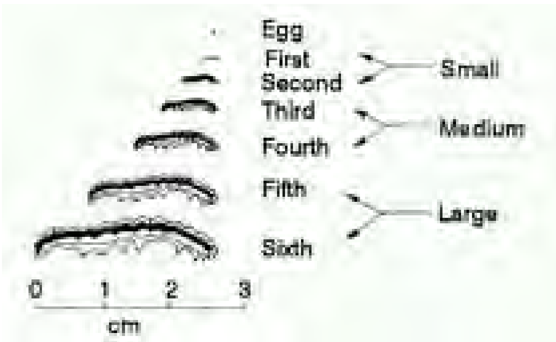

Figure 2: *Approximate sizes of the six instars of* Helicoverpa *spp.*

Source: Agriculture Victoria.

Sometimes the two *Helicoverpa* spp. can be identified by visually examining the larvae. Small *H. armigera* (third instar) have a saddle on the fourth segment but *H. punctigera* do not. While this method can be difficult in the field and is not completely reliable, it may provide a good guide.

In larger (fifth and sixth instar) larvae, hair colour in the segment immediately behind the head is a good species indicator. These hairs are white for *H. armigera* and black for *H. punctigera* (Photo 3).[34]

31 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

32 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

33 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

34 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

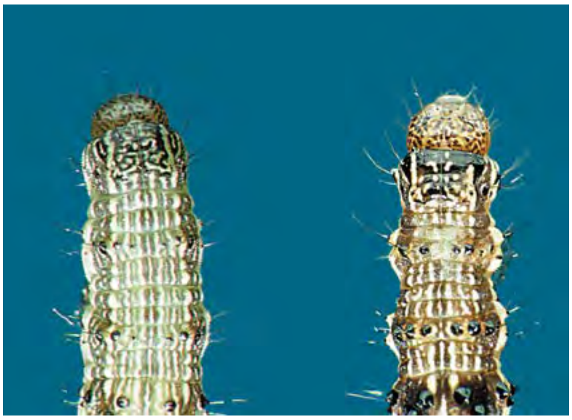

Photo 3: H. punctigera *with black hairs from head (left) and* H. armigera *with white hairs and 'saddle' on fourth abdominal segment (right).*

Photo: L Turton and M Cahill.

Distinguishing *Helicoverpa* spp. from other caterpillars

Helicoverpa spp. larvae can be easily identified, despite the colour variation, by a broad yellow stripe along the body. Young larvae (<10 mm) prefer to feed on foliage; older larvae prefer to feed on pods.

In southern Australia, other larvae which look like native budworm may be found in a pulse crop, for example, southern armyworm and pink cutworm. These are primarily grass feeders and rarely do any damage to pulses.[35]

H. punctigera larvae have black hairs around the head, no dark 'saddle' and light-coloured legs. In contrast, medium larvae of *H. armigera* have white hairs around the head, a dark 'saddle' on the fourth segment back from the head and dark-coloured legs. Pupae of *H. armigera* are readily separated from *H. punctigera* which have spines that are close together.

Medium and large larvae, pupae and adult of *Helicoverpa* spp. can be distinguished visually. Both species of *Helicoverpa* larvae have a group of four pairs of 'legs' in the back half of the body; loopers can have a group of two, three or four pairs of legs at the rear and loop when walking.[36] *Helicoverpa* spp. larvae do not taper noticeably towards the head, as do loopers.

Armyworm larvae can be distinguished by the lack of hairs and by bodies that taper at both ends.

Medium *H. armigera* larvae may also be confused with cluster caterpillar (*Spodoptera litura*) but are more hairy and lack the cluster caterpillar's distinctive spots and hump behind the head.

Helicoverpa eggs are paler than looper eggs, which have a green tinge and are squatter.[37]

35 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

36 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

37 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp

Identification of *Helicoverpa* spp. moths

Helicoverpa spp. moths have a 30–45 mm wingspan with stout bodies.[38] Moths are a dull light brown with dark markings.

Adult moths of *H. punctigera* are usually active during the evening and night and are rarely seen during the day. For native budworm (*H. punctigera*), the fore-wings are buff-olive to red-brown with numerous dark spots and blotches.[39] The hind wings are pale grey with dark veins and a dark band along the lower edge. The hind wings have a dark, broad band on the outer margin.[40]

Photo 4: Helicoverpa punctigera *(native budworm) moths, showing female (left) and male (right).*

Photo: SARDI.

H. armigera has a small light or pale patch in the dark section of the hind-wing while the dark section is uniform in *H. punctigera*.

38 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

39 G McDonald (1995) Native budworm. Agnote Ag0417. Agriculture Victoria. June 1995. http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/native-budworm

40 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

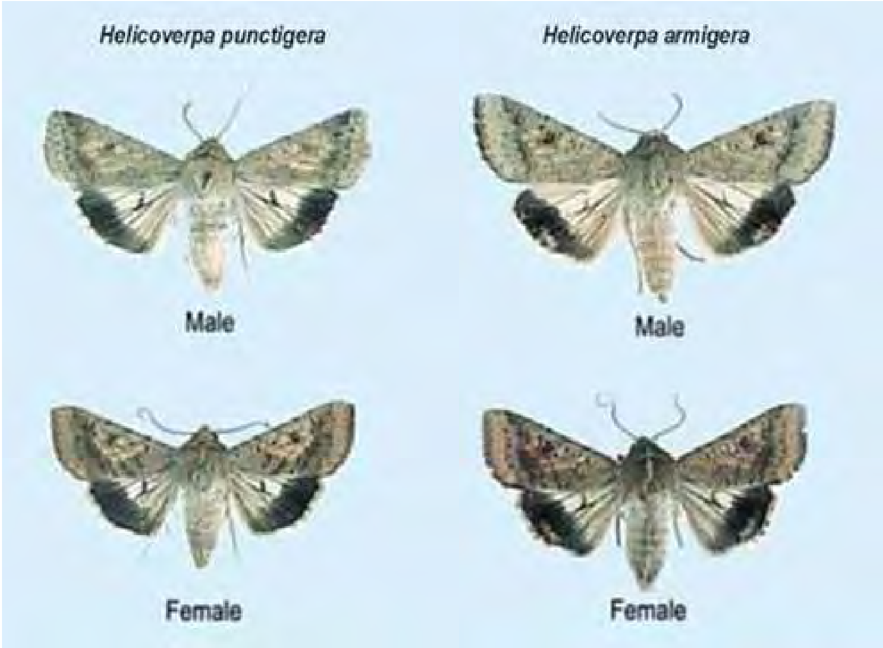

Photo 5: Helicoverpa punctigera *(native budworm) and* H. armigera *moths. The two species are distinguished by the presence of a pale patch in the margin of the hind-wing of* H. armigera*. Most helicoverpa in southern Australia from September to early November will be* H. punctigera.

Photo: Northern Faba Bean GrowNote (2014), Grains Research and Development Corporation,https://grdc.com.au/Resources/GrowNotes

Life cycle of ***Helicoverpa*** spp.

Each female helicoverpa can lay more than 1,000 eggs. In southern Australia, native budworm may produce up to five generations a year. The eggs hatch 1–2 weeks after laying in spring (or 2–6 days in summer) and the larvae feed in crops for 4–6 weeks.[41 42]

Once larvae are fully grown, they crawl to the base of the plant, tunnel into the soil and form a chamber in which they pupate. During spring, summer and early autumn, the pupae develop quickly and a new generation of moths emerges after about two weeks. As with all insect development, the duration of pupation is determined by temperature, taking longer in spring and autumn. Diapausing pupae take much longer to emerge.

The moth emerges, feeds, mates and is then ready to begin the cycle of egg laying and larval development.

Native budworm eggs and holes on soursob (oxalis) petals are signs of native budworm activity in the area.

The spring generation causes the most damage, especially to pulse crops.

During winter, native budworm enters a resting period as a pupa in the soil. Adult moths emerge from these overwintering pupae in August and September and live for about 2–4 weeks.[43]

41 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

42 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

43 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Diapause in *Helicoverpa* spp.

Both species of *Helicoverpa* survive winter as pupae in the soil, when host plants and thus food sources are scarce. *H. punctigera* are capable of overwintering in southern cropping regions, but only a few are ever found. By contrast, substantial numbers of overwintering *H. armigera* pupae can be found under late summer crops, particularly when helicoverpa activity has been high, late into March.

Not all pupae that form in late summer go into diapause; a proportion continues to develop, perhaps emerging during winter, or early in spring.

Overwintering pupae can be killed without use of chemicals. Pupae in the soil are susceptible to soil disturbance and disruption of the emergence tunnel. Cultivation is enough to create this disturbance.

Damage by *Helicoverpa* spp.

Helicoverpa spp. attack most major field crops as well as many horticultural crops. They attack all above-round plant parts. Once crops reach flowering, larvae focus on buds, flowers and pods.[44]

Native budworm (*H. punctigera*) larvae bore into lentil pods and usually destroy several seeds in each pod. A single larva may attack four to five pods before reaching maturity.

The amount of damage to each seed varies considerably, but the damaged area has jagged edges. In contrast, etiella leaves a 'pin-prick' hole.

Helicoverpa spp. cause most damage from podset to maturity, and can reduce grain yield and quality. Lentil grain affected by native budworm damage is classified as 'defective'.[45]

It is important to control larvae while they are still very small to small (<7 mm). Ninety per cent of all feeding (and therefore damage) by helicoverpa is done by larvae from the third instar (small to medium larva that are 8–13 mm long) onwards. Large helicoverpa larvae (>24 mm) are the most damaging stage, since larvae consume about 80% of their diet in the fifth and sixth instars.[46]

44 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp

45 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

46 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

Photo 6: *Native budworm.* Helicoverpa *spp. attack all above-ground parts of plants.*[47]

Photo: Wayne Hawthorne, formerly Pulse Australia.

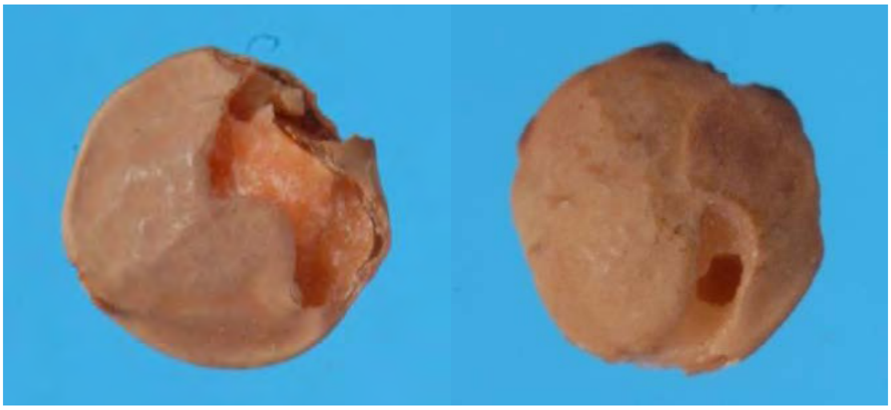

Photo 7: *Native budworm damage to lentil grain downgrades its quality. Affected grains are classified as defective.*[48]

Photo: Pulse Australia.

While the feeding behaviour of *H. armigera* and *H. punctigera* is expected to be the same, no research has been undertaken to assess this.

No studies have compared the behaviour of larvae in drought-stressed crops compared with crops with adequate moisture. Consequently there is no certainty about whether there is more, or earlier, flower and pod feeding when foliage appears to be less attractive.[49]

Monitoring *Helicoverpa* spp. larvae

Helicoverpa spp. cause most damage between podset and maturity.

Regularly monitor the lentil crop for insect pests and/or damage, to make timely decisions on control. It is important to target small larvae.[50]

Begin monitoring crops for helicoverpa larvae when crops start flowering and continue until late maturity.[51] One recommendation is to inspect crops weekly for before podset, then two or three times a week until late podding. Another recommendation is to monitor crops every three or four days from the beginning of flowering. Moth flight activity can provide an early warning for egg laying and

47 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

48 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

49 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

50 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

51 D Lush (2013) Time to watch for native budworm. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-106-Sept-Oct-2013/Time-to-watch-for-native-budworm

potential future larval activity in the crop, and also signals the time to start monitoring crops for larvae.[52]

Growers also need to take into account beneficial species and populations in lentil crops.

Experienced agronomists suggest that helicoverpa numbers alone do not always give an accurate assessment of damage. In some situations (for example, if the crop is severely moisture stressed), monitoring crop damage will assist in assessing the accumulating yield loss.

The quickest and easiest method to sample most crops is to use a 38 cm diameter sweep net. Repeat the sweeping process of ten sweeps in at least 12 places throughout the paddock to obtain an average caterpillar density.[53] For more details, see: Section 9.1.7.

Beat-sheet sampling is the preferred sampling method for medium to large helicoverpa larvae. Scout for small larvae by opening vegetative terminals, buds and flowers.[54] Sample six widely spaced locations per paddock and take five 1-m-long samples at each site with a standard beat sheet. Convert larval counts per metre to larvae per square metre by dividing the counts by the row spacing, in metres.[55]

Helicoverpa eggs are difficult to see, so egg counts are an unreliable indicator of control thresholds. Egg survival to larvae can also be highly variable. If an egg count is taken, use it as an indication of an egg-laying event and determine the potential development rate of the helicoverpa.[56] Rates of native budworm (*H. punctigera*) development have been estimated for South Australia, based on meteorological data (Table 2); eggs laid on 20 August will take about three weeks to hatch, while eggs laid one month later will take 13 days. In some seasons, a second spray is needed.[57]

Table 2: Estimated developmental rate (number of days between stages) for native budworm in South Australia. Development is faster in spring than winter. In some years, a second spray is required. Based on former Victorian Department of Primary Industries estimates using DARABUG software using moth counts, larvae developmental stages and weather pattern information. These are a guide only.

Stage	Aug 20	Aug 30	Sep 10	Sep 20	Sep 30
Egg laying to egg hatch	21	18	16	13	13
Egg hatch to larvae 7–10 mm	32	30	28	27	24
Egg laying to larvae 7–10 mm	53	48	44	40	37

Source: Southern Lentil Best Management Practices Training Course Manual, (2016), Pulse Australia; Budworm Watch program – more than monitoring, (2003), Pacific Extension Network 2003 Forum, www.regional.org.au/au/apen/2003/abstracts/p-37.htm

It is difficult to estimate the number of very small larvae hatched in the previous 24 hours. Often they are low in the canopy. When using a beat sheet, they often remain on leaflets, making them very difficult to see and count. Very small larvae do no economic damage to the crop, their feeding confined to leaves. Early research on helicoverpa has shown high mortality of very small larvae; their value in monitoring is potential activity of larger larvae in a week or two.

In studies of helicoverpa larval feeding behaviour in soybean, large larvae were found to cause the majority of damage, in the order of 80%, with medium larvae contributing about 15% and other instars the remainder.

52 D Lush (2013) Time to watch for native budworm. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-106-Sept-Oct-2013/Time-to-watch-for-native-budworm

53 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

54 M Miles, P Grundy, A Quade and R Lloyd (2015) Insect management in fababeans and canola recent research. GRDC Update Paper. 25 February 2015. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/insect-management-in-fababeans-and-canola-recent-research

55 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

56 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

57 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Monitoring *Helicoverpa punctigera* (native budworm) moth flights

Helicoverpa punctigera (native budworm) moths migrate to southern Australia from breeding grounds in the northern pastoral and desert areas after winter rainfall.

Large numbers of native budworm moths usually fly into cropping areas during late winter and spring, with infestations commencing in the northern cropping areas.

Moths are attracted to traps containing a chemical sex-attractant (pheromone), specific to the species so only the helicoverpa is caught.

Photo 8: *Pheromone traps can be used as a guide to identifying and monitoring moth numbers.*

Photo: Unknown

Take note of news of helicoverpa moth flights and inspect crops for the presence of caterpillars when crops are flowering and podding.

Growers should begin monitoring crops when moths are detected in their region. However, as there is no established relationship between the numbers of moths trapped and the resulting caterpillar population in nearby crops, growers cannot determine the need for sprays by the moth traps.

Control thresholds for *Helicoverpa* spp.

An economic control threshold is the number of caterpillars that will cause more financial loss than the cost of spraying.[58] Further research is needed into control thresholds for helicoverpa in lentil in southern Australia.

The thresholds used for helicoverpa are based on yield loss rather than quality; however, in pulses for human consumption, the quality threshold (defective grain) is probably reached before significant yield loss. Even in low numbers, helicoverpa can affect the marketability of grain while not economically affecting yield, meaning that control measures may be needed before economic thresholds are reached.

The control thresholds used in the southern region are those developed for Western Australia. This threshold is the only one used in Australia that may be derived from research, rather than 'best guesses', and assumes 60 kg/ha yield loss per larva in 10 sweeps (Table 3).[59 60]

58 P Mangano, S Micic (2016) Management and economic thresholds for native budworm control. Department of Agriculture and Food Western Australia, www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

59 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

60 M Miles, P Grundy, A Quade and R Lloyd (2015) Insect management in fababeans and canola recent research. GRDC Update Paper. 25 February 2015. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/insect-management-in-fababeans-and-canola-recent-research

Note that the Western Australian thresholds are only a guide for the Southern Region.[61] To calculate the threshold, use the formula:

Economic threshold (ET) for grubs in 10 sweeps = C ÷ (K x P)

Where:
C = control cost ($/ha), i.e. chemical plus application costs per hectare
K = 60 kg/ha lentil grain eaten for every one caterpillar netted in 10 sweeps or per square metre
P = price of grain per kg, i.e. price per tonne ÷ 1,000

For example, with lentil:
P = $420/t, (i.e. $0.42/kg)
C = $10/ha
K = 60 kg/ha

Therefore:
ET = 10 ÷ (60 x 0.42)
ET = 10 ÷ 25.2
ET = 0.4 grubs per 10 sweeps.

Table 3: Examples of economic thresholds for native budworm control in lentil.

	P	**C**	**K**	**Economic thresholds**	
Grain price per tonne ($)	**Grain price per kg ($)**	**Control costs including application ($/ha)**	**Loss per grub in each of 10 sweeps (kg/ha/grub)**	**Average grubs in 10 sweeps**	**Grubs in 5 lots of 10 sweeps (5x previous column)**
210	0.21	10	60	0.8	4
280	0.28	10	60	0.6	3
420	0.42	10	60	0.4	2
840	0.56	10	60	0.2	1

These thresholds were developed in Western Australia and are a guide only, as no thresholds have been developed for south-eastern Australia. They are based on yield loss only, not loss of quality.

Source: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia; P Mangano, S Micic (2016) Management and economic thresholds for native budworm control. Department of Agriculture and Food Western Australia, www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

Helicoverpa punctigera (native budworm) control

Few control options are currently available other than the use of chemical insecticides or bio-pesticides for above-threshold populations of larvae in a crop.

Spray promptly once the threshold are exceeded. *Helicoverpa punctigera* (native budworm) larvae are easily killed by all registered products, including products to which *H. armigera* is resistant.[62 63]

Where insecticide has been used to control etiella, helicoverpa moths are often deterred from laying eggs in lentil crops.

Registered chemicals can be used at the same time as ascochyta fungicides, if necessary, as long as products are compatible.[64]

Because *H. punctigera* moths migrate annually into eastern Australian cropping regions, any resistance that might be selected for, because of exposure to insecticides in crops, is lost among the larger susceptible population. In other words,

61 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

62 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

63 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

64 R Rundell-Gordon (2016) Growing lentils: lessons learnt from growing lentils in central and north west Victoria, GRDC Update paper, 17 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Growing-lentils-lessons-learnt-from-growing-lentils-in-central-and-north-west-Victoria

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

as new *H. punctigera*, moths appear each year, insecticide resistance is unlikely to be a threat to pulse production in southern and western regions of Australia.

Commonly used insecticides registered for use on native budworm are shown in Table 7 with details in "Table 8: Green lentil disease traits." on page 23.

Aim to control larvae less than 10 mm long, because bigger larvae require higher rates of insecticides. The larvae must be sprayed before they burrow into the seed pods or they will be shielded from insecticides and will continue to damage seed.[65]

Helicoverpa armigera control

H. armigera has developed resistance to synthetic pyrethroids, organophosphates and carbamates. Unlike *H. punctigera*, populations tend to remain local, so their resistance to insecticides is maintained in the population from season to season.

If *H. armigera* is the dominant species, spray with carbamates or pyrethroids may fail because of resistance. The bio-pesticides *Helicoverpa* nucleopolyhedrovirus (NPV) and *Bacillus thuringiensis* (Bt) currently have no known resistance problems.[66]

Before flowering, bio-pesticides are recommended in preference to chemical insecticides in all pulses, particularly older, less selective products, for integrated pest management.

After flowering, control is recommended only for small larvae 5–7 mm long, depending on the product and if resistance levels are within acceptable limits for the region.

If using a product that is effective only against early instar larvae, another spray may be necessary during flowering to prevent large larvae damage at podset.

Where newer, more selective pesticides, are used for *H. armigera*, the number of spray applications per crop is restricted (usually to one) for resistance management. Because of this, and because they are often more expensive. New chemical pesticides are best reserved for 'at risk' flowering and podding stages.

For best results, all 'ingestion' products (including bio-pesticides) require thorough plant coverage. The addition of Amino Feed® or equivalent is strongly recommended for bio-pesticides.[67]

Spray applications

Correct timing and coverage are critical to achieving good control of helicoverpa larvae, whether using a chemical insecticide or a biopesticide (such as NPV or *Bt*).

Inappropriate timing risks crop loss and the costs of re-treating. It also increases the likelihood of insecticide resistance by exposing larvae to sub-lethal doses (for *H. armigera*). Regular crop scouting enables assessment of the number of helicoverpa larvae and the age structure of the population.

Early detection is critical to ensure effective timing of sprays. Larvae in the open are more easily contacted by spray. Target larvae before they move into flowers and pods.

Very small (1–3 mm) to small (4–7 mm) larvae are the most susceptible stages to insecticide and require a lower dose to kill. If a spray application is delayed more than two days, rechecked and reassessed.

Only spray if the value of the crop saved is more than the cost of spraying. Vegetative feeding generally does not equate to significant yield loss.

65 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

66 GRDC (2014) Northern faba bean GrowNotes, Grains Research and Development Corporation, https://grdc.com.au/Resources/GrowNotes

67 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp

Good coverage is increasingly important with the introduction of ingestion-active products because the larvae must actually feed on plant material covered with an adequate dose of the insecticide or biopesticide.

Attract-and-kill products such as Magnet® consist of a liquid moth lure based on floral volatiles mixed with an insecticide. Only a relatively small area needs to be treated (less than 2% of the total crop), minimising impact on natural enemies. Reducing the pest moth population decreases the number of eggs laid into a crop, which can lower subsequent pest pressure and delay the need for foliar insecticides.

9.3.2 Etiella (*Etiella behrii*)

Etiella, also known as lucerne seed web moth, attacks lentil, lupin and field pea crops. Lentil is its favourite winter pulse crop, of which etiella is a sporadic but major pest.[68]

Etiella is found over the whole of Australia, including Tasmania.

Etiella identification

Adult moths are grey, 10–15mm long, with a prominent beak or 'snout'. Their wing span varies between 20–25 mm. The are grey-brown with a distinctive white stripe running along the full length of the fore-wing.[69] Moths have an orange band on each fore-wing.

At rest, the wings are folded over the body, making the moth appear long and narrow. The moths will fly one to two metres if disturbed by walking through a crop.

Moths are sometimes confused with those of other non-pest *Etiella* spp. Other snout nosed moths similar to etiella may be found in lentil crops, but only etiella has the prominent white stripes running along the wing.

Adult females lay approximately 200 eggs, which are about 0.5–0.6 mm in diameter and difficult to see with the naked eye.[70] They are initially cream-coloured, and flattened but turn pink-orange just before hatching.[71] In lentil crops, eggs are commonly laid under the calyx and hatch in 4–7 days.[72]

Etiella larvae leave frass (excrement) inside pods and may web pods together.

Etiella has five larval stages (instars). Newly hatched larvae are very small, approximately 1mm,and are light orange with a dark head. As they develop, small larvae may be cream or green, lacking stripes, with a dark head.

Mid-sized larvae may be pale green or cream, with pale brown, pink or red stripes running along their length.[73]

Mature larvae are 10–12mm long. They are characteristically green with pink or red stripes and a brown head or pink-red. Larvae in the pre-pupal stage can be aqua blue or dark pink with no stripes.

Mature larvae exit pods to pupate in the soil. Pupae are smooth, light to dark brown in colour, and 9–12 mm long.

68 C Krawec (2006). Etiella management in lentils, brochure, 10 pp., South Australian Research and Development Institute, http://www.pulseaus.com.au/storage/app/media/crops/2008_Lentil-Etiella-management.pdf

69 C Krawec (2006). Etiella management in lentils, brochure, 10 pp., South Australian Research and Development Institute, http://www.pulseaus.com.au/storage/app/media/crops/2008_Lentil-Etiella-management.pdf

70 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

71 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

72 C Krawec (2006). Etiella management in lentils, brochure, 10 pp., South Australian Research and Development Institute, http://www.pulseaus.com.au/storage/app/media/crops/2008_Lentil-Etiella-management.pdf

73 C Krawec (2006). Etiella management in lentils, brochure, 10 pp., South Australian Research and Development Institute, http://www.pulseaus.com.au/storage/app/media/crops/2008_Lentil-Etiella-management.pdf

Etiella damage

Etiella larvae feed on seeds within pods. Pods are susceptible to damage while they are green.[74] Etiella larvae consume far less than large caterpillars like helicoverpa; seeds are usually only partially eaten, often with characteristic pin-hole damage. While damaged seeds have jagged edges similar to native budworm damage, they are distinguished by the presence of silken webbing associated with large larvae.[75]

Etiella damage is difficult to grade out and its unattractive appearance reduces seed quality.

Larval frass (excrement) adhering to damaged seeds is frequently mistaken for bruchid eggs. However, unlike bruchids, etiella are unable to re-infect stored seed.[76]

Etiella damage results in inferior quality lentil and yield losses due to a reduction in grain weight and grain breakage. Insect damaged grain is often unsaleable. Australian lentil producers face significant cleaning costs to meet receival standards, which allow for no more than 1% insect damaged grain.

Typically, only the first generation of etiella moths is a concern for lentil growers. However, in seasons that finish late, the second generation may also cause significant seed damage.

First instar etiella larvae bore into pods shortly after hatching and begin feeding on the developing grain. Usually each larva damages more than a single pod, and often webs several pods together to continue feeding.

74 M Raynes (2015) Etiella moths active in southern lentil crops, Pulse Industry Update, 22 September 2015, Pulse Australia, http://pulseausblog.tumblr.com/post/129634859040/etiella-moths-active-in-southern-lentil-crops

75 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

76 H Brier (2008) Break crop IPM short course manual. Southern Region IPM Workshop Training Manual: Soybeans and Winter Pulses, 11 March 2008, Griffith and Coleambally, NSW, 82pp.

Etiella life cycle

Etiella flights can often occur in mid to late September, coinciding with early pod development in most districts, however, the first moth flights are usually in late September to early October.

Female moths lay their eggs under the calyx or on the pod surface, and these hatch in 4–7 days depending on temperature.

Newly hatched larvae bore into green pods within 24 hours to begin feeding on developing grain. This can make etiella more difficult to manage than native budworm.

Etiella has two to three generations per year, from spring to autumn. Larvae over-winter in the soil and emerge as adults the following spring. Researchers do not know if etiella moths colonising lentil crops emerge locally, or whether they migrate from further distances. Etiella moths may live from 1–3 weeks.[77 78]

Etiella monitoring methods

Etiella is considered a high priority pest and successful control relies on thorough crop monitoring in order to properly time insecticide applications to target adult moths before egg laying. Also monitor lentil crops during peak flight for the larvae of etiella, as the larvae damage plants.

Lentil is susceptible to etiella damage from late flowering onwards, as soon as the first pods appear. Monitor every 4–5 days and recommence monitoring within one week of spraying.

Etiella flights commonly occur in mid to late September and frequently coincide with early pod development in lentil.

A number of monitoring methods are available and should be implemented from the beginning of pod formation. These include:

- degree-day model;
- pheromone traps;
- light traps; and
- sweep netting.

77 C Krawec (2006). Etiella management in lentils, brochure, 10 pp., South Australian Research and Development Institute, http://www.pulseaus.com.au/storage/app/media/crops/2008_Lentil-Etiella-management.pdf

78 M Raynes (2015) Etiella moths active in southern lentil crops, Pulse Industry Update, 22 September 2015, Pulse Australia, http://pulseausblog.tumblr.com/post/129634859040/etiella-moths-active-in-southern-lentil-crops

IN FOCUS

Day degree model for monitoring etiella

The SARDI etiella degree-day model is a proxy for estimating rates of insect development. It uses maximum and minimum daily temperature data to forecast the timing of peak etiella flight activity for the various lentil-growing districts. The model identifies the date to commence in-crop monitoring for etiella moths.

Peak etiella moth activity in lentil crops (for most areas) is estimated as the date when the model reaches 351 degree-days.

Begin monitoring lentil crops at least two weeks before 351 degree-days accumulate, or at about 300 degree-days, to ensure detection of early etiella. The degree-day accumulation cut-off is 341 in the Streaky Bay area, South Australia. SARDI will refine guidelines in 2017 based on a network of field observations in different districts in 2016.

Download the model at: SARDI etiella degree-day model.

www.pir.sa.gov.au/__data/assets/file/0003/45759/etiella_degree_day_model.xls

Temperature data for your local region can be obtained from the Bureau of Meteorology website (http://www.bom.gov.au) and must be entered into the model from 21 June onwards.

Detailed instructions for running the model can be obtained by emailing Bill Kimber (bill.kimber@sa.gov.au).

MORE INFORMATION

The Pest Facts newsletter provides updated model predictions to growers in South Australia. To subscribe, click on Pest Facts.
www.pir.sa.gov.au/research/services/reports_and_newsletters/pestfacts_newsletter

Pheromone traps for etiella

Pheromone traps are useful to indicate the presence and timing of moth flight activity. These are sticky traps baited with a specific sex attractant. They have the advantage over light trapping of being specifically attractive to etiella.

Pheromone traps provide a crude measurement of etiella abundance; trap catches depend on moth movement, as well as numbers.

A minimum of two to three traps should be placed within a crop, positioned approximately 25 cm above the crop canopy. Traps may be effective for up to one month.

Sweep nets for etiella

Sweep netting is a common method for monitoring etiella moths. Lentil crops should be sampled at least weekly during podding for evidence of etiella activity.

Randomly take a minimum of three groups of 20 sweeps in each lentil paddock. The control threshold for etiella is 1–2 moths per 20 sweeps. This is an average count from a minimum of three sets of 20 sweeps in a lentil paddock.

Begin sweep netting when the degree-day figure is close to 300 degree-days.[79, 80, 81]

Light traps for etiella

Light traps are another means of monitoring etiella moths. However, they catch a wide range of insects. Checking outdoor lights around buildings during the evening is a simple means of detecting etiella flight activity in spring.

Chemical control of etiella

Effective management of the etiella moth relies on controlling the adults with well-timed insecticide treatments, if required, before they lay eggs on lentil pods; understanding the timing of moth flights is critical.[82]

Growers need to be ready to control the first generation of etiella as soon as the control threshold of sweeps is reached. Insecticide should be applied immediately after peak flights of etiella, targeting adult moths before they lay eggs.[83]

Esfenvalerate and deltamethrin are registered for the control of etiella moths in lentil. The short withholding periods (14 days and 7 days, respectively) of these insecticides allow them to be used late in the season.

Both products provide excellent and rapid control of adult moths and small larvae before they burrow into pods. Once inside the pods, larvae are protected from insecticide sprays and damage is usually only identified at harvest.[84, 85]

Etiella damage can be controlled within the acceptable industry threshold if insecticide is applied at the correct time.

An indication of damage and the inability to fully control etiella with the wrong insecticide timing, is given in Table 4. Note that timing of the insecticides used in the trial is now considered too late. Although the levels of damage caused to pods were consistently lower in the insecticide-treated plots, the percentage of *E. behrii* damaged grain was commercially unacceptable (>1% damaged).

Table 4: Mean percentage of insect-damaged pods, insect-damaged grain and yield of Nugget lentils in an early evaluation trial of three insecticides at Netherby, Victoria, November 2003.[86] Treatments were applied seven days after peak moth flights, which is now known to be too late.

Treatment	Pre-treatment assessment (% damaged pods)	5 days post-treatment (% damaged pods)	19 days post-treatment (% damaged pods)	Grain quality (% damaged grains)	Grain yield (t/ha)
Untreated	4.1 a**	12.6 a	4.8 a	2.16 a	2.83 a
Deltamethrin	1.8 a	4.2 a	1.5 b	1.14 a	2.87 a
Methomyl*	2.9 a	3.3 a	2.8 ab	1.82 a	2.79 a
Esfenvalerate	2.8 a	4.3 a	1.2 b	2.07 a	2.82 a

**Different letters within columns indicate significant differences among treatments at the $p < 0.05$ level using the Tukey's HSD comparisons of means test.

* Methomyl is not registered for control of etiella in lentil.

Source: Agriculture Victoria

79 C Krawec (2006). Etiella management in lentils, brochure, 10 pp., South Australian Research and Development Institute, http://www.pulseaus.com.au/storage/app/media/crops/2008_Lentil-Etiella-management.pdf

80 SARDI (2016) The etiella degree-day model, Pestfacts newsletter, Issue 11, 15 September 2016, www.pir.sa.gov.au/research/services/reports_and_newsletters/pestfacts_newsletter/pestfacts_issue_11_2016/etiella_degree-day_model

81 M Raynes (2015) Etiella moths active in southern lentil crops, Pulse Industry Update, 22 September 2015, Pulse Australia, http://pulseausblog.tumblr.com/post/129634859040/etiella-moths-active-in-southern-lentil-crops

82 SARDI (2016) The etiella degree-day model, Pestfacts newsletter, Issue 11, 15 September 2016, http://www.pir.sa.gov.au/research/services/reports_and_newsletters/pestfacts_newsletter/pestfacts_issue_11_2016/etiella_degree-day_model

83 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

84 C Krawec (2006). Etiella management in lentils, brochure, 10 pp., South Australian Research and Development Institute, http://www.pulseaus.com.au/storage/app/media/crops/2008_Lentil-Etiella-management.pdf

85 M Raynes (2015) Etiella moths active in southern lentil crops, Pulse Industry Update, 22 September 2015, Pulse Australia, http://pulseausblog.tumblr.com/post/129634859040/etiella-moths-active-in-southern-lentil-crops

86 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited.

Helicoverpa (native budworm) moths may be deterred from laying eggs in lentil crops where insecticide has been used for etiella.[87] Conversely, sprays applied to control native budworm in early podding may offer some control of etiella. Importantly, note monitoring for etiella should recommence no longer than one week after spraying.[88, 89]

The glossy shield bug can attack etiella moth, while parasitic wasps and flies have been recorded from larvae and pupae.[90]

9.3.3 Snails

Snail populations can build up readily in lentil crops and can become a major problem if not controlled. They can enter the grain sample at harvest, even when they have not climbed onto the lentil plant.[91] Snail numbers can explode in seasons with wet springs, summers and autumns.[92] Particular attention must be paid to snails under no-till and stubble retention. [93]

Comprehensive information on snail management is available in the publications:

- Snail Bait Application Factsheet;[94] www.grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application
- *Bash 'Em, Burn 'Em, Bait 'Em: Integrated snail management in crops and pastures*.[95] www.grdc.com.au/GRDC-Snails-BashBurnBait
- *Snail Identification and Control: The Back Pocket Guide*. www.grdc.com.au/BPG-SnailIdentificationAndControl

MORE INFORMATION

For more details on snail management, please see the GRDC Snail Management Fact Sheet: www.grdc.com.au/GRDC-FS-SnailManagement

White snails or round snails (*Cernuella virgata* and *Theba pisana*)

Two species of white (or round) snails exist: the vineyard or common white snail (*Cernuella virgata*) and the white Italian snail (*Theba pisana*). They are found throughout the agricultural districts of South Australia, the Victorian Mallee and Wimmera. They also occur in Western Australia, New South Wales and Tasmania.

Both species have similar shapes: white coiled shells up to 20 mm diameter, which may have brown bands around the spiral. The common white snail has an open umbilicus whereas the umbilicus of the Italian snail is partly closed. The umbilicus of a white snail is the hollow space on the underside of the shell.[96 97]

87 R Rundell-Gordon (2016) Growing lentils: lessons learnt from growing lentils in central and north west Victoria, GRDC Update paper, 17 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Growing-lentils-lessons-learnt-from-growing-lentils-in-central-and-north-west-Victoria

88 C Krawec (2006). Etiella management in lentils, brochure, 10 pp., South Australian Research and Development Institute, http://www.pulseaus.com.au/storage/app/media/crops/2008_Lentil-Etiella-management.pdf

89 M Raynes (2015) Etiella moths active in southern lentil crops, Pulse Industry Update, 22 September 2015, Pulse Australia, http://pulseausblog.tumblr.com/post/129634859040/etiella-moths-active-in-southern-lentil-crops

90 http://ipmguidelinesforgrains.com.au/pests/etiella/

91 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

92 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Factsheet. 6 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

93 J Kirkegaard (2017) Opportunities and challenges for continuous cropping systems, GRDC Update Paper, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/opportunities-and-challenges-for-continuous-cropping-systems

94 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Factsheet. 4pp. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

95 D Hopkins, E Leonard, G Baker (2003) "Bash 'Em, Burn 'Em, Bait 'Em: Integrated snail management in crops and pastures". 40 pp. South Australian Research and Development Institute, www.grdc.com.au/GRDC-Snails-BashBurnBait

96 Pulse Australia (2016) Agronomy. Southern Faba Bean Best Management Practices Training Course Manual 2016, Pulse Australia Limited

97 GRDC (2011) Snail Identification and Control: The Back Pocket Guide, www.grdc.com.au/BPG-SnailIdentificationAndControl

Photo 9: *Vineyard or common white snail. Note the umbilicus (hollow space) is open.*

Photos: SARDI

Photo 10: *White Italian snail. Note the umbilicus (hollow space) is partly closed.*

Photos: SARDI.

Conical snails or pointed snails or (*Prietocella acuta* and *Prietocella barbara*)

Two species of conical snails exist: conical snails (*Prietocella acuta*) and small conical snails (*P. barbara*).

Conical snails are also known as pointed snails. They have fawn, grey or brown shells. Mature conical snails have shells 12–18 mm long whereas the shells on the small conical snails are 8–10 mm long.

Highest numbers of conical snails (*P. acuta*) are found on the Yorke Peninsula in South Australia. Isolated populations are also present in other parts of South Australia, Victoria, New South Wales and Western Australia.

The small conical snail, *P. barbara*, occurs throughout South Australia, but is most abundant in the higher rainfall areas (>500 mm). It is also widely spread in Victoria, New South Wales and Western Australia.[98 99]

98 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

99 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Factsheet. 4pp. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

The ratio of shell length to base diameter is always >2 for conical snails and <2 for small conical snails.

Photo 11: *Conical snail, also known as pointed snail. The shell length is always more than double the base diameter. Mature conical snail shells are 12–18 mm long.*

Photo: SARDI.

Photo 12: *Small conical snail, also known as small pointed snail. The shell length is always less than double the base diameter. Mature small conical snail shells are 8–10 mm long.*

Photo: SARDI.

MORE INFORMATION

For more information on managing snails at harvest, refer to: Section 12.5 Snails.

Damage by snails

White snails mainly damage crops during establishment and harvest. Both common white and Italian snails may feed on young crops and destroy substantial areas which then need re-sowing. In late spring, snails climb plants. The juveniles, in particular, contaminate the grain at harvest.

Conical snails, *Prietocella acuta*, contaminate grain at harvest, especially cereals and canola. They feed mostly on decaying plant material but can damage cereal and canola seedlings.[100]

The small conical snail *P. barbara* feeds on growing plants and can contaminate grain. Lucerne is a favoured plant.

The contaminated grain may be downgraded or rejected and live snails in grain pose a threat to exports. Grain will be rejected if more than half a dead or one live snail is found in a 200 g pulse sample.[101] Check with your buyers for specific regulations.

Crushed snails clog up machinery causing delays during harvest. Modify headers and clean grain to eliminate snail contamination of grain.

Life cycle of snails

Snails appear to build up most rapidly in canola, field pea and faba bean. However, they can feed and multiply in all crops and pastures. White snails are dormant in summer. Young snails hatch about two weeks after eggs are laid. They feed and grow through the winter and spring before climbing fence posts or plants in late spring or summer, where they enter summer dormancy. Snails live for 1–2 years, and move only short distances. They are spread in hay, grain, machinery, or vehicles.[102]

Conical snails have a similar life cycle to white snails. Conical snails may over-summer under stones and on posts and plants.

Small conical snails over-summer on the ground in the leaf litter and under stones and stumps.[103]

Monitoring snails

Monitor snails regularly to establish their numbers, types and activity as well as success of controls. Monitoring and early baiting before eggs are laid is critical.[104 105 106]

Look for snails in the early morning or evening when conditions are cooler and snails are more active.

The key times to monitor snail populations are:

- summer to pre-sowing: check numbers in stubble before and after rolling, slashing or cabling;
- 3–4 weeks before harvest, to assess need for harvester modifications and cleaning; and
- after summer rains: check if snails are moving from resting sites.

100 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

101 Pulse Australia (2016) Australian pulse standards 2016/2017, 68 pp., www.graintrade.org.au/sites/default/files/Pulse_Standards_2016-2017_01Aug16.pdf

102 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Factsheet. 6 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

103 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Factsheet. 4pp. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

104 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

105 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Factsheet. 6 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

106 http://ipmguidelinesforgrains.com.au/pests/slugs-and-snails/snails-in-seedling-crops/

A wide range of snail sizes in an area indicates that snails are breeding there; if most snails are the same size, snails are moving in from other areas. The size range of snails is important as juveniles do not take baits.

Various monitoring techniques are recommended for snails. Methods include:

- sampling with 10 x 10 cm quadrats at 50 locations across the paddock. Take samples from the perimeter to the interior of the paddock and note density in different areas;
- sampling with a 0.1 m^2 (32 x 32 cm) quadrat. Place the quadrat on the ground and count all live snails within it. Take five counts along the fence at approximately 10 m apart, then five counts into the paddock every 10m.
- sampling with a 30 x 30 cm quadrat at 50 locations across the paddock.

When sampling at 50 locations, take five sampling transects in each paddock. One transect is taken at 90 degrees to each fence line whilst the fifth transect runs across the centre of the paddock. Take five samples (counts), 10 m apart along each transect. Record the size and number of the snails in each sample. Average the counts for each transect and multiple this figure by 10 to calculate the number of snails per square metre in that area of the paddock.

If both round and conical snails are present, record the number of each group separately.

Place the snails in a simple sieve box and shake gently to separate into larger snails and those <7 mm. Round snails and small conical snails (<7 mm) are unlikely to be controlled by bait. Record two size groups (juveniles <7 mm and adults >7 mm). Sieve boxes can be constructed from two stackable containers, such as sandwich boxes. Remove the bottom from one and replace by a punch hole screen. The suggested screen size is 7 mm round or hexagonal.[107]

When looking for snails, check under weeds, and shake and thresh samples of mature crops onto a small tarp or sack, to see if snails are in the portion of crop that will enter the harvester.[108]

Record live snails before and seven days after baiting or the paddock operation and calculate the reduction in numbers.[109]

107 http://ipmguidelinesforgrains.com.au/pests/slugs-and-snails/snails-in-seedling-crops/

108 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Factsheet. 6 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

109 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Snail control

To control snails, you will need to apply a combination of treatments throughout the year.

The keys to snail management and control are:

- Stubble management:
  - cabling or rolling in summer;
  - slashing in summer; and
  - burning in autumn.
- Summer weed control.
- Baiting in autumn.
- Harvest and delivery:
  - reducing snail intake during harvest (windrowing, brushes, bars);
  - header settings; and
  - cleaning after harvest.

Cultural management for snail control

Snail control starts in the summer before sowing.

While control measures for conical snails are the same as those used on white snails, they are generally less effective, as conical snails can shelter in cracks in the ground or under stones. Dragging harrows or a cable before burning improves the control of conical snails by exposing more snails to burning.

The best control is achieved by stubble management on hot days or burning, followed by baiting in autumn before egg laying.

Rolling, harrowing or dragging a cable over stubble on hot days reduces snail numbers by knocking snails to the ground to die in the heat (air temperature >35°C). Some snails may also be crushed by rollers.

Burning in autumn can reduce snail numbers by up to 95%, provided there is sufficient stubble for a hot and even burn. Note that wind or water erosion become a risk on burnt stubble.

Windrowing can reduce white snail numbers harvested. Snails are knocked from the crops during windrowing, and most re-climb the stalks between the windrows rather than in the windrow.

Grain can be cleaned on-farm where snail contamination is so high that grain will be downgraded or rejected.

Baiting snails

If lentil crops have more than 5 snails/m^2, growers are likely have grain contamination at harvest.

Bait in autumn when snails have commenced activity following rain. This must be done before egg laying.[110] Baiting may be necessary to reduce damage to young crops. Juvenile snails (less than seven mm) cannot be controlled after sowing. Fence line baiting can also be vital to prevent re-infestation of the paddock. Do not bait within two months of harvest to avoid bait contamination in grain.

Timing and choice of controls will depend on the season.[111] Three bait types are available for snail control: methiocarb, metaldehyde and iron chelates, which are similar in efficacy. (However, methiocarb and iron chelates are not registered for use in lentil). The metaldehyde rate used depends on the product.

110 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

111 GRDC (2012) Snail Management: All-year-round attack on snails required. Southern and Western Region Factsheet. 6 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SnailManagement

Most spreaders are designed for fertiliser; a South Australian trial has shown that snail and slug bait is not spread as widely as expected and can become fragmented. Ute spreaders give uneven coverage.[112] For optimal coverage, calibrate spreaders for snail bait. For details, see the snail bait application factsheet. https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application.

Photo 13: *Growers must calibrate spreaders especially for snail bait for optimal bait coverage. Baits come in different shapes and sizes, which affects the evenness of spread.* Photo: Felicity Pritchard.

Biological control of snails

Biological controls are not yet available for white snails.[113] Native nematode species have shown promise against the four pest snail species but commercially trialled with limited success.[114]

112 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Factsheet. 4pp. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

113 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

114 M Nash (2013) Slug control – new insight. GRDC Update paper. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Slug-control-new-insights

9.3.4 Slugs (*Deroceras reticulatum*, *Milax gagates* and others)

MORE INFORMATION

For more information see *Slugs in Crops: the Back Pocket Guide*: www.grdc.com.au/GRDC-BPG-Slug

MORE INFORMATION

For details on a GRDC project that explored a range of management strategies to effectively reduce damage caused by slug species in the High Rainfall Zone, please see 'Slugging Slugs': www.grdc.com.au/Media-Centre/Hot-Topics/Slugging-slugs/Details

Slugs are a growing problem in the high rainfall zones with zero-till and stubble retention.

No single control method will provide complete protection; an integrated approach is best.

Slug populations are regulated by moisture. Cool, wet summers and heavy stubble provide ideal conditions for slugs as they need moisture and shelter to thrive.

Slug species identification

The two main pest species are the grey field or reticulated slug (*Deroceras reticulatum*), and the black keeled slug (*Milax gagates*). The grey field slug is the most common slug species in southern Australia. Brown field slugs, *D. invadens* or *D. laeve*, can also pose a serious threat.

Details of other species can be found in the *Slug in Crops: The Back Pocket Guide*. www.grdc.com.au/GRDC-BPG-Slug[115]

Adult grey field slugs are usually grey and about 2–5 cm long. They may have dark brown mottling and range from light grey to fawn. The black keeled slug is uniform black to grey, with a ridge down its back, and 4–6 cm long. The brown field slug is 25–35 mm, and usually brown all over with no distinct markings.[116]

The brown field slug is mainly surface active but can burrow to shallow depths.[117]

Grey field slugs are mainly active on the surface while the black keeled slug can burrow up to 20 cm underground to escape the heat. For this reason, black keeled slugs may become active in emerging crops later than grey field slugs, as the autumn break develops. This means the optimal timing of control will differ for the two species.[118]

As black keeled slugs are a burrowing species, they are considered better suited to drier environments.

115 P Horne, J Page (2006) Slugs in Crops: The Back Pocket Guide, 2 pp., Grains Research and Development Corporation, www.grdc.com.au/GRDC-BPG-Slug

116 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

117 M Nash, H Brier, P Horne, J Page, S Micic, G Ash, A Wang (2013) Slug control: Slug identification and management factsheet. 4pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SlugControl

118 GRDC (2014) Slugging Slugs: findings from recent GRDC High Rainfall Zone (HRZ) trials, 2 pp. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Hot-Topics/Slugging-slugs/Details

Photo 14: *The two main slug species in Southern Australia, grey field slug (*Deroceras reticulatum*) (top) and the black keeled slug (*Milax gagates*).*

Photo: Peter Mangano, DAFWA.

Damage by slugs

Slugs will attack all plant parts. Seedlings are the most vulnerable and can suffer major economic damage.

Slugs can be underestimated as pests because they are nocturnal and shelter during dry conditions.

Although slugs can cause major damage to emerging pulse, canola and wheat crops in high rainfall areas, they have also caused damage in lower rainfall areas in wetter years. Damage is usually greater in cracking clay soils.

Life cycle of slugs

Slugs are hermaphrodites, that is, individuals are both male and female. Slugs will breed whenever moisture and temperature conditions are suitable – generally from mid-autumn to late spring. Both individuals of a mating pair lay eggs in batches. Each individual can lay about 100 eggs; some species can produce about 1,000 eggs per year.[119] [120]

Eggs are laid in moist soils and will hatch within 3–6 weeks, depending on temperature. Juveniles look like smaller versions of the adult.

Moisture is essential for slug survival. Some species, such as the black keeled slug, may move down the soil to depths of 20 cm or more in dry periods and reappear when conditions improve.

119 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

120 M Nash, H Brier, P Horne, J Page, S Micic, G Ash, A Wang (2013) Slug control: Slug identification and management factsheet. 4pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SlugControl

Photo 15: *Slug eggs hatch within 3–6 weeks of laying. Some species can produce up to 1,000 eggs per year.*

Photo: Michael Nash

Monitoring of slugs

Research suggests that monitoring slugs is unreliable because populations vary so much. Growers need to know the hot spots for slugs in each paddock and use baits at crop establishment when the risk is high.

If monitoring, use surface refuges, such as 30 x 30cm pavers, to monitor slugs. This represents approximately 1 m^2 for slugs. Ideally use a minimum of 10 tiles per 10 ha placed evenly across the entire paddock.

Growers can also use either a tile, hessian bag or slug trap left in the paddock over night to count snail or slug numbers. Use surface traps baited with layers' mash and check them early in the morning, as slugs move out of the traps as the day starts to warm up.

Slug control

When slugs are actively breeding, no current control measure will reduce populations below established thresholds.[121] Particular attention must be paid to slugs under no-till and stubble retention[122].

Cultivation and rolling, and burning stubble after weed control will reduce slug populations. Rolling the soil immediately after sowing can markedly reduce slug damage. Shallow discing may reduce populations of grey field slugs by 40–50%. While burning may help control surface-active species, it will not control the burrowing black keeled slugs.[123 124]

If anticipating crop damage from slugs, bait after sowing, before crop emergence. Differences in biology between species can affect control options and chemical efficacy.

Always use the highest possible label rates or adjust the rate to the perceived size of the slug population.[125] Bait is commonly applied at 4–5 kg/ha, but be aware that the density of bait points needs to be at about 25–30 bait points/m^2 for a paddock population of 20 slugs/m^2, giving 80% chance of slugs encountering the baits. Spreading bait with fertiliser spreaders can lead to poor distribution of bait.[126 127 128]

MORE INFORMATION

For details on identifying slugs, please see the GRDC Fact Sheet on slug identification and management www.grdc.com.au/GRDC-FS-SlugControl

121 M Nash, M Richards, H De Graff, G Baker (2016) New insights into slug and snail control. 7 pp. GRDC Update Paper. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/New-insights-into-slug-and-snail-control

122 J Kirkegaard (2017) Opportunities and challenges for continuous cropping systems, GRDC Update Paper, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/opportunities-and-challenges-for-continuous-cropping-systems

123 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

124 GRDC (2014) Slugging Slugs: findings from recent GRDC High Rainfall Zone (HRZ) trials, 2 pp. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Hot-Topics/Slugging-slugs/Details

125 M Nash, H Brier, P Horne, J Page, S Micic, G Ash, A Wang (2013) Slug control: Slug identification and management factsheet. 4pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SlugControl

126 GRDC (2015) Snail Bait Application: Lessons from the Yorke Peninsula to improve snail baiting effectiveness. Factsheet. 4pp. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2015/01/Snail-Bait-Application

127 M Nash (2013) Slug control – new insight. GRDC Update paper. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Slug-control-new-insights

128 GRDC (2010) Aphids and viruses in pulse crops, Factsheet, 4 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

Preliminary trials found the effective bait life is between 2–3 weeks. More than one bait application may be necessary, particularly with wet winters. Cheaper options give similar results if baiting occurs monthly.

Buried bait is less effective than bait on the soil surface.

Similar to snails, three bait types are available for slug control: methiocarb, metaldehyde and iron chelates, which are similar in efficacy.[129] (However, methiocarb and iron chelates are not registered for use in lentil.)

Baiting will generally only kill half of the slug population at any one time.

Consider placing baits with the seed when sowing, when black keeled slugs are present.

For grey field slugs, broadcasting baits is more effective.[130]

Predators may provide some regulation of slug populations. The carabid or ground beetle, *Notonomus gravis*, reduces grey field slug numbers but not below damage thresholds.[131]

MORE INFORMATION

For more details on aphids and viruses, please see the GRDC fact sheet: www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

9.3.5 Aphids

Aphids are a pest of lentil chiefly because they spread viruses during feeding which can reduce crop yields, especially when infection is extensive in early crop stages. A few aphids can cause substantial damage if they are spreading viruses, especially early in the season.

It takes large numbers of aphids to damage crops by direct feeding.[132] Insecticides aimed at controlling damage from aphid feeding are normally too late to control virus spread and damage.

Aphids and virus transmission

Virus transmission typically occurs well before aphid colonies are evident. A pre-emptive and integrated management approach (taking into account the risk factors) is required to minimise the impact of virus.[133]

Prolonged, high levels of aphids arriving early in the season are associated with unique cases of viruses causing major yield losses in lentil crops. Combinations of Cucumber mosaic virus (CMV), Alfalfa mosaic virus (AMV) and Turnip yellows virus (TuYV), (also known as Beet western yellows virus, BWYV) are often present.[134]

Lentil crops are also susceptible to Bean leaf roll virus (BLRV), Bean yellow mosaic virus (BYMV) and Pea seedborne mosaic virus (PsbMV), Subterranean clover red leaf virus (SCRLV) and Subterranean clover stunt virus (SCSV).[135] [136] [137]

Most lentil crops surveyed in South Australia and Victoria have CMV, which occasionally becomes a major problem.

129 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

130 M Nash, H Brier, P Horne, J Page, S Micic, G Ash, A Wang (2013) Slug control: Slug identification and management factsheet. 4pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-SlugControl

131 M Nash (2013) Slug control – new insight. GRDC Update paper. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Slug-control-new-insights

132 GRDC (2010) Aphids and viruses in pulse crops, Factsheet, 4 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

133 http://ipmguidelinesforgrains.com.au/crops/winter-pulses/lentils/

134 W Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015) Lentil: integrated disease management, Australian Pulse Bulletin, 20 November 2015, Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

135 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

136 M Aftab, A Freeman, F Henry (2013) Temperate Pulse Viruses: Pea-seedborne Mosaic Virus (AMV), Agnote AG1267, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/temperate-pulse-viruses-pea-seed-borne-mosaic-virus-psbmv

137 M Aftab, A Freeman, F Henry (2013) Temperate Pulse Viruses: Bean yellow Mosaic Virus (BYMV), Agnote AG1266, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/temperate-pulse-viruses-bean-yellow-mosaic-virus-bymv

MORE INFORMATION

For more information on viruses, refer to Section 10 Diseases

The most important factors that predispose lentil crops to severe virus infection are:

- close proximity to a large virus reservoir (such as lucerne and summer weeds);
- high summer and autumn rainfall, followed by uncontrolled multiplication of aphids on host plants; and
- early aphid flights to newly emerged crops causing early infection. Infected plants act as a reservoir for the disease to spread even further.

Aphids can spread viruses persistently or non-persistently (Table 5). Once an aphid has picked up a persistently transmitted virus, it carries the virus for life, infecting every plant where it feeds. Aphids carrying non-persistently transmitted viruses carry the virus temporarily and only infect new plants in the first one or two probes.

Table 5: Examples of transmission of some persistent and non-persistent viruses by four aphid species affecting pulse crops, including lentil. Non-persistently transmitted viruses may be seedborne but require aphid vectors to spread during the season.

Aphid	Cucumber mosaic virus (CMV)	Pea seedborne mosaic virus (PSbMV)	Turnip yellows virus (TuYV)*
	Non-persistent	Non-persistent	Persistent
Green peach aphid	Yes	Yes	Yes
Pea aphid	Yes	Yes	No
Cowpea aphid	Yes	Yes	Yes
Bluegreen aphid	Yes	No	No

*Formerly known as Beet western yellows virus, BWYV

Source: Aphids and viruses in pulse crops Fact Sheet (2010), Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

Different aphid species transmit different viruses to particular crop types, so species identification is important because management strategies can vary.

MORE INFORMATION

Information on this widespread and common pulse crop pest can be found at PestNotes Southern: http://pir.sa.gov.au/__data/assets/pdf_file/0003/275826/Cowpea_Aphid.pdf

Cowpea aphid (*Aphis craccivora*)

The cowpea aphid is a widespread and common pest of pulse crops, including lentil. It has a wide range of host plants and can tolerate warm, dry weather that causes many other aphid species to suffer.

Cowpea aphid is the only black aphid. All stages have black and white legs.[138] Adults are shiny black, up to 2.5 mm long and may have wings. Nymphs are slate grey. Superficially, nymphs of the brown smudge bug look like cowpea aphid nymphs.

Photo 16: *Cowpea aphids can transmit a number of viruses. Note the different aphid ages. The older aphids are shiny black. The white cast is a skin, shed as the aphid grows.*

Photo: SARDI

Before they colonise a lentil crop, cowpea aphids can transmit viruses (Table 6).

Table 6: Some persistent and non-persistent viruses spread by cowpea aphid that affect lentil. This list is not exhaustive and the viruses may be spread by other aphid species[139]

Persistent	Non-persistent
Bean leaf roll virus (BLRV)	Pea seedborne Mosaic Virus (PSbMV)
Subclover red leaf virus (SCRLV)	Bean yellow mosaic virus (BYMV)
Subclover stunt virus (SCSV)	Cucumber mosaic virus (CMV)
Turnip yellows virus (TuYV)*	Alfalfa mosaic virus (AMV)

*Also known as beet western yellows virus, BWYV

Sources: Southern Lentil Best Management Practices Training Course Manual, (2016), Pulse Australia Limited and Cowpea aphid, Pest Notes Southern, (2015), cesar and the South Australian Research and Development Institute, www.pir.sa.gov.au/__data/assets/pdf_file/0003/275826/Cowpea_Aphid.pdf

A cowpea aphid infestation is generally patchy at first but will spread through the crop if the weather is fine and warm.

Infestations start when winged females colonise a few plants in a crop and give birth to wingless nymphs that live in colonies. This may occur from early winter onwards. As the plant deteriorates, the aphids move to neighbouring plants, increasing the area of infested patches within the crop.[140]

138 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

139 P Umina, S Hangartner (2015) Cowpea aphid, Pest Notes Southern, 6 pp. cesar and the South Australian Research and Development Institute, www.pir.sa.gov.au/__data/assets/pdf_file/0003/275826/Cowpea_Aphid.pdf

140 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

MORE INFORMATION

More information on Bluegreen aphids can be found in the information sheets developed between cesar and the South Australian Research and Development Institute (SARDI).

See PestNotes Southern: http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

Bluegreen aphid (*Acyrthosiphon kondoi*)

Adult bluegreen aphids grow up to 3 mm, may have wings and vary from matte blue-green to grey-green. They are oval, with long legs and antennae. They have two large cornicles (tubes) that extend beyond the base of the abdomen. Nymphs are similar to adults but smaller.[141]

Photo 17: *Bluegreen aphid.*

Photo: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook.

Photo 18: *Bluegreen aphids of various ages. The brown insects are dead bluegreen aphids which have been parasitised by wasps.*

Photo: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Bluegreen aphids can colonise lentil plants and transmit important viruses including the non-persistent viruses Cucumber mosaic virus (CMV) and Bean yellow mosaic virus (BYMV).[142] Bluegreen aphids do not transmit Pea seedborne mosaic virus (PSbMV).

Bluegreen aphids cause feeding damage to upper leaves, stems and terminal buds of host plants. Heavy infestations can cause damage to plants by direct removal of nutrients. In general, aphids have the greatest impact on crops when soil moisture is limited.[143]

Bluegreen aphids prefer cooler weather (10–18°C) for breeding. Females produce up to 100 young at a rate of approximately seven young per day. Winged aphids develop

141 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

142 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

143 P Umina, W Kimber (2015) Bluegreen aphid, Pest Notes Southern, 6 pp. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

when infestations become crowded; they fly or are blown by wind to start new infestations elsewhere.

Monitoring aphids

Frequent monitoring is necessary to detect rapid increases of aphid populations.

Aphids invade lentil crops from adjacent crops, pastures and roadsides. Monitor all crop stages. In particular, regularly monitor lentil crops in the seedling and establishment stages and between bud formation to late flowering.

Aphids will target stressed plants and often progress into crops from the edges. Monitoring adjacent paddocks and fence lines before crop emergence can help, as aphids will transmit the viruses as soon as they reach crops; knowing if aphids are present in the area will help avoid virus problems.

Note with early monitoring of aphids in lentil crops for virus control, non-colonising aphids may be found. Even when colonising aphids are found, the virus may have already spread by the time they are observed.

Aphid distribution may be patchy, so monitoring should include at least five sampling points across the paddock. Inspect at least 20 plants at each sampling point. Search for aphids looking at the youngest flowers of each plant. Look for clusters of aphids or symptoms of leaf-curling.[144] Stem samples give useful estimates of aphid density.

Sticky traps might assist in identifying early aphid activity, as well as the presence of beneficial insects including hoverflies, lacewings, lady beetles and parasitic wasps. These species will attack aphids.

While beneficial insects can help reduce virus spread and spring feeding damage, some virus spread will have occurred before aphid numbers subside.

Aphid control for viruses

Use an integrated management approach to reduce the risk of virus transmission by aphids.[145] Particular attention must be paid to pests that develop resistance to available pesticides, such as green peach aphid.[146]

The best protection against aphid infestation and virus spread in lentil is to prevent aphids landing in the crop. Use imidocloprid seed dressing. A prophylactic insecticide spray in lentil to prevent aphid incursion is not desirable.

When crops are damaged, control may be necessary. Beneficial insects always arrive later than the pest. Although beneficial species may help reduce virus spread (and spring feeding damage), some virus spread will have already occurred before aphid numbers subside.

Control the aphids if virus spread and direct feeding damage is of concern. Lentil suffers some mechanical damage from aphids.[147 148]

Thresholds for managing aphids in lentil crops have not been established. Any threshold to prevent the incursion of aphid-vectored virus will be much lower than any threshold to prevent yield loss via direct feeding.

Aphid infestations can be reduced by heavy rain or sustained frosts. If heavy rain occurs after deciding to spray, check the crop again to see if treatment is still needed.[149]

144 P Umina, W Kimber (2015) Bluegreen aphid, Pest Notes Southern, 6 pp. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

145 GRDC (2010) Aphids and viruses in pulse crops, Factsheet, 4 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

146 J Kirkegaard (2017) Opportunities and challenges for continuous cropping systems, GRDC Update Paper, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/opportunities-and-challenges-for-continuous-cropping-systems

147 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

148 GRDC (2010) Aphids and viruses in pulse crops, Factsheet, 4 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

149 W Kimber (2015) Bluegreen aphid, Pest Notes Southern, 6 pp. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

Use integrated management practices to control aphid populations early in the season. Virus risks can be managed by:

- sowing seed with <0.1% infection;
- considering seed dressings (see below);
- controlling volunteer weeds during summer and autumn where lentil is to be sown, as aphids (and the viruses they spread) have alternative hosts between growing seasons;
- rotating pulse crops with cereals to reduce virus and vector sources;
- where possible, avoiding close proximity to perennial pastures (such as lucerne) or other crops that host viruses and aphid vectors;
- monitoring in nearby crops and pastures early in the season;
- reducing aphid landing rates with retained stubble, as bare soil is more attractive to some aphid species. While higher sowing rates and narrow row spacing can also help, this can create difficulties with fungal disease management. Minimum-tillage with standing stubble and inter-row sowing is ideal to discourage aphid landings; and
- applying insecticide for virus control, but only if crops are at high risk.[150] Spray if cowpea aphid is easily found and only where damage to growing points is obvious.[151]

Pirimicarb is registered for field pea, lupin and broad bean but not lentil. However, an emergency use permit is usually in place when needed.

Insecticide seed treatments can delay aphid colonisation and reduce early infestation and aphid feeding.[152] Gaucho® 600 SD Red Flowable (imidacloprid) is registered. When applied as a seed treatment, it will help protect lentil seedlings from early season aphid attack and reduce spread of the persistently transmitted viruses early in the season.[153 154] These include Bean leaf roll virus (BLRV), Turnip yellows virus (TuYV, synonym BWYV), Subterranean clover red leaf virus (SCRLV) and Subterranean clover stunt virus (SCSV).

Several insecticides for aphid control are highly toxic to bees and should not be applied while bees or native insects are foraging or pollinating lentil. Avoid broad-spectrum insecticides to conserve beneficial species. If blue green aphid is the predominant pest, use insecticides that do not kill aphid parasites and predators; for mixed infestations, systemic chemicals that control aphids and mites should be used. Refer to Table 7 “Registered insecticides commonly used”.

Natural enemies of aphids are hoverfly larvae, aphid parasites, green lacewing larvae, brown lacewing and lady beetles.[155]

‘Soft’ insecticides used soon after emergence help control persistently transmitted viruses only.

150 Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015) Lentil: integrated disease management, Australian Pulse Bulletin, 20 November 2015, Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

151 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

152 P Umina, W Kimber (2015) Bluegreen aphid, Pest Notes Southern, 6 pp. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

153 GRDC (2010) Aphids and viruses in pulse crops, Factsheet, 4 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

154 Pulse Australia (2015) Managing viruses in pulses, Australian Pulse Bulletin, 20 November 2015, Pulse Australia, www.pulseaus.com.au/growing-pulses/publications/manage-viruses

155 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

MORE INFORMATION

For more information of insecticide resistance and management of green peach aphid and TuYV (formerly BWYV), watch: https://youtu.be/1MIRtsfydkc

Only use a synthetic pyrethroid (SP) if aphids are present. Use of an SP is controversial; while it prevents early colonisation due to 'anti feed' properties, it can also agitate uncontrolled aphids to increase virus spread. Impact on beneficial insects can also lead to higher aphid numbers.

Synthetic pyrethroid insecticides should not be used to control green peach aphid, an important vector of TuYV (formerly known as BWYV) as most populations are resistant to SPs.[156 157] Commonly used insecticides registered for use on bluegreen aphid are shown in Table 7 with details in Table 8.

Aphid control for direct feeding damage

No thresholds have been developed for aphids in lentil crops. However, bluegreen aphid control is recommended when damage becomes evident.[158]

In general, stressed crops will attract insect pests. Crops that are not moisture stressed have a greater ability to compensate for aphid damage and will generally be able to tolerate far higher infestations than moisture stressed plants before a yield loss occurs.[159]

156 GRDC (2010) Aphids and viruses in pulse crops, Factsheet, 4 pp. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

157 Pulse Australia (2015) Managing viruses in pulses, Australian Pulse Bulletin, 20 November 2015, Pulse Australia, www.pulseaus.com.au/growing-pulses/publications/manage-viruses

158 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

159 P Umina, W Kimber (2015) Bluegreen aphid, Pest Notes Southern, 6 pp. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/275492/Bluegreen_Aphid.pdf

MORE INFORMATION

More information on redlegged earthmites can be found in the Agriculture Victoria Agnote: agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

Or watch GroundCover™ TV: GCTV9: Redlegged earthmites, https://www.youtube.com/watch?v=tMnUVGOUXu8

GCTV16: IPM beatsheet demo. Mung bean, https://www.youtube.com/watch?v=MwtqG6lC49E

9.3.6 Redlegged earth mite (*Halotydeus destructor*)

RLEM identification

Redlegged earth mites (RLEM) are active from autumn to late spring and are found in southern Australia.

Adults and nymphs of RLEM have a 'velvety' black body. Adult RLEM are 1 mm long with eight red-orange legs. Newly hatched mites are only 0.2 mm, pinkish-orange with only six legs.[160] [161]

Photo 19: *Redlegged earth mite (RLEM) close up.*

Photo: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook.

Photo 20: *RLEM feeding causes leaves to first turn silvery, then brown and shrivelled, so that the plants look scorched.*

Photo: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook.

RLEM damage

RLEM feed on the foliage for short periods and then move around. Other mites are attracted to compounds released from damaged leaves.

Typical RLEM damage appears as 'silvering' or 'whitening' of the attacked foliage. RLEM are most damaging to emerging crops, greatly reducing seedling survival and development.

160 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/resources-and-publications/app

161 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans; The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

In severe cases, entire crops may need re-sowing following RLEM attack. RLEM feed on a wide range of plant species.[162]

RLEM life cycle

RLEM are usually active between April and November. During this period, RLEM may pass through 2–3 generations, with each generation surviving 6–8 weeks. Long, wet springs favour the production of over-summering eggs. When this occurs, subsequent crops can be at risk.

Autumn rains trigger hatching in 3–9 days. False autumn breaks can cause large losses in mite numbers. Mites take 20–25 days from hatching to mature and start laying eggs.

RLEM monitoring

Inspect lentil crops from autumn to spring for mites and their damage, particularly in the first few weeks after sowing.

Mites feed on the leaves in the morning or on overcast days. In the warmer part of the day RLEM tend to gather at the base of plants, sheltering in leaf sheaths and under debris. They crawl into cracks in the soil to avoid heat and cold. When disturbed during feeding they will drop to the ground and seek shelter.

RLEM control and insecticide resistance management

Control strategies that only target RLEM may not entirely remove pest pressure. Other pests can fill the gap, and this is particularly evident after chemical applications which are generally more effective against RLEM than other mite pests.

Non-chemical options are becoming increasingly important due to evidence of resistance in RLEM populations and concern about long-term sustainability. If using a chemical spray, choose one that has least environmental impact and aim to reduce the number of chemical applications. Pesticide groups exist with low to moderate impacts on many natural enemies, such as cyclodienes.[163]

Insecticide resistance in RLEM is presently confined to Western Australia. High levels of resistance to pyrethroids exist within Western Australian populations. Resistance to organophosphates has also evolved. A strategy to manage insecticide resistance in RLEM populations is available for use by grain growers and their advisers.

MORE INFORMATION

For details on a resistance management strategy for the redlegged earth mite, please see the GRDC Fact Sheet www.grdc.com.au/FS-RLEM-Resistance-strategy-South

Chemical control of RLEM

While insecticides are registered for control of active RLEM, no registered insecticides are effective against RLEM eggs. Commonly used insecticides registered for use on RLEM are shown in Table 7 with details in Table 8.

Four chemical sub-groups are registered to control RLEM in grain crops: organophosphates (Group 1B); synthetic pyrethroids (Group 3A); phenylpyrazole (Group 2B); and neonicotinoids (Group 4A). The latter two are registered only for use as seed treatments.[164] Fipronyl is the only Group 2B pesticide but it is not registered for lentil.

If spraying in autumn, control the first generation of mites before they lay eggs. Pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, before adults begin to lay eggs. Rotate products with different modes of action to reduce the risk of insecticide resistance.

162 P Umina (2007) Redlegged earthmite, Agnote AG0414, January 2007, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

163 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

164 GRDC (2016) Resistance management strategy for the redlegged earth mite in Australian grains and pastures in New South Wales, South Australia, Tasmania and Victoria, factsheet. 4pp. Grains Research and Development Corporation, https://grdc.com.au/FS-RLEM-Resistance-strategy-South

MORE INFORMATION

For details on climatic variables, and tools such as TIMERITE® please go to www.wool.com/globalassets/start/woolgrower-tools/timerite/timeriteinformationpackage.pdf

Autumn insecticide application includes:

- pesticides with persistent residual activity used as bare-earth treatments to protect seedlings;
- foliage sprays applied after crop emergence, which are generally an effective control; and
- systemic pesticides applied as seed dressings, which act by maintaining the pesticide at toxic levels within the seedling. Note, if mite numbers are high, plants may suffer significant damage before the pesticide has much effect.

Bare-earth insecticides and seed dressings for RLEM are not registered in lentil but can be used in other parts of the rotation.

A correctly timed spray in spring can reduce populations of RLEM the following autumn. Use climatic variables, and tools such as TIMERITE® to determine the optimum date for spraying. While TIMERITE® has less relevance in pulse cropping, it has an important role in pastures and RLEM population management. Research in southern Australia has shown the use of a TIMERITE® spring spray is effective in reducing RLEM populations by 93%.[165]

Users need to be mindful of its limitations and the issues around repeated insecticide applications according to this approach. Spring RLEM sprays will generally not be effective against other pest mites.

Biological control of RLEM

At least 19 predators and one pathogen are known to attack earth mites in eastern Australia, particularly other mites, although small beetles, spiders and ants also play a role. None of these natural enemies can be relied on to provide control if there has been a favourable spring for RLEM prior to sowing the new crop. The benefits of a predatory mite (*Anystis wallacei*), which has been released, are yet to be demonstrated.[166]

Natural enemies of RLEM residing in windbreaks and roadside vegetation need to be protected as well, so avoid pesticides with residual activity applied as border sprays to prevent mites moving into a crop or pasture.

Cultural control of RLEM

Cultural control measures include:

- rotating crops or pastures with non-host crops, such as cereals;
- cultivating, which can also help reduce RLEM populations;
- clean fallowing and controlling weeds around crop and pasture perimeters and
- controlling weeds, especially thistles and capeweed, to remove breeding sites for RLEM.[167]

165 TJ Ridsdill-Smith, C Pavri (2015) Controlling redlegged earth mite, Halotydeus destructor (Acari: Penthaleidae), with a spring spray in legume pastures. Crop and Pasture Sci., 66: 938–946

166 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

167 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

MORE INFORMATION

For details on lucerne flea please visit PestNotes Southern www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-flea

9.3.7 Lucerne flea (*Sminthurus viridis*)

Lucerne flea is mostly found on loam or clay soils and can damage a wide range of crops. It is commonly found in all southern states of Australia.

High numbers of lucerne flea are often found in the winter rainfall areas of southern Australia, or in irrigation areas where moisture is plentiful. Lucerne flea is often patchily distributed within paddocks and across a region.[168]

Lucerne flea identification

Lucerne flea springs off plants when disturbed. It is yellow-green and may have dark markings. Adults are plump and wingless and approximately 2–3 mm long.

Photo 21: *Lucerne flea with eggs. Adults are yellow-green and may have black or brown markings.*

Photo: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook.

Lucerne flea damage

Lentil is susceptible to lucerne flea, in contrast to chickpea. In addition to pulses, the insect can damage pastures, lucerne, oilseeds and cereals.[169]

Lucerne flea is present in autumn to spring. Crops are most susceptible to damage immediately following seedling emergence. Numbers tend to peak in spring.[170]

Although a serious pest of young crops, lucerne flea can also damage older crops. They move up plants from the soil level, leaving a distinctive transparent 'window' on leaves. A severe infestation may remove all green material.[171]

168 P Umina, S Hangartner, G McDonald (2015) Lucerne flea, Pest Notes Southern, cesar and the South Australian Research and Development Institute, www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-flea

169 D Hopkins, M Miles (1998) Insect ID: The Ute Guide, Southern Region. 98 pp. Primary Industries and Resources SA

170 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

171 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia

Photo 22: *Leaf damage caused by lucerne flea feeding, causing a distinctive transparent 'window' appearance.*

Photo: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook.

Lucerne flea life cycle

High humidity and moisture and a mild auumn and winter favour growth.[172]

Long wet springs favour lucerne flea, often causing more serious outbreaks in the following autumn. It requires cool, moist conditions.

Lucerne flea will produce up to five generations in most years. Activity stops in late spring when dry conditions lead to the production of over-summering eggs by the final generation of females.

Over-summering eggs hatch the following autumn, usually soon after opening rains in southern Australia, when the right combination of temperature and moisture occurs.

Monitoring lucerne flea

Regularly monitor for damage from autumn to spring. Lentil crops are most susceptible to damage immediately following seedling emergence.[173]

Lucerne flea is often concentrated in localised patches or 'hot spots' so it is important to have a good spread of monitoring sites within each paddock.

Examine foliage for the characteristic damage and check the soil surface, where insects may be sheltering. Monitoring usually involves working on hands and knees.

Monitoring lucerne flea populations for growth stage as well as numbers can also be important for accurate timing of some sprays.

Chemical control of lucerne flea

There are no formal spray thresholds for lucerne flea damage in crops. However, the key is early control because of the impact of seedling vigour on crop performance. Damage levels can be used to determine whether or not spraying is necessary.[174]

Avoid 'insurance sprays' which select for insecticide resistance and rotate insecticide groups to avoid resistance developing.[175]

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172 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

173 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

174 G Jennings (2002) Knowledge, timing, key to lucerne flea control, 2 pp. Grains Research Advice, November 2002, Grains Research and Development Corporation

175 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Assess the complex of pests present before deciding on the most appropriate control strategy. Lucerne flea competes for food and resources with other pests such as redlegged earth mite and blue oat mite. When both lucerne flea and redlegged earth mite are present, control strategies should consider both pests, as control strategies that only target one species may not necessarily reduce the overall pest pressure because other pests can fill any gaps.

Control lucerne flea in the paddock the season before sowing susceptible crops like lentil. Spring spraying can reduce the number of insects in the following autumn by preventing the laying of over-summering eggs.

If lucerne flea requires control, treat the infested area with an insecticide three weeks after the pest first emerges in autumn in the newly sown crop. While this will allow for the further hatching of over-summering eggs, it will be before lucerne flea has a chance to lay winter eggs.

Insecticides provide the most effective means of control.[176] However, lucerne flea should not be treated with synthetic pyrethroids (SPs) as it has a high natural tolerance. Most SPs are also ineffective on bryobia or balaustium mites.

To avoid developing multiple pesticide resistance, rotate chemical classes across generations rather than within a generation of a pest.

A border spray may be enough to prevent lucerne flea moving in from neighbouring paddocks. Spot spraying may also be sufficient as lucerne flea is often distributed patchily in crops. Do not blanket spray unless necessary.

Biological and cultural control of lucerne flea

Several predatory mites, for example, snout mites, various ground beetles and spiders, prey on lucerne flea.[177]

Clean fallows and control of weeds within crops and around pasture perimeters, especially capeweed, helps reduce lucerne flea numbers.

Cultivation, using traps, border crops and mixed cropping can help reduce the overall infestation levels, particularly when used in conjunction with other measures. Grasses and cereals can be useful for crop borders as they are less favourable to lucerne flea.[178]

176 G Jennings (2002) Knowledge, timing, key to lucerne flea control, 2 pp. Grains Research Advice, November 2002, Grains Research and Development Corporation

177 P Umina, S Hangartner, G McDonald (2015) Lucerne flea, Pest Notes Southern, cesar and the South Australian Research and Development Institute, www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Lucerne-flea

178 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

9.4 Other pests of lentil

A range of other species are potentially major pests in some pulses, including lentil. These should not be ignored in the monitoring and management of lentil crops.

MORE INFORMATION

For more details on blue oat mite, please see Pest Notes Southern http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

9.4.1 Blue oat mite (*Penthaleus* spp.)

Blue oat mite identification

Adult blue oat mites (BOM) are 1 mm, with eight red-orange legs. They have a dark blue-black body with an oval red or orange spot on their back, which distinguishes them from redlegged earth mite (RLEM). Mites generally feed singularly. They share similar life cycles with RLEM.[179, 180] (See section 9.3.6)

Three pest species of BOM exist in Australia, which complicates identification and control. These are *Penthaleus major*, *P. falcatus* and *P. tectus*.

Photo 23: *Blue oat mite has a blue-black or deep purple body with a distinct red to orange spot on its back, which distinguishes it from redlegged earth mite.*

Photo: Gordon Cumming, Pulse Australia.

Blue oat mite damage

The BOM species *P. major* and *P. tectus* occasionally attack lentil crops, while *P. falcatus* is rarely a problem in lentil.

Blue oat mites attack most crops and pastures, but cereals, canola and lucerne are most susceptible.

Blue oat mite life cycle

BOM is active from April to late October, and over-summer as eggs. Autumn rains trigger hatching within 3–9 days. False breaks in the season can cause large losses in mite numbers. Mites take 20–25 days from hatching to mature and start laying eggs.[181]

179 D Hopkins, M Miles (1998) Insects: the Ute Guide, Southern Region. 98 pp. Primary Industries and Resources SA

180 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

181 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Blue oat mite monitoring

It is important to monitor germinating pulse crops. Check paddocks before sowing in autumn and throughout winter.

Examine plants for damage and search for mites on leaves and the soil, especially in late-sown crops.

BOM spend most of their time on the soil surface, rather than on the foliage. They are most active during the cooler parts of the day, feeding in the mornings and in cloudy weather. They seek protection during the warmer part of the day on moist soil surfaces or under foliage, and may even dig into the soil under extreme conditions.

Chemical control

Each species differs in its distribution, pesticide tolerance and crop plant preferences.

BOM is often misidentified as RLEM but some BOM species are more tolerant than RLEM to a range of synthetic pyrethroid and organophosphate insecticides.[182]

All current pesticides are only effective against the active stages of mites, and do not kill mite eggs. Commonly used insecticides registered for use on BOM are shown in Table 7 with details in Table 8.

While seed dressings are registered for blue oat mite in other crops, none are registered for this pest in lentil.

P. falcatus has a high natural tolerance to a range of pesticides registered for use against earth mites. The other BOM species, which are more likely to affect lentil, have a lower level of tolerance to pesticides and are generally easier to control with chemicals.

Control first generation mites before they can lay eggs to avoid a second spray. Pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, as adults will then begin laying eggs.

Spraying in spring is usually ineffective and not recommended for BOM.[183]

Pesticides with persistent residual effects can be used as bare-earth treatments. If applied by sowing, these treatments can protect the plants throughout their seedling stage.[184]

Systemic pesticides applied as seed dressings can help minimise crop damage during establishment but if mite numbers are high, significant damage may still occur before the pesticide has much effect. However, there are no seed dressing products registered for use with lentil for BOM.

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182 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

183 P Umina, S Hangartner (2015) Blue oat mite, Pest Notes Southern, 6 pp. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

184 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Biological and cultural control

A number of predator species are known to attack earth mites in Australia. Leaving shelter belts or refuges between paddocks will help maintain natural enemy populations.

Preserving natural enemies when using chemicals is often difficult for growers because the pesticides generally used are broad-spectrum and kill beneficial species with the pests.

Cultural controls such as rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival, decreasing the need for chemical control. Non-preferred crops are:

- *P. major* – canola;
- *P. tectus* – chickpea; and
- *P. falcatus* – wheat and barley.[185]

Lentil is considered vulnerable, and not a useful rotational crop to help control BOM species.

Pre and post-sowing weed management (particularly of broadleaf weeds) is important.

MORE INFORMATION

Information on plague locust control can be found in this GRDC Fact Sheet www.grdc.com.au/Resources/Factsheets/2010/08/Plague-Locust-Control-Factsheet

9.4.2 Australian plague locust (*Chortoicetes terminifera*)

Australian plague locust identification

Adults of the Australian plague locust have a characteristic black spot on the tip of the hind wing. Nymphs or hoppers are more difficult to identify. If swarming in a large band, it is likely to be the Australian plague locust.

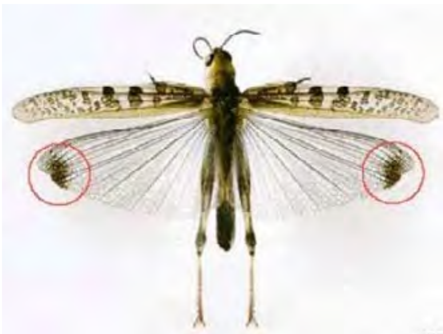

Photo 24: *Australian plague locust. Note the black spot at the tip of the hind wing.*

Photo: APLC via PIRSA.

Australian plague locust damage

Locusts and grasshoppers will cause damage to lentil in the same way that they cause damage to any green material when in plague numbers.[186]

Pulses are susceptible to attack while they remain green. The susceptibility of drying pulse crops is not known.[187] Grain can be rejected at delivery if adult locust, or parts of them, are present in the sample, or if objectionable stains and odours exist.

185 P Umina, S Hangartner (2015) Blue oat mite, Pest Notes Southern, 6 pp. cesar and the South Australian Research and Development Institute, http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/274090/Blue_oat_mite.pdf

186 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

187 GRDC (2010) Plague locust control: a coordinated approach to control plague locusts. Factsheet. 8 pp. September 2010, Grains Research and Development Corporation and Australian Plague Locust Commission, https://grdc.com.au/Resources/Factsheets/2010/08/Plague-Locust-Control-Factsheet

MORE INFORMATION

Comprehensive details and government responses to plague locust threats can be found on state government websites and at:

Australian Plague Locust Commission: http://www.agriculture.gov.au/pests-diseases-weeds/locusts/about/australia

Australian plague locust life cycle

Most locust plagues originate in south-west Queensland and adjacent areas of South Australia, New South Wales and the Northern Territory. Populations develop following rainfall in this area.

With suitable conditions, autumn swarms may migrate 200–500 km into pastoral and adjacent agricultural areas. On arrival, they lay millions of eggs in bare ground which can produce the spring outbreak.

Control

The Australian Plague Commission (APLC) undertakes surveillance threat assessments, forecasting and control measures when locust populations in outbreak areas have the potential to cross into agricultural locations.

In the event of a plague, local government may undertake some spraying operations within their own area. Where significant problems are expected, government agencies may undertake large-scale control in pastoral and adjacent agricultural areas.

Effective locust suppression can only be achieved by landowners, local government and government agencies working cooperatively, together with ongoing APLC activities.

Cultivating egg beds will destroy the eggs. Use approved insecticides to target the bands of nymphs before they take flight. Advice on timings and chemicals can be obtained from state government departments or local chemical resellers. Often APVMA permits are required for chemical use.[188]

9.5 Occasional pests of lentil

The pests listed below are seldom seen in lentil crops, but have been known to occur and under ideal conditions may occasionally represent an economic threat. See more specific publications for full details.

Helicoverpa armigera is an occasional pest of lentil in the southern region and is detailed in “9.3.1 Helicoverpa species: native budworm and corn earworm (Helicoverpa punctigera and H. armigera)”.

Cutworms

Cutworms include the common cutworm or Bogong moth (*Agrotis infusa*), black cutworm (*Agrotis ipsilon*), brown or pink cutworm (*Agrotis munda*), herringbone cutworm and other *Agrotis* species.

MORE INFORMATION

For more details on identification, see: Insect ID: The Ute Guide: https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/South/Cutworms

Cutworm identification and life cycle

Cutworm larvae are hairless with dark heads and usually dark bodies. They live in the soil and grow to 50 mm. They curl up and remain still if disturbed.[189]

Female moths lay eggs in soil in lightly vegetated or bare areas. Larvae have six growth stages (instars).

Cutworm monitoring, damage and control

Cutworm is a sporadic emergence pest. It attacks all crops and pastures including lentil.

Large larvae (20–40 mm) ringbark or cut off seedlings at ground level; the final sixth-stage larvae eat 86% of food.

188 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

189 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

Check crops from emergence to establishment. Look for patchy or thin parts of the crop. Scratch the soil to reveal hidden larvae near the base of recently damaged plants.

Larvae feed at ground level, chewing through leaves and stems. Stems are often cut off at the base. Damage mostly occurs at night. When larva numbers are high, crops can be severely thinned.

Treat affected patches with a registered insecticide. Spraying in the evening can be more effective.[190] Commonly used insecticides registered for use on cutworm are shown in Table 7 with details in Table 8.

Biological controls include a number of parasites, disease and spiders.

9.5.1 Balaustium mite (*Balaustium medicagoense*)

MORE INFORMATION

For more details on identification, see: Insect ID: The Ute Guide: https://grdc.com.au/Resources/Ute-Guides/Insects/Mites/South/Balaustium-Mite

Balaustium mite identification and life cycle

Correct identification is critical for control.

Balaustium mite adults grow to 2 mm, with variable colours but are mainly dark red to brown.. They are slow-moving and have characteristic short hairs covering the body. They also have a 'pad'-like structure on the forelegs. Newly hatched nymphs have six bright orange legs, while adults have eight red legs.

Balaustium mite activity is from March to November in a Mediterranean climate. The mite requires autumn rainfall for over-summered eggs to hatch.[191]

Balaustium mite monitoring, damage and control

Recorded cases of balaustium mite damage have increased markedly in the past decade.

Balaustium mite probes leaves and sucks the sap. It usually causes little damage, except when numbers are high and plants are already stressed, when it can cause significant damage. Under high infestations, plants can wilt and die.

In lentil, balaustium mite causes irregular white spotting or bleaching of the leaves. With good conditions, crops often outgrow the damage.[192]

Check crops throughout the growing season, particularly in paddocks with a history of chemical treatments for redlegged earth mite (RLEM).[193]

Aim to manage balaustium mite without relying on chemicals as no insecticides are registered in pulses and the mite has a high natural tolerance to many insecticides. It will generally survive applications aimed at other mite pests. Research in Victoria has shown balaustium mite to be much more tolerant of omethoate, bifenthrin, chlorpyrifos, methidathion and alpha-cypermethrin than redlegged earth mite.

Most synthetic pyrethroids are not effective on balaustium mite, lucerne flea or bryobia mite (and no insecticides are registered for balaustium or bryobia mites in lentil). Balaustium mite is also more tolerant of organophosphate insecticides than RLEM.[194]

190 S Hangartner, G McDonald, P Umina, R Kimber (2015) Cutworm, Pest Notes Southern, cesar and the South Australian Research and Development Institute, www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/cutworm

191 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

192 P Umina, S Hangartner, B Kimber, A Govender (2015) Balaustium Mite, Pest Notes Southern, cesar and the South Australian Research and Development Institute, http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Balaustium-mite

193 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

194 T Yeatman, W Hawthorne, J Paull, J Bellati, J Egan, K Henry, R Kimber, M Seymour, J van Leur, K Lindbeck, P Matthews, I Rose (2009) Faba beans: The Ute Guide. 127 pp. Primary Industries and Resources South Australia, https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/faba-beans-the-ute-guide

MORE INFORMATION

For more details on identification, see: Insect ID: The Ute Guide: https://grdc.com.au/Resources/Ute-Guides/Insects/Mites/South/Clover-Mite

9.5.2 Clover mite or bryobia mite (*Bryobia* spp.)

Bryobia mite identification and life cycle

Adults are 0.75–1 mm long with pale orange legs with a dark grey-brown to fawn-orange body, which is oval and flattened. Their front legs are 1.5 times body length. Bryobia mite leave distinct feeding trails.

Bryobia mite is highly active during warm conditions in autumn, spring and early summer. They are found in low numbers in winter when they are unlikely to cause problems. Summer rains followed by a warm autumn increases their survival.[195]

Bryobia mite monitoring, damage and control

Bryobia mite is becoming an increasing problem in lentil grown in stubble-retention systems.[196]

Bryobia mite causes most damage in autumn, attacking emerging crops, greatly reducing seedling survival and slowing development. It feeds on the upper surfaces of leaves and cotyledons by piercing and sucking, causing distinctive trails of white-grey spots. Extensive feeding damage can lead to cotyledons shrivelling.

Monitor paddocks during crop establishment and in early autumn and spring, during the warmer parts of the day in fine weather. Look for mites and evidence of feeding damage on newly established crops, as well as clovers and brassica weeds before sowing. Bryobia mite is mostly found on the lower and upper leaf surfaces. Mites can be sampled with a garden vacuum with a fine sieve or stocking placed over the end of the suction pipe to trap mites.

No control thresholds have been developed for bryobia mite.

Control summer weeds early in paddocks to be cropped, especially broadleaf weeds. Before sowing, look for damage and their presence on clover and cruciferous weeds.

No products are registered for control of bryobia mite in lentil. There are no known biological control agents for bryobia mite in Australia.[197]

195 Pulse Australia (2016) Agronomy. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

196 R Rundell-Gordon (2016) Growing lentils: lessons learnt from growing lentils in central and north west Victoria, GRDC Update paper, 17 March 2016, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/03/growing-lentils-lessons-learnt-from-growing-lentils-in-central-and-north-west-victoria

197 P Umina, S Hangartner, G McDonald, A Govender, B Kimber (2015) Bryobia Mite, Pest Notes Southern, cesar and the South Australian Research and Development Institute, www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Bryobia-mite

9.5.3 Earwigs

Earwig species include the European earwig (*Forficulina auricularia*) and Native Earwig (*Labidura truncata*) plus other species.

For more details on identification, see: Insects the Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Earwigs/South/European-Earwig-and-Native-Earwig

For information on management, see: European earwigs Fact Sheet, https://grdc.com.au/Resources/Factsheets/2013/11/European-Earwigs-Fact-Sheet

9.5.4 Mandalotus weevil (Mandalotus spp.)

Mandalotus weevil is becoming an increasing problem in lentil crops with stubble retention.[198]

For more details on identification, see: Insect ID: The Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/Mandalotus-Weevil

There are no control thresholds, cultural control methods or registered insecticides for controlling mandalotus weevil.[199] For more information, see http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Mandalotus-weevil

9.5.5 Thrips

Thrip species include onion thrips (*Thrips tabaci),* plague thrips (*Thrips imaginis*) and western flower thrips (*Frankliniella occidenttalis*).

For more details on identification, see: Insect ID: The Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Thrips/South/Onion-Thrips-Plague-Thrips-and-Western-Flower-Thrips

9.5.6 Brown pasture looper (Ciampa arietaria)

For more details on identification, see: Insect ID: The Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/South/Brown-Pasture-Looper

9.5.7 Looper caterpillar (*Chrysodiexis* spp.)

For more details on identification, see: Insect ID: The Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Moths-butterflies-caterpillars/South/Looper-Caterpillar

9.5.8 Bronze field beetle (Adelium brevicorne)

For more details on identification, see: Insect ID: The Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/Bronzed-Field-Beetle

9.5.9 False wireworm (Gonocephalum misellum)

For more details on identification, see: Insect iD: The Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Beetles-larvae/South/False-Wireworms

9.5.10 Onion seedling maggot (Delia platura)

For more details on identification, see: Insects the Ute Guide. https://grdc.com.au/Resources/Ute-Guides/Insects/Flies/South/Onion-Maggot

198 R Rundell-Gordon (2016) Growing lentils: lessons learnt from growing lentils in central and north west Victoria, GRDC Update paper, 17 March 2016, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/03/growing-lentils-lessons-learnt-from-growing-lentils-in-central-and-north-west-victoria

199 K Perry, B Kimber (2015) Mandalotus weevil, Pest Notes Southern, cesar and the South Australian Research and Development Institute, http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Mandalotus-weevil

9.6 Exotic lentil insects – biosecurity threats

9.6.1 Exotic seed beetles/bruchids

(Coleoptera; Family: Chrysomelidae, sub-family: Bruchinae)

Seed beetles, also known as bruchids, are a group of relatively small beetles that attack ripe or ripening seeds, especially legumes. More than 200 species of bruchids exist world-wide from several genera that are important primary pests with significant economic impact to pulses.

While several pest bruchid species occur in Australia, bruchid damage in lentil is rarely seen in Australia. The potential exists for other exotic lentil-attacking bruchids to be introduced and established in Australia. The host range for these may be quite specific, such as *Bruchus lentis* and *Bruchus ervi*, while other species can attack a wide range of pulse crops. Early detection of new bruchids in lentil may have consequences across a range of crops.

The presence of damaged seed (round holes) in stored grain is an indication of bruchids.

The general form of bruchids and their association with pulses make them unlikely to be confused with other beetle pests associated with stored product. Any bruchids found in lentil – in the field or in storage – should be sent away for further identification. Call the Exotic Plant Pest Hotline (1800 084 881) for more information.

MORE INFORMATION

Plant Health Australia has a Fact Sheet on exotic bruchids, Please see http://www.planthealthaustralia.com.au/wp-content/uploads/2014/02/Exotic-Bruchids-FS.pdf

9.6.2 Exotic leaf-miners (Diptera: family Agromyzidae)

The Agromyzidae are a group of small flies whose larvae feed internally on living plant tissue, often as leaf and stem miners. Key exotic Agromyzidae species for lentil include the American serpentine leafminer (*Liriomyza trifolii*) and pea leafminers (*Chromatomyia horticola, Liriomyza huidobrensis*).

Leaf-mining (tunnelling) is the most obvious symptom that can be seen and surveyed for in the field. Leaf-mining damage caused by exotic Agromyzidae species can be confused with native leaf-miner species and moth larvae. Any suspicious examples of mining should be sent in for identification. Call the Exotic Plant Pest Hotline (1800 084 881) for more information.

Control of *Liriomyza* is difficult. The economic impact could be highly significant in most crops and across most cropping regions if exotic *Liriomyza* enter Australia and is not eradicated.[200]

200 Pulse Australia (2016) Insect management. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

9.7 Beneficial species

All pest populations are regulated to some degree by the direct effects of other living organisms. Beneficial organisms include a range of wasps, flies, bugs, mites, lacewings, beetles and spiders that can reduce insect pest populations through predation and parasitisation. Viruses and fungal diseases also provide control.

A wide range of beneficial organisms can be grouped into three categories:

- Parasites: Organisms that feed on, or in the body, of another host. Most eventually kill their host and are free living as an adult (parasitoids) for example, aphid wasp parasites.
- Predators: Mainly free-living insects that consume a large number of prey during their lifetime, for example, shield bugs, lacewings, hoverflies, spiders, predatory mites and predatory beetles.
- Insect diseases: Including bacterial, fungal and viral infections of insects.

Inappropriate use of an insecticide that reduces the number of beneficial species can result in a more rapid build-up of insect populations and reliance on further use of insecticide.

Integrated pest management (IPM) in its simplest form is a management strategy in which a variety of biological, chemical and cultural control practices are combined to provide stable long-term pest control.[201] See Section 9.1 Integrated pest management.

Photo 25: *A pea aphid being consumed by the seven-spotted lady beetle (*Coccinella septempunctata*).* Photo: Brad Stokes, University of Idaho

A list of some beneficial organisms is provided below. For more details and photographs of beneficial organisms in insect management, see:

- CESAR website: http://www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/[202]
- the GRDC booklet Insect ID: The Ute Guide.[203, 204]

201 Pulse Australia (2016) Insect management. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

202 www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/

203 D Hopkins, M Miles (1998) Insects: the Ute Guide, Southern Region. 98 pp. Primary Industries and Resources SA

204 GRDC (2013) Insect ID: The Ute Guide, iOs app, Version 1.1, 14 October 2013. https://grdc.com.au/resources-and-publications/app

9.7.1 Beetles

- Carabid beetle (*Notonomous gravis*); https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Carabid-Beetles
- Transverse ladybird and common ladybird; https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Predatory-Ladybird-Beetles-Transverse-Ladybird-Common-Spotted-Ladybird-Minute-TwoSpotted-Ladybird-And-Others

9.7.2 Bugs

- Damsel bug (Family Nabidae); https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Damsel-Bug
- Assassin bug; https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Assassin-Bugs
- Glossy shield bug; https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Glossy-Shield-Bug
- Spined predatory shield bug (*Oechalia schellenbergii*); https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Spined-Predatory-Shield-Bug

9.7.3 Flies

- Hoverfly (Family Syrphidae);
- Tachinid fly; https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Tachinid-Calliphorid-and-Sarcophagid-Flies

9.7.4 Lacewings

- Green lacewing (Family Chrysopidae); https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Green-Lacewings
- Brown lacewing (Family Hemerobiidae); https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Brown-Lacewings

9.7.5 Mites

- Pasture snout mite (*Bdellodes lapidaria*); https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/Snout-Mites-Pasture-Snout-Mite-And-Spiny-Snout-Mite
- French anystis mite; https://grdc.com.au/Resources/Ute-Guides/Insects/Predators/South/French-Anystis-Mite

9.7.6 Caterpillar wasps

- Orange caterpillar parasite wasp; https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Orange-Caterpillar-Parasite
- Two-toned caterpillar wasp
- Banded caterpillar wasp; https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/North/Banded-Caterpillar-Parasite
- Telenomus wasp and Trichogramma wasp; https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Caterpillar-Egg-Parasites
- Orchid dupe; https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Orchid-Dupe
- Braconid wasp (*Microplitis demolitor*); https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/North/Microplitis-demolitor

9.7.7 Aphid wasps

Aphidius ervi and *Trioxys complanatus* wasp; https://grdc.com.au/Resources/Ute-Guides/Insects/Parasites/South/Aphid-Parasites

9.7.8 Spiders

Wolf spider (Family Lycosidae);

Jumping spider (Family Salticidae).

9.7.9 Insect diseases – viral & fungal

Bacillus thuringiensis (*Bt*);

Nuclear polyhedrosis virus (NPV).

9.8 Commonly used registered insecticides

Table 7: Registered insecticides commonly used in pulses in Australia. Adhere to registered rates and withholding periods.

Active ingredient Example trade name	Red legged earth mite (RLEM)	Blue oat mite (BOM)	Lucerne flea	Bluegreen aphid	Native budworm	Brown pasture looper	Cutworm	Locust	Withholding period (days)	
									Harvest	Grazing
alpha-cypermethrin DOMINEX® DUO	NSW ACT Vic TAS SA WA	NSW ACT Vic TAS SA WA			NSW, ACT, Vic, SA, WA		NSW ACT Vic TAS SA WA	P	21	35
chlorpyrifos LORSBAN® 500 EC	NSW	NSW								2
cypermethrin SCUD®					NSW Vic TAS SA WA			P	21	35
deltamethrin DECIS® OPTIONS				All states			NSW WA		7	
dimethoate Various	Vic Tas SA		WA							14
endosulfan* Various	All States	NSW WA							Nil	49
esfenvalerate SUMI-ALPHA FLEX®	All states	All states			All states				14	7
gamma-cyhalothrin TROJAN®	NSW Vic Tas SA WA				Sth NSW, WA, Vic, SA, ACT			P	7	7
lambda-cyhalothrin KARATE® ZEON	NSW Vic Tas SA WA				NSW Vic SA WA			P	7	7
Maldison FYFANON® ULV	NSW									1
omethoate LE-MAT®	NSW Vic Tas SA WA	Qld NSW								1
metarhizium anisopliae GREEN GUARD®								All states		

■ Registered for use in the indicated states. * Endosulfan not permitted post-emergence in pulses. P = Permit only so check if still applicable and which crops are listed on the permit.

Source: Southern Lentil Best Management Practices Training Course Manual (2016), Pulse Australia

9.8.1 Comments on insecticides

Registrations and use details may differ between states. Always read the label for specific details and information on registration status and insects controlled.[205] Check the APVMA website (http://apvma.gov.au) for labels.

Table 8: Comments on insecticides.

Insecticide & trade name	Remarks
alpha-cypermethrin DOMINEX® DUO	Best results if sprayed at egg hatching of native budworm. Apply when damaging numbers first appear in the crop. Use higher rate if native budworm larvae are longer than 10 mm. Use higher rate if native budworm are longer than 20 mm for Fastac®. Can be used post-emergence for redlegged earth mite control in field pea.
chlorpyrifos LORSBAN®	Active against a wide range of insect pests. Not systemic. Very highly toxic to fish.
dimethoate Various	Apply to the emerged crop. Has contact and systemic activity.
esfenvalerate SUMI-ALPHA FLEX®	Use 130 ml/ha for native budworm larvae less than 10 mm, 200 ml/ha if 10–20 mm long and 330 ml/ha for >20 mm long.
gamma-cyhalothrin TROJAN®	For native budworm use higher rate if larvae are longer than 10 mm or the crop is dense. Rainfast after 30 minutes. S5 poison schedule.
lambda-cyhalothrin KARATE® ZEON	For control of native budworm apply at hatching or soon after when the larvae are small. Use the higher rate if larvae are longer than 10 mm or if the crop is dense.
omethoate LE-MAT®	Spray crop 2–5 weeks after opening rains and before serious damage occurs. Rainfast in 1 hour. Application in spring will reduce redlegged earth mite the following year.
metarhizium anisopliae GREEN GUARD®	Biological control agent. Apply in 75–225 L/ha of water for best results when locusts and grasshoppers are at the nymph stage. Do not apply in gusty conditions with winds >8 m/sec or rainfall imminent in next 6 hours. Surfactant and oil supplied.

Source: Southern Lentil Best Management Practices Training Course Manual (2016), Pulse Australia Limited

205 Pulse Australia (2016) Insect management. Southern Lentil Best Management Practices Training Course Manual 2016, Pulse Australia Limited

Diseases

Key points

- **Lentil need good disease management to ensure a quality, blemish-free seed product.**
- **The key diseases in the southern region are Botrytis grey mould (BGM) and Ascochyta blight.**
- **Avoid growing susceptible varieties and use good agronomic management to minimise the risk of disease. Use a three-year break between lentil crops and sow at least 250 m from other lentil, faba bean, chickpea, vetch or lathyrus crops or stubble.**
- **Crop monitoring for disease is essential. There are three critical periods for fungicide application. Accurately identify disease to choose the appropriate fungicide.**
- **Disease pathogens can mutate and overcome resistance. Monitor all varieties regardless of resistance rating.**

The major fungal diseases affecting lentil grown in the Southern Region are Botrytis grey mould (BGM) and Ascochyta blight.[1]

The Pulse Breeding Australia lentil program aims to breed varieties that have resistance to BGM and Ascochyta blight and to investigate options for resistance to viruses.[2]

These diseases can be effectively controlled to prevent them from causing yield loss. Management decisions and seasonal conditions play a significant role in disease outbreaks and grain yield. Lentil growers need to take an integrated approach to disease management in most years to produce a profitable crop.

10.1 Impact and cost of diseases

A 2012 GRDC study reported that disease cost the Australian pulse industry an average of $74 million per year or 14.8% of the gross value of pulse production.[3] Losses would be far higher without the current range of controls, which include the use of resistant varieties, rotation, paddock management and the use of pesticides.

In the Australian lentil industry, disease causes an estimated current average annual loss of $2.7 million, or $21.76 per hectare. This is 4.3% of the average annual value of the crop. Most lentil crops (97%) are treated with foliar fungicides at a cost of $114.15/ha per year. These figures are the same for the southern region as the area of lentil grown elsewhere in Australia is minimal.

In the southern region the most important lentil diseases, with a yearly incidence of 25% or more, are Ascochyta blight, BGM caused by *Botrytis cinerea* and/or *B. fabae*, Alfalfa mosaic virus (AMV), Cucumber mosaic virus (CMV) and Turnip yellows virus (TuYV, formerly Beet western yellows virus (BWYV)).[4]

Based on the value of estimated yield losses, the most important diseases are Ascochyta blight ($133/ha) and BGM (>$131/ha). Cucumber mosaic virus ($54/ha) is less of an issue.

While diseases are not going to be an issue every year, when conditions are right such as in 2016, disease can have devastating results.

10.2 Integrated pest management (IPM) strategies

Disease management in pulses is critical, and relies on an integrated management approach to variety choice, crop hygiene and strategic use of fungicides. The initial source of the disease can be from the seed, the soil, the pulse stubble and self-sown seedlings, or in some cases other plant species. Once the disease is present, the source is then from within the crop itself.

A plant disease may be devastating at certain times and yet, under other conditions, it may have little impact. The interaction of host, pathogen and environment are all critical in disease development and can be represented by the two disease triangles.

1 W Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015) Lentil: Integrated disease management, Pulse Australia website, http://pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

2 GRDC (2016) Pulse Breeding Australia (PBA). GRDC website, https://grdc.com.au/Research-and-Development/Major-Initiatives/PBA

3 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

4 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/Resources/Publications/2012/06/The-Current-and-Potential-Costs-from-Diseases-of-Pulse-Crops-in-Australia

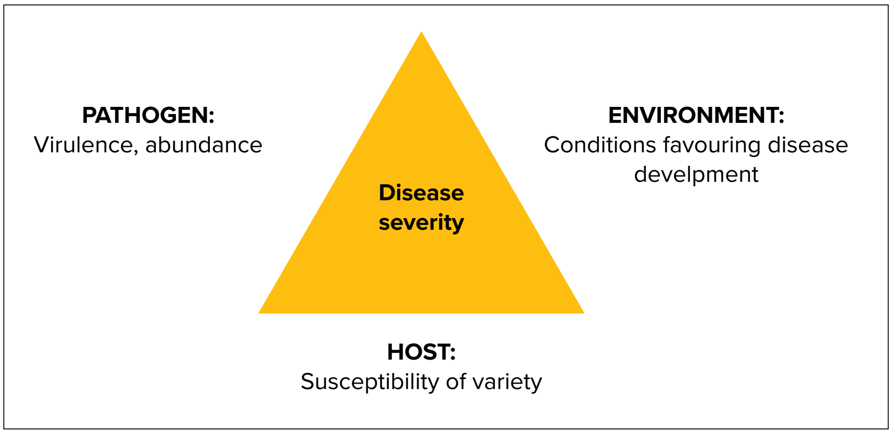

Figure 1: *Fungal disease triangle.*

Source: GN Agrios (1988) Plant Pathology (3rd edition). Academic Press, New York.

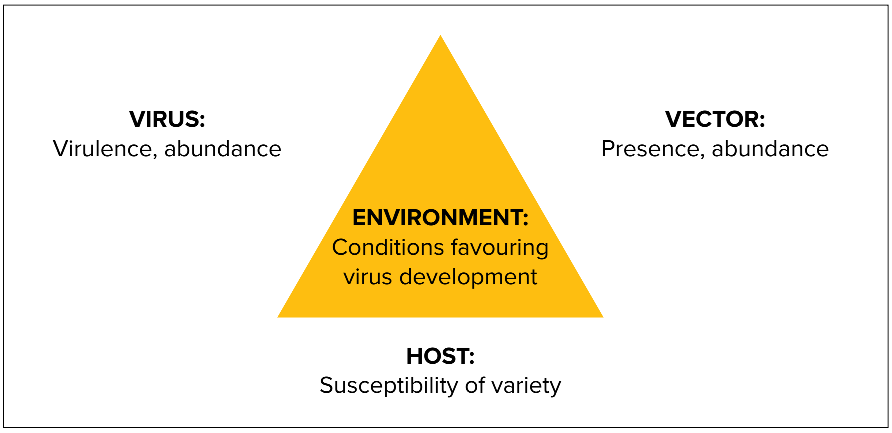

Figure 2: *Viral (and some bacterial) disease triangle.*

Source: RAC Jones, MJ Barbetti (2012) Influence of climate change on plant disease infections and epidemics caused by viruses and bacteria. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 7, 1-31.

Where possible choose a pulse variety that is resistant to the most important diseases in your area. Choose a paddock with low disease risk based on rotation and proximity to other pulse crops. Strategic fungicide application is necessary to minimise disease impact. In high-risk situations fungicide disease-control strategies alone may not be sufficient, particularly if susceptible varieties are grown.

The key aspects to managing diseases in pulses are detailed in Sections 10.3 to 10.12. In summary:

- **Varietal resistance** – Select a resistant variety. Spread risk by sowing more than one variety.
- **Distance** – Separate by at least 250 m from stubble of the same pulse from the previous year. This reduces infection for some diseases.
- **Rotation** – Aim for at least a three-year rotation between planting the same pulse crop. A high frequency of crops like lentil, faba bean, vetch, field pea, chickpea, lathyrus or clover pasture puts pulses at greater risk to multi-host diseases such as BGM, Phoma and Sclerotinia; and canola in the rotation can increase the risk of Sclerotinia.
- **Hygiene** – Practice hygiene by reducing last year's pulse stubble, if erosion is not a risk, and removing self-sown pulses before the new crop emerges.
- **Clean seed** – Sow seed from crops with no disease or a low level of infection, especially at podding. Avoid using seed where there was a known disease infection, particularly for susceptible varieties. Have seed tested for disease.

- **Fungicide seed dressing** - In high-risk situations seed dressings provide partial early suppression of diseases like BGM and Ascochyta blight. They are not effective against viruses and bacterial diseases.
- **Sowing date** - Aim for the optimum sowing window for the pulse variety and your district.
- **Sowing rate** - Aim for a plant population of 100–120 plants per square metre.
- **Wider row spacing** - Wide rows (23–42 cm) delay canopy closure, and may reduce disease if lodging does not occur. Standing cereal stubbles help to keep lentil erect.
- **Sowing depth** - The normal sowing depth is 2–6 cm. When a seed lot is infected with disease deeper sowing will help reduce the emergence of infected seedlings. The seeding rate must be adjusted upwards to account for the potential of a lower emergence and establishment percentage.
- **Foliar fungicide applications** – Susceptible varieties require a more intense fungicide program. Success depends on timing, weather conditions that follow and the susceptibility of the variety grown. Monitoring for early detection and correct disease identification is essential. Correct fungicide choice is also critical.
- **Mechanical damage** - Physical damage from excessive traffic, wind erosion, frost, hail, post-emergent rolling or herbicide damage can increase the spread of foliar disease in pulses.
- **Control aphids** – Integrated pest management to reduce the incidence of aphids can reduce the spread of viruses. Spraying insecticide may assist, but is not always effective or and rarely economic. Usually the virus spread has occurred by the time the aphids are detected.
- **Harvest** - Harvest early to minimise disease infection of seed. Consider desiccation as a tool to enable earlier harvesting.

MORE INFORMATION

For more information see Section 9.2 Identifying pests

MORE INFORMATION

Visit the Pulse Australia webpage for information lentil integrated disease management: http://www.pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

10.3 Select a resistant variety

Selecting a resistant variety is the most effective method of disease control. Other management practices are not always effective and can be expensive and highly dependent on seasonal conditions. Resistant varieties reduce the reliance on foliar fungicides.

The variety resistance ratings are defined as follows:

- Resistant (R) varieties – no economic yield loss is expected under average conditions. Control measures are unlikely to be profitable. Resistant varieties are not immune when conditions are conducive to disease.
- Moderately resistant (MR) varieties are expected to sustain low to moderate yield loss and control measures are likely to be cost effective.
- Moderately resistant to moderately susceptible (MR-MS) varieties are expected to sustain moderate to high losses and control measures are necessary to ensure a profitable crop.
- Moderately susceptible (MS) or susceptible (S) will sustain very high to total yield loss and control measures are essential to produce a harvestable crop.

Most new lentil varieties released across the southern region are resistant to Ascochyta blight at the time of their release.

Variety resistance status may change over time. This can result from disease incursions from overseas or a high population pressure through frequent planting of varieties all relying on the same resistance gene. For instance, a strain with increased virulence to PBA Flash^Φ^, Nipper^Φ^ and Northfield has increased in prevalence and these varieties are now more susceptible to Ascochyta blight.

Under extreme disease pressure Ascochyta blight can still develop in a moderately resistant (MR) variety. Growing lentil in a three-year rotation and away from previous crop stubbles is essential to preserve the resistance genes.[5]

Varieties are now rated for Ascochyta blight on both foliage and pods/seed because there are differences. This may influence control strategies and fungicide timings during podding to preserve seed quality and marketability.

Under high disease pressure, all varieties will require fungicide protection to control disease epidemics. In wet seasons, such as 2016 when repeated cycles of infection occurred, even MR varieties can have yield-reducing levels of disease.

The disease ratings in Table 1 were current in early 2016. Always check the updated disease ratings each year in the current crop variety guides for each state or in the National Variety Trials (NVT) Crop Disease Au app.

MORE INFORMATION

Crop variety guides https://grdc.com.au/Research-and-Development/National-Variety-Trials/Crop-Variety-Guides

Natinoal Variety Trials (NVT) Crop Disease Au app: http://www.nvtonline.com.au/interactive-tools/apps/

MORE INFORMATION

For more information see Section 9.3 Key pests of lentil

Table 1: Lentil disease ratings

Variety	Ascochyta blight foliar	Ascochyta blight seed/pod	Botrytis grey mould (BGM)
Small red seed			
Nipper⚐	MR-MS	MR	R/MR
Northfield	MR-MS	MR	S
PBA Bounty⚐	MR-MS	MS	MS
PBA Herald XT⚐	R	R	R/MR
PBA Hurricane XT⚐	MR	R/MR	MR-MS
Medium red seed			
Nugget	MR-MS	MR-MS	MR-MS
PBA Ace⚐	R	R	MR-MS
PBA Blitz⚐	MR	MR-MS	MR
PBA Bolt⚐	MR	R/MR	S
PBA Flash⚐	MS	MS	MR-MS
Large red seed			
Aldinga	MR-MS	MS	MS
PBA Jumbo⚐	MR-MS	S	MS
PBA Jumbo2⚐	R	R	R/MR
Medium green lentil			
PBA Greenfield⚐	MR-MS	MR-MS	MR
Large green lentil			
Boomer⚐	MR	MR-MS	MR-MS
PBA Giant⚐	MR	MS	MS
Tiara	–	–	S

Resistance order from best to worst: R > R-MR > MR > MR-MS > MS > S.
R = resistant, M = moderately, S = susceptible.

Disease ratings from Pulse Breeding Australia. Varieties with a disease rating up to R-MR may require fungicide application under severe disease pressure.

Source: W Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015) Lentil: Integrated disease management, Pulse Australia, http://pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

5 A Lawson (2016) Disease pressure builds with intensive lentil production. GRDC Media Release, 14 April 2016, https://grdc.com.au/Media-Centre/Media-News/South/2016/04/Disease-pressure-builds-with-intensive-lentil-production

MORE INFORMATION

See GRDC Media release: Disease pressure builds with intensive lentil production https://grdc.com.au/Media-Centre/Media-News/South/2016/04/Disease-pressure-builds-with-intensive-lentil-production

10.4 Paddock selection

Sow lentil into standing stubble of previous cereal stubble to protect against rain-splash of soilborne spores, protect against erosion and reduce attractiveness of the crop to aphids that can spread viruses.

Rotational crops

Allow three years between growing lentil crops in the same paddock. Do not sow adjacent to lentil stubble, particularly downwind. If possible, aim to separate this year's lentil crop from last year's lentil stubble by a distance of at least 250 m to minimise the inoculum for BGM and Ascochyta blight.

Some diseases have potential for cross infection across more than one pulse crop (Table 2). Reduce disease risk by not sowing adjacent or into faba bean, chickpea, vetch or lathyrus stubble. If this is not possible, manage the lentil crop with a high-BGM-risk management strategy.

In district of high Sclerotinia risk, avoid planting lentil after canola or other broadleaf crops which act as alternative hosts to this disease.

Avoid paddocks with high soil nitrogen, as this can lead to greater vegetative growth in lentil (i.e. heavy canopies), predisposing the crop to disease development, particularly BGM.

Table 2: Diseases occurring on pulses with potential for cross-infection.

	Chickpea	Faba bean	Lentil	Lupin	Pea	Vetch
Botrytis grey mould						
Botrytis cinerea[1]	★★	★★	★★		★★	★★
Chocolate spot						
Botrytis fabae	★	★★	★★			★★
Cercospora leaf spot						
Cercospora zonta		★★				
Sclerotinia						
Sclerotinia sclerotiorum	★★		★★	★★	★★	
Sclerotinia trifoliorium	★★	★★		★★		
Bacterial blight						
Pseudomonas andropogonis						
Pseudomonas syringae pvv *syringae*		★★	★		★★	
Pseudomonas syringae pvv ***pisi***					★★	
Ascochyta blight						
Ascochyta fabae		★★				★
Ascochyta lentis			★★			
Ascochyta pisi					★	★
Ascochyta rabiei	★★					
Phoma blight						
Phoma medicaginis var *pinodella*	★		★	★	★★	★★
Black spot (see also Phoma and Ascochyta)						
Mycosphaerella pinodes	★★	★	★		★★	★

	Chickpea	Faba bean	Lentil	Lupin	Pea	Vetch
Anthracnose						
Colletotrichum gloeosporoides				★★		
Brown leaf spot						
Pleiochaeta setosa				★★		
Grey leaf spot						
Stemphylium botryosum	★		★★	★★		
Downy mildew						
Peronospora viciae					★★	★
Powdery mildew						
Erysiphe pisi					★★	
Septoria						
Septoria pisi					★★	
Phomopsis						
Phomopsis leptostromiformis				★★		
Rust						
Uromyces viciae-fabae[2]		★★			★	★★
Root-lesion nematode						
Pratylenchus neglectus	★					
Pratylenchus thornei	★★					★★
Stem nematode						
Ditylenchus dipsaci	★	★★			★★	★
Viruses						
Bean yellow mosaic virus		★		★★		
Cucumber mosaic virus	★★	★	★★	★★		
Luteo viruses complex (eg BLRV & BWYV)[3]	★★	★★	★★	★	★★	★★
Pea seedborne mosaic virus (PSbMV)[4]		★★			★★	
Alfalfa mosaic virus	★★	★	★★			★
Wilt						
***Fusarium oxysporum*[2]**				★★	★★	
Root rots						
Aphanomyces root rot *(Aphanomyces euteiches)*[5]		★★			★	
Fusarium	★	★	★	★	★	★
Macrophomina	★				★★	
Phytophthora medicaginis	★★					
Pleiochaeta setosa			★★			
Pythium[1]	★		★	★	★	
Rhizoctonia	★	★★	★★	★★	★★	★★
Sclerotinia[6]	★		★	★	★	

★ This disease occurs in this crop, but does not caused major damage. ★★ This disease has caused major damage to this crop.

1 Pythium and Botrytis grey mould is worse (★★★) in white peas than dun peas (★★) 2 Strain differences between crops. 3 Luteovirus complex on pulse crops consists of Bean leafroll virus (BLRV), Beet western yellows virus (BWYV, syn. Turnip yellows virus, TuYV), Soybean dwarf virus (SbDV) and Phasey bean virus. Each of these viruses can be found on each of the pulse crops, but their impact varies between host species and regions. 4 PSbMV causes seed markings on faba bean that can have a serious impact on price. However, as Australian PSbMV strains are only seed-borne in field pea, faba bean infections only occur if the crop is grown in the vicinity of PSbMV infected field pea crops. 5 Aphanomyces root rot has been identified as a cause of severe root rot on faba bean in commercial fields in NSW. So far it is not reported as a problem in Australian field pea, but it is considered a very serious field pea disease overseas. 6 Sclerotinia (root rot) is worse (★★) in Kabuli than Desi (★).

Source: Pulse Australia (2016) Southern lentil best management practices training course

MORE INFORMATION

For more information on variety cross-contamination, see: http://pulseaus.com.au/growing-pulses/bmp/lentil/variety-cross-contamination

Herbicide interaction

Herbicide residues in soil and crop damage from herbicides are known to increase the risk of disease. This may be by directly damaging the plant, making it easier for the disease to enter, or by reducing the overall health of the plant, making it more vulnerable to disease.

Ensure the maximum plant-back period for all herbicides is adhered to, as herbicide residues may weaken plants' resistance to disease.

When diagnosing damage in the field it can be difficult to determine whether the cause of damage is disease or herbicide or a combination of both.

It is not recommended to grow a pulse again after a failed pulse crop because disease pressure is increased, herbicide residues can be limiting, and there is the potential for cross-contamination of seed, reducing its market value.[6] Please see "Table 3: Minimum re-cropping intervals and guidelines" for more information.

10.5 Good hygiene

Diseases can carry over on stubble, seed or soil (Table 3).

Table 3: Carryover of major lentil diseases.

Disease	Stubble	Seed	Soil
Botrytis grey mould (BGM)	★★★	★	★
Ascochyta blight	★★★	★★	★

The relative importance as sources of infection is indicated by the number of stars, with three starts being the most important.
Source: Pulse Australia (2016) Southern lentil best management practices training course.

The BGM and Ascochyta blight pathogens can carry over from one season to the next on infected lentil seed, stubble and volunteer plants. Purchase disease-free seed or retain seed from the healthiest crop to avoid carryover on infected seed.

Control volunteer lentil during the summer–autumn season and in fallows to avoid carryover of inoculum of BGM and Ascochyta blight.

Some of the viruses affecting lentil have wide host ranges. Weeds, particularly perennial legumes, can host viruses and their aphid and leafhopper vectors (e.g. Cucumber mosaic virus).

Weeds may also host Sclerotinia and should be controlled prior to planting and during crop growth.

BGM can carry over on the stubble of alternate hosts such as faba bean, vetch, chickpea or lathyrus as they may be a potential harbour of the same botrytis species (*Botrytis fabae* and *B. cinerea*) that can attack lentil.

Burn or bury last year's pulse stubble if erosion is not a risk. Grazing over summer may reduce stubble, but be aware that stock can carry infected stubble between paddocks. Adhere to grazing restrictions on stubble from crops treated with fungicides.

Infected stubble may also be carried by wind, water (particularly flooding) or machinery at harvest.

Where practical, clean all machinery, transport equipment and storage bins thoroughly with compressed air before moving to the next paddock. Spray rigs, should also be cleaned to reduce the risk of disease transmission particularly if contractors are used.

Paddock inspections should be carried out using clothing suitable to the task and footwear should ideally be disinfected prior to entering a crop. This is an important point for agronomists who may move through several crops in one day.

Floodwaters may transport disease agents.

6 W Hawthorne (2007) Residual Herbicides and Weed Control. Pulse Australia Southern Pulse Bulletin, PA 2007 #03, http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides

10.6 Use clean seed

Seed retained on-farm for sowing should be from the cleanest paddocks or section of paddock. Preferably use seed with nil disease infection.

A fungal threshold of <1% is acceptable. Definitely avoid using seed with >5% Botrytis or 5% Ascochyta infection.

Avoid using seed infected with either Cucumber mosaic virus (CMV) or Alfalfa mosaic virus (AMV). A threshold of <0.1% seed infection is recommended for sowing in high-risk areas, and <0.5% seed infection for sowing in low-risk areas.

If seed is more than one year old, frosted, weather damaged or diseased, its germination and vigour may have deteriorated. This may increase its susceptibility to disease attack.

10.6.1 Seed dressings

Fungicide seed dressings are registered in lentil to control seedborne Ascochyta blight and BGM (Table 4).

Table 4: Seed dressings registered for use with lentil.

Active ingredient	**Thiram + thiabendazole**
Example trade name	**P-Pickel® T**
Ascochyta blight	Registered
Botrytis grey mould (BGM)	NR
Damping off	Registered
Fusarium	Registered
Phoma root rot	NR
Phytopthora root rot	NR
Pythium	Registered
Jurisdiction	**All states**

NR = not registered for use in this crop.
Refer to the current product label for complete 'Direction for Use' prior to application.
Prior to the use of any crop protection product, ensure that it is currently registered or that a current permit exists for its use in lentil.

Source: Southern lentil best management practices training course, (2016), Pulse Australia

Thiabendazole plus thiram (eg P-Pickel T®) is registered in lentil for Ascochyta blight and seedling root rots (*Fusarium* spp. and *Pythium* spp.), but also has efficacy against botrytis seedling blight. Seed dressings are not effective on viruses nor on bacterial diseases.

Seed dressings reduce the establishment of seedborne diseases in crops and protect seed from infection by soilborne fungi including seedling root rots. Some fungicide seed dressings also protect seedlings from external airborne infection for the first few weeks. This is important in reducing the subsequent establishment and spread of disease within crops. Seed treatments provide effective control for a maximum of 4–6 weeks after sowing, but do not provide absolute control.

Sowing untreated seed infected by botrytis can result in the development of botrytis seedling blight, which causes early seedling death and reduced seedling establishment

It is important that seed treatments are evenly distributed on seed to ensure each seed gets an effective dose. This is enhanced for flowable seed treatments by dilution with water (refer to the label). Secondary mixing of treated seed through an auger assists to obtain even seed coverage. Correct calibration of the applicator and a consistent seed flow are critical for the recommended rate of seed treatment to be applied.

Many fungicide seed dressings are toxic to rhizobia so their contact time must be minimised. Read the labels for compatibilities. Ideally, seed should be treated with fungicide and then, in a separate operation, inoculated with rhizobium just before sowing. Sowing should occur immediately after rhizobium has been applied, particularly in acid soils. Granular or liquid injection of inoculum in-furrow eliminates the contact between seed treatments and rhizobia.

10.7 Sowing

10.7.1 Sowing date

Lentil are quick to emerge, but their early growth is slow, and they can take a long time to completely cover the ground, especially if maximum daily temperatures are below 15°C.

Early sowing results in more vegetative growth and crops may be prone to lodging, increasing the risk of disease infection. Frost risk also needs to be considered.

Later sowings reduce disease risk, but can result in lower yields due to the risk of dry conditions, high temperatures at flowering and pod-fill and reduced crop height making harvest difficult.

Disease-resistant varieties may be sown earlier than other varieties since disease risk is reduced.

The optimum sowing time for lentil is dependent on location and disease risk:

- Early sowing is usually beneficial in medium to low rainfall areas or in areas prone to early, quick finishes to the season. This is provided that weeds, BGM and Ascochyta blight are effectively controlled.
- Delayed sowing is required in areas where high biomass production occurs in spring, and lodging occurs pre-flowering making effective BGM control more difficult. The ideal is for the lentil to remain standing until flowering has finished.
- Spring sowing is desirable in some higher rainfall areas, or areas with a long, late growing season.
- In a BGM-prone area, sow at the later end of the recommended window for your district and sow resistant varieties like Nipper⚜ or PBA Jumbo2⚜ before BGM-susceptible varieties like PBA Bolt⚜ or Aldinga.

The optimum sowing times for lentil are in Section 4 "Planting".

10.7.2 Sowing rate and row spacing

Higher plant populations can exacerbate foliar disease development by encouraging a dense canopy and a more humid environment.

Optimum plant populations for most lentil are 100–120 plants per square metre. Calculate actual seeding rates (kg/ha) based on seed size because sizes vary widely with variety and season. These may typically range from 40 to 70 kg/ha.

Sow to minimise overlap, or avoid sowing headlands, as the higher seeding rate can favour the development of a BGM epidemic.

Seeding rates resulting in lower than recommended plant populations can reduce disease but may also reduce potential crop yield.

Wider row spacing can be part of BGM disease management in lentil by keeping the canopy open and drier for longer, provided lodging does not occur.

Inter-row sowing lentil between standing cereal stubble rows allows trellising and keeps the lentil more erect. Without stubble trellising, row spacings greater than 23 cm make the lentil crop susceptible to lodging and increase the risk of disease development. Botrytis can colonise wet cereal straw, but the ability of cereal stubble to act as a multiplier for BGM is still unclear.

10.8 Risk assessment

Risk assessment is about assessing the known risks (e.g. paddock history), deciding what can be changed and weighing these up against the unknowns (e.g. seasonal conditions). While the overall aim is to reduce the level of risk, each grower will have a different level of tolerance to risk.

There are three steps in risk assessment.[7]

1. Identify factors that determine risk

Pathogen: Exotic *v.* endemic, biotypes, pathogenicity, survival and transmission, amenable to chemical management.

Host: Host range, varietal reactions, disease rating, does susceptibility change with growth stage?

Environment: Weather dependency, interactions with nutrition, herbicides, other diseases, agronomic factors, e.g. planting depth, row spacing, no-tillage, soil conditions.

Risk Management: Access to components of management plan, ease of implementing plan, how many options; cost of implementation.

2. Assess level of factors

Pathogen: Level of inoculum, infected seed, aggressiveness of isolate, weed hosts prevalent in paddock or nearby, paddock history.

Host: How susceptible, nutritional status, frost susceptibility, herbicide susceptibility.

Environment: Length of season, likelihood of rain, drought, waterlogging, irrigation; availability of spray gear; paddock characteristics, herbicide history.

Risk management: Has it not yet been considered, a plan is being developed, or is a plan in place?

3. What risk level is acceptable?

High: Grower is prepared to accept substantial yield loss as potential returns are high and financial situation sound, crop failure will not impact on rotation or other components of the farming system.

Low: Grower needs cash flow and cannot afford to spend much or lose the crop, failure impacts seriously on farming system.

10.9 Symptom sorter

This symptom sorter (Table 5) can be used to help diagnose diseases from other crop-damage causes starting from the symptom description.

7 Pulse Australia (2016) Southern lentil best management practices training course – 2016. Pulse Australia.

Table 5: Lentil symptom sorter (diseases shown in bold)

Crop effect	Distribution	Plant symptom	Disorder
Poor emergence	Patches	Seed rotted	**Damping off**
			Botrytis seedling blight
		Plants chewed	Mice
			Snails
	General	Plants distorted	Trifluralin damage
		Plants stunted	Seed sown too deep
		Ungerminated seed	Poor storage
			Insect damage
Wilting	Scattered plants	Reduced growth - yellow	**Fusarium wilt**
		Yellow – red	**Virus**
		Premature death	**Root rots**
	Patches	Stunted	Herbicide damage
		Premature death	**Fusarium wilt**
			Botrytis grey mould (BGM)
			Waterlogging
			Virus
			Salinity
	General	Plants limp	Herbicide damage
Stunted, distorted	Scattered	Reduced growth	Orobanche (broomrape)
		Leaves, stem distorted	**Stem nematode**
			Virus
			Mites
	Patches	Yellow – death of leaves	Iron deficiency
			Manganese deficiency
			Sulfonylurea damage
			Broadstrike® damage
		Yellow/red	**Damping off (Pythium root rot)**
			Virus
			Nodulation failure
		General	Herbicide damage (e.g. ormone)
Leaf and stem spotting and discolouration	Scattered plants	Brown lesion with pepper spots	**Ascochyta blight**
		Yellow leaves, grey mould growth on lower stems	**Botrytis grey mould (BGM)**
		Yellow/red	Diflufenican damage
		Tip death	Triazine damage
		Tip death. Shrunken – purplish brown	Zinc deficiency
		Shrunken – purplish brown	**Ascochyta blight**
Pods discoloured	General	Mainly within canopy, may have small black sclerotia	**Botrytis grey mould (BGM)**
		Tan spots on pods with small, dark fruiting bodies within spots	**Ascochyta blight**

Crop effect	Distribution	Plant symptom	Disorder
White fungal growth	Stems and leaves	May be with soft, slimy rot, may have larger black sclerotia	**Sclerotinia blight**
Physical damage	Patches	Plants chewed	Mouse damage
		Plants chewed	Snail damage
		Pods chewed	Native budworm
		Pods chewed	Lucerne seed web moth
		Stem, leaves and pods damaged	Mouse damage
	General	Stem, leaves and pods damaged	Hail damage
		Stem bent and twisted	Frost

Source: Lentils: The Ute Guide, Southern region, (2008), GRDC and PIRSA

Crop monitoring

The two main diseases where monitoring is necessary are BGM and Ascochyta blight.[8] Monitoring for these diseases also provides the opportunity to look for other diseases, weeds or plant disorders. To be effective, crop monitoring needs to include a range of locations in the paddock, preferably following a 'V' or 'W' pattern.

10.9.1 Botrytis grey mould

BGM is more likely to occur in bulky crops following canopy closure. The critical stage for the first action is just before canopy closure when a protective fungicide needs to be applied to ensure coverage and protection of the lower canopy. Inspect just before the commencement of flowering, as temperatures begin to increase, and then regularly through the flowering and seed-filling period.

Symptoms appear as small dark-green, tan or white spots on leaves. Light brown or blanched stem lesions develop and become covered in grey mould, girdling the stems and leading to dead patches in the crop. Small black sclerotes may form on the stem lesions. Infected flowers lead to flower drop and lesions can also occur on pods, creating seed abortion or shrivelled and discoloured seed.

BGM can infect lentil at any time during the growing season, but epidemics generally develop late, after the crop canopy has closed.

BGM develops quickly when conditions are conducive. It requires high leaf moisture or humidity (>70%) within the crop canopy and optimal temperatures of 15°C–25°C for 4–5 days, particularly at flowering and after canopy closure. When humidity levels decrease or maximum daily temperature exceed approximately 25°C, infection levels decline sharply.

Yield losses due to BGM arise from infection of lower stems and leaves, which will spread and lead to stem and plant death, and the eventual formation of dead patches within crops that produce small seed or no seed at all.

More regular crop monitoring and protection may also be required if high-risk situations exist such as:

- immediately adjacent to last year's crop;
- bulky, dense canopy and sown with narrow row spacing;
- non-optimal paddock selection (e.g. waterlogging);
- high disease pressure experienced last year;
- a susceptible variety is planted; and
- shortened lentil rotation interval.

8 Pulse Australia (2016) Southern lentil best management practices training course – 2016. Pulse Australia

10.9.2 Ascochyta blight

The initial symptoms of Ascochyta blight are lesions on the leaves and stems of young plants. A distinguishing feature is fungal fruiting structures (small black dots) visible within the centre of lesions, although these may not be visible in the first few days of lesion development.

Monitoring should commence 6–10 weeks after emergence, or 10–14 days after a rain event. This allows time for disease expression after an infection event, such as transmission from infected seed or rain-splashed inoculum. Infected seedlings can deteriorate quickly and plant parts above the lesion may also break off, making symptoms difficult to detect.

Timing is critical. After the initial inspection, subsequent inspections should occur every 10–14 days after a rain or heavy dew event. During dry periods, inspections can be less frequent. When monitoring, look for signs of lesions on leaves or, if severe, wilting in upper foliage or small areas of dead or dying plants. If present examine individual affected plants for symptoms of infection. This method will allow more of the crop to be inspected than a plant-by-plant check.

Most new lentil varieties for the southern region are resistant to Ascochyta blight at the time of their release. However, variety resistance status can change over time, for instance PBA Flash⦶, Nipper⦶ and Northfield are now more susceptible to Ascochyta blight than when they were released.

10.10 Free alert services for diseases

IN FOCUS

Growers can subscribe to newsletters that provide local disease updates. The services listed below are all free.

South Australian Research and Development Institute (SARDI):

- Crop Watch disease newsletter by email. Subscribe by emailing DK Communications.
- Follow the Crop Watch Twitter account @CropWatchSA

Agriculture Victoria:

- Crop Alert disease update by email. Subscribe by emailing crop.safe@ecodev.vic.gov.au
- General grains information is available on the Twitter @VicGovGrains

Southern NSW and northern Victoria:

- NSW DPI and GRDC provide the Crop Disease Bulletin for advisers in southern NSW and northern Victoria. To subscribe contact Kurt Lindbeck or Andrew Milgate.

Australia-wide:

- GrowNotes Alert on the latest weed, pest and disease issues in your area delivered via app, SMS, voice, email, social media or web portal (or a combination of preferred methods). Subscribe to this GRDC and Agriculture Victoria service on the GRDC website.
- For disease issues across Australia follow extensionAus on Twitter @AusCropDiseases or Facebook.

MORE INFORMATION

More information about free information services is available at http://extensionaus.com.au/field-crop-diseases/resources/newsletters

10.11 Using fungicides

The legal considerations for using fungicides are the same as for herbicides (see Section 8.4 in weeds)

10.11.1 Registered products

Managing foliar disease in lentil is all about reducing the risk of infection. Fungicides are preventative and need to be sprayed before disease is evident. Fungicides protect against new infection, but do not cure existing infection. Getting the timing right is critical.

Unprotected crops can lose more than 50% in yield and in severe cases the crop may drop all of its leaves.

Foliar fungicides are essential for the management of BGM in all varieties, and are an important tool for the management of Ascochyta blight. Varieties with higher levels of disease resistance do not require as many sprays as susceptible varieties.

Early detection of disease is vital and makes disease monitoring essential. Ensure any disease is correctly identified to make sure the correct fungicide is selected. Controlling disease with fungicides depends on:

- the timeliness of spraying;
- the weather conditions that follow; and
- the susceptibility of the variety grown.

The first fungicide spray must be applied as early as necessary to minimise the spread of the disease. Additional sprays are required if the weather conditions favour the disease.

Fungicides give protection for around 2–3 weeks. Any new growth after fungicide is applied is not protected. In periods of rapid growth and intense rain (50 mm over several days) the protection period will reduce to 7–14 days.

Plan ahead to ensure that fungicides can be applied as soon as a decision is made. Do not compromise a fungicide spray to wait until it can be combined with herbicide application. Ideally, spray 1–2 days before significant rain is forecast. Don't delay if rain has already started. Although some fungicide will wash off, the disease will still be controlled.

Foliar fungicides registered for the control of Ascochyta blight and BGM are chlorothalonil, mancozeb and metiram, with carbendazim and procymidone also registered for BGM ("Table 6: Foliar fungicides for the control of foliar diseases in lentil."). Other products may be temporarily available by permit (See Section 10.12.2 Current minor use permits (MUP)). Check pesticide registrations and permits for any changes in use patterns before using fungicides.

Spraying against BGM before canopy closure is essential to ensure fungicide penetrates deep into the crop. BGM can only be controlled if it is not allowed to develop before the crop canopy becomes too dense to allow penetration of the fungicide into the lower canopy.

There is no data on efficacy of fungicides to control Sclerotinia white mould in lentil and none are registered for this use.

Check the efficacy of each fungicide against each disease. Some products are broad-spectrum and are registered against a number of diseases (such as products containing mancozeb and chlorothalonil), while others are specific against single diseases (such as products containing carbendazim and procymidone).[9]

Mancozeb, chlorothalonil and metiram are protectants and have no curative action on existing infections. Newly grown, untreated foliage will not be protected.

9 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

Carbendazim and procymidone have protectant and limited curative action and work best when applied before an infection event. These fungicides are not translocated from sprayed leaves so foliage that grows after spraying is not protected.

Label regulations limit carbendazim and procymidone each to a maximum of two consecutive sprays at 14-day intervals. These are systemic fungicides with single-site specificities so the probability of resistance developing increases with regular use. It is best to alternate these with each other or with either chlorothalonil or mancozeb. Observe the withholding period for grain prior to harvest for all fungicides.

Take note of grain and grazing withholding periods (WHPs). For crops that are desiccated or windrowed, the WHP is to that date, not the actual harvest date. For chlorothalonil the grazing withholding period (14 days) and the export slaughter interval (ESI) restriction (63 days).

Table 6: Foliar fungicides for the control of foliar diseases in lentil.

Active ingredient	Carbendazim	Procymidone	Chlorothalonil	Mancozeb	Tebuconazole
Example trade name	**Spin Flo®**	**Sumisclex®**	**Barrack®/Unite®**	**Dithane® Rainshield**	**Folicur®**
Botrytis grey mould (BGM)	Registered	Registered	Registered	Registered	-
Ascochyta blight	-	-	Registered	Registered	-
Jurisdiction	All states	All states	QLD, NSW, Vic, SA, WA	All states	All states

Refer to the current product label for complete 'Directions for Use' prior to application. Prior to the use of any crop protection product, ensure that it is currently registered or that a current permit exists for its use in lentil.
Source: Southern Lentil Best Management Practices Training Course Manual (2016), Pulse Australia

Good leaf coverage with lots of fine droplets will maximise the benefit. Use high water rates. For ground application use 100 L water/ha unless a different minimum rate is specified on the label. For air application use 30 L/ha. Spray early in the morning when dew is present to assist fungicide spread.

A fungicide spray at the commencement of flowering minimises infection and so also protects early podset (Table 6 When to spray for fungal disease control in lentil). Additional protection may be needed in longer growing seasons until the end of flowering. Fungicides last around 2–3 weeks in winter, but as the weather warms in spring they may need to be reapplied to protect new growth every 7–14 days.

Table 7: When to spray for fungal disease control in lentil.

Disease	Occurrence	When to spray
Botrytis grey mould (BGM)	Develops late winter and spring (15–25°C) in humid (>70%) conditions, usually at flowering	Spray just before canopy closure. Subsequent applications may be required during early to mid flowering to maintain protection, depending on the varietal susceptibility, growth and seasonal conditions. These additional sprays become necessary through pod filling if seasonal conditions enable disease progression.
Ascochyta blight	First appears in cool and wet conditions before flowering, but also affects pods and seeds.	Spraying in a moderately susceptible (MS) variety may be required at 10–14 weeks after sowing. Monitor for disease presence in other varieties. Spraying may be required during podding if Ascochyta blight is detected and rain is likely.

Source: Southern Lentil Best Management Practices Training Course Manual (2016), Pulse Australia

Disease-resistant varieties require a much less intensive foliar fungicide program than susceptible varieties.

Photo 1: *Varieties with resistance or managed with fungicide show less disease.*

The BGM-susceptible variety Northfield (front, centre) showing BGM compared with the same variety (immediately behind) treated with fungicide and other varieties (left and right) that have resistance to BGM.

Photo: Lentil: Integrated disease management, (2015), Pulse Australia, http://pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

10.11.2 Current minor-use permits (MUP)

Some products may be available under permit, with conditions attached, until enough data is generated for full registration. In other cases, a temporary permit may be granted when there is a particular seasonal issue.

Pulse Australia holds several minor-use permits on behalf of the pulse industry and is actively involved in the pursuit of new permits and label registrations to meet industry needs.[10]

The current minor-use permits for fungicides are:

- PER81533
  Custodia® for use in lentil to control Ascochyta blight and BGM.
  Current to 30-Sep-2017
- PER81406
  Captan® for use in lentil to control Ascochyta blight, chocolate spot and BGM.
  Current to 30-Sep-2018

MORE INFORMATION

For more information visit:
Pulse Australia webpage: Crop protection products – minor-use permits http://www.pulseaus.com.au/growing-pulses/crop-protection-products

10.11.3 The critical periods for fungicide use

During the critical periods, monitor crops at least once every week and react by spraying ahead of rain events. Fungicide sprays for BGM are likely to be required depending on variety, rainfall and canopy.[11]

Fungicide application during the critical periods is a standard practice in high disease risk situations, e.g. high rainfall regions, in a wet year or in known disease risk zones. A crop is considered to be at high risk if susceptible varieties are grown, crop rotation is tight, planting is adjacent to lentil stubble, where all preventative management strategies cannot be followed, or any combination of factors put the crop at risk.

10 Pulse Australia (2016) Crop protection products, http://pulseaus.com.au/growing-pulses/crop-protection-products

11 W Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015) Lentil: Integrated disease management, Pulse Australia website, http://pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

Additional fungicide applications may be required, particularly if conditions are conducive to disease.

The timing based on the resistance status of varieties is detailed in Figure 3.

Ascochyta blight (AB) Use registered fungicide e.g. chlorothalonil, mancozeb

seeding	seedling & vegetative growth	canopy closure		flowering & podding	dry-down & harvest
	R & **MR** varieties – spray 2–3 days ahead of rain fronts		Mid-Sept if ascochyta blight is present	Extra podding spray if it rains	
Plant mid-May with thiram seed dressing	**S** & **MS** varieties – spray 3 weeks ahead of rain fronts	During August if ascochyta blight is present	Mid-Sept if ascochyta blight is present	Extra podding spray if it rains	Last spray 4 weeks before harvest

Botrytis grey mould (BGM) Use registered fungicide e.g. chlorothalonil, cabendazim, procymidone

seeding	seedling & vegetative growth	canopy closure	flowering & podding
Plant mid-May with thiram seed dressing	**S** & **MS** varieties	Spray at canopy closure if high risk. Mix or rotate with ascochyta spray	Spray ahead of major rain front. Spray every 2–3 weeks if high risk continues (i.e. high humidity and temperatures 18–25°C. Mix or rotate with ascochyta spray.
	R & **MR** varieties	Spray at canopy closure if high risk. Mix or rotate with ascochyta spray	If extreme risk continues, spray ahead of major rain front. Mix or rotate with ascochyta spray.

Figure 3: *Fungicide timing for lentil disease control.*

The specific times are based on variety Resistance (R) or Susceptibility (S) to that specific disease.
Source: Jenny Davidson, SARDI via W Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015), Lentil: Integrated disease management, Pulse Australia website, http://pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

First critical period

This is 10–14 weeks after emergence, shortly prior to canopy closure.

Early application of fungicide is critical to restrict the early development and spread of BGM. In susceptible varieties, or all varieties in districts prone to BGM epidemics, apply a fungicide, irrespective of BGM being present. An application at this stage is the final chance for spray penetration deep into the crop canopy to protect stems.

The presence of Ascochyta blight at this stage is unlikely to cause significant yield losses in varieties that have moderate resistance to foliar infection by Ascochyta blight. Varieties like PBA Flash⁽ᶦ⁾ and Tiara that are more susceptible may require Ascochyta blight protection at this early stage depending on level of infection.

Second critical period

This is at mid-flowering/early pod fill, 14–16 weeks after emergence.

If either BGM or Ascochyta blight is present, or weather is conducive to disease, apply a fungicide. The type of fungicide used will be dependent on the disease susceptibility of the variety. Mixtures of foliar fungicides may be required to give control for both diseases in some susceptible lentil varieties.

Continued infection by BGM at this stage will impact on yield by causing stem infection under the canopy and subsequent plant death. Infection of pods by Ascochyta blight or BGM at this stage will impact on seed quality and yield if seed is aborted.

Third critical period

This is at the end of flowering/mid-pod-fill, 16–18 weeks after emergence.

This is the final growth stage where all pods are formed and protection against Ascochyta blight infection ensures good seed quality is achieved.

If Ascochyta blight is present during pod formation and filling, seed staining can occur in many older varieties. Varieties with seed resistance (Table 1) to ascochyta infection and subsequent staining are the exception. However, in a wet spring even these may require a spray during podding to prevent seed staining. Severe disease pressure from Ascochyta blight can result in yield loss in some varieties due to seed abortion.

BGM control may be required if that disease is severe and weather is conducive to spread.

10.12 Correctly identifying diseases

Correct disease identification is important as this will determine the choice of product.

Symptoms of Ascochyta blight can be easy to confuse with BGM or Stemphylium blight until the pycnidia (fruiting bodies) are formed. In addition, symptoms may be similar to damage on leaves from herbicides or physical events, which then allow minor diseases such as Alternaria to infect the plant tissue. Correct disease identification is important to avoid unnecessary spraying or incorrect fungicide use.

MORE INFORMATION

For more information visit:

NVT online: Disease app for android and ios http://www.nvtonline.com.au/interactive-tools/apps/

GRDC app: GRDC Lentils ute guide https://itunes.apple.com/au/app/grdc-lentils-ute-guide/id1061505797?mt=8

10.12.1 Diagnostic skills

Accurate diagnosis is essential to effectively manage disease.[12] An incorrect diagnosis can be more costly than inaction.

Not all plant disorders are cause by plant pathogens; consider genetic, insect, animal, environmental and agronomic causes.

Some problems involve more than one cause, although usually there will be only one major cause.

Looking at the problem in the paddock is more likely to lead to a correct diagnosis than examining specimens in the office.

Take notes and photographs as well as recording historical information (e.g. sowing date, variety, herbicide history, previous crop, etc) because describing the distribution and symptoms in writing forces us to see what we're looking at. Include this information when sending a sample away for diagnosis.

Follow these steps for an accurate diagnosis:

What is the distribution of the disorder across the district?

- Regional distribution of a problem can eliminate many causes and may identify likely ones.
- If only one crop or one grower in the district has the problem, the cause is unlikely to be environmental (but it could be lightning), or an airborne disease e.g. BGM.
- Isolated problems often reflect some agronomic problem e.g. wrong type or rate of herbicide, poor quality seed, inadequate nutrition, nodulation failure, deep seeding or a soilborne pest or disease.

What is the distribution of the disorder across the paddock? Is the pattern linked with a farming operation (past or present)?

- For example, cultivation, old fence line, sheep camp, sowing, varieties, spraying, harvesting?
- Does it follow drainage lines or is it confined to low or high parts of the paddock?
- Does it affect individual plants throughout the paddock; individual plants at the edge of the crop or in thin areas?
- Does it occur in patches?

12 Pulse Australia (2016) Southern lentil best management practices training course – 2016. Pulse Australia

What's the weather been like?

- Could it be frost, heat stress, drought, waterlogging?

What's the insect activity been like?

- Aphids on the windscreen, moths in the crop?

Determine the progression of symptoms. Look at plants showing the range of symptoms from apparently healthy to just starting to show the problem to just about the die.

- Are plants easy to pull up?
- Do they break off at ground level?
- Look for evidence of feeding by insects, birds or rodents.

Dig up plants:

- Is soil clinging loosely to their roots (evidence of fungal hyphae)?
- Wash soil from roots in bucket and examine against a light-coloured background.
- Make progressive tangential slices into the root, collar and stem looking for vascular discolouration.

Finally, if you suspect a plant disease, remember the disease triangles (Figure 3 and Figure 2). A crop can only have a serious disease problem if three conditions are met:

- susceptible host;
- prevalent causal agent; and
- favourable environment.

10.12.2 Sending samples for disease diagnosis

For accurate diagnoses it is imperative that specimens are carefully selected, well presented and submitted with adequate information.[13]

Selection of specimens

Select plants that show the range of symptoms from slightly to severely affected. Include several healthy plants for comparison. Collect whole plants if practicable, including the roots. For root diseases, include roots and some soil from the root zone (i.e. roots contained in a soil plug).

Preservation

Fresh plant specimens are preferred. If delays in transit are likely and plant material is likely to break down and/or become mouldy, dry specimens are recommended.

DO NOT FREEZE samples.

Fresh specimens are best stored in aerated conditions at high humidity and cool temperatures, preferably not on the back seat of a ute in the sun. Use an esky with fridge bricks to keep samples cool. Diagnosis of viruses requires very fresh specimens. Plants should be wrapped in dry paper and placed in a plastic bag. The paper should not be wet. If dead tissue is present on the sample, damp paper should be avoided as moulds may develop.

Dried specimens are best when dried rapidly, but again not in the back of the ute. Place plant parts between sheets of newspaper (with some pressure), and change paper daily for one week.

13 Queensland Department of Agriculture and Fisheries (2016) How to collect, prepare and package samples for analysis. Queensland Department of Agriculture and Fisheries, https://www.daf.qld.gov.au/plants/health-pests-diseases/plant-pest-diagnostic-services/grow-help/collecting-samples

Packaging

Fresh specimens: specimens likely to decompose e.g. pods should be wrapped in paper and placed in a suitable container. Other plant parts can be placed in partially inflated plastic bags and tied-off (fairly loosely to allow aeration but not desiccation). Soil samples should be packed in a sealed plastic bag or airtight container.

Dry specimens: should be supported between 2 firm surfaces e.g. cardboard, before dispatch.

Note that diagnoses for suspect virus diseases can only be made with fresh specimens.

Labelling

Use waterproof ink. All containers should be clearly marked. If labels are placed inside bags use plastic as paper can become mush.

Dispatch

Specimens should be sent ASAP after collection. Send early in the week to avoid delays over the weekend. Label the item 'Plant Specimens – Perishable' or 'Soil Samples'.

Before sending check whether the relevant authority has a submission form.

The information usually required includes:

- Name and address of grower and location of crop
- Host and variety (if not obvious)
- Area of injury e.g. leaves, roots, pods
- Nature of injury e.g. leaf scorch, root rot, leaf spot
- Prevalence/distribution e.g. localised, entire field, scattered
- Severity
- Soil type, moisture and drainage
- Previous cropping history
- Other useful details such as chemical usage, fertiliser applications, irrigations, growing conditions, frost, weather conditions.

Relevant contacts

South Australia SARDI Plant Diagnostic Centre Ph: (08) 8303 9400 Seed and crop testing: http://pir.sa.gov.au/research/services/crop_diagnostics/seed_and_crop_testing Post to: SARDI Crop Pathology Locked Bag 100, Glen Osmond, SA, 5064 Courier to: Plant Research Centre, Waite Institute Gate 2B, Hartley Grove, Urrbrae, SA 5064	**South Australia** SARDI Molecular Diagnostics Group Ph: (08) 8303 9400 PreDicta B nematode testing: http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b Post to: C/- SARDI RDTS Locked Bag 100, Glen Osmond, SA, 5064 Courier to: SARDI Molecular Diagnostics Group Plant Research Centre Gate 2B Hartley Grove Urrbrae SA 5064

Victoria
DEDJTR Pulse Pathology,
Ph: (03) 5362 2111

Post to: Private Bag, Natimuk Rd, Horsham, VIC 3401	Courier to: 110 Natimuk Rd Horsham, VIC 3401

Victorian samples may also be submitted via agronomists through the CropSafe program. The program aims to provide the early detection of exotic diseases. http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/cropsafe-program

Tasmania
Ph: 1300 368 550
Email: biosecurity.planthealth@dpipwe.tas.gov.au

Prices:
http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories

New South Wales
Submission form: http://www.dpi.nsw.gov.au/about-us/services/laboratory-services/sample-submission

Plant Health Diagnostic Service – Wagga Wagga Ph: (02) 6938 1608 Post to: Wagga Wagga Agricultural Institute, Private Bag, Pine Gully Road, Wagga Wagga, NSW 2650	Plant Health Diagnostic Service - Tamworth Ph: (02) 6763 1133 Post to: Tamworth Agricultural Institute, RMB 944, 4 Marsden Park Rd, Calala, NSW 2340

MORE INFORMATION

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

ExtensionAUS webpage: Disease testing services around Australia https://extensionhub.com.au/web/field-crop-diseases/-/disease-testing-services-around-australia

10.13 Botrytis grey mould (BGM)

Botrytis cinerea and *B. fabae*

10.13.1 Symptoms

BGM is caused by the fungi *Botrytis cinerea* and *B. cinerea causes* BGM in lentil, chickpea and other crops and *B. fabae* causes BGM in lentil as well as chocolate spot in faba and broad beans and vetch.[14]

Plants may be attacked by *Botrytis* at any stage of growth and all above-ground plant parts can be affected. When infected seed is planted the seedlings can suffer seedling blight and die soon after emergence.

Later in the season BGM may appear as small white or greyish-brown lesions on leaves (Figure 5). The affected areas can become covered with a fluffy grey mould under the canopy (Figure 6).

Stem lesions can be light brown or bleached and covered in grey mould. Dark fungal sclerotia on the stems can survive over the summer on lentil stubble (Figure 7).

The mould has masses of spores (Figure 8). These rise from infected plants if disturbed and can quickly spread to other plants.

Infected leaves, flowers and pods wilt and fall to the ground. Plants may ripen prematurely due to infection on the lower stem. Under continuing wet conditions stems can become girdled and whole plants die, leaving gaps in the crop.

Infected pods may not fill properly or may produce no seed (Figure 9). Botrytis grey mould on lentil pods. Infected seed can be discoloured and shrivelled, downgrading quality.

Photo 2: *Early leaf lesions of Botrytis grey mould (BGM) on lentil leaves.*

Photo: Southern Lentil Best Management Practices Training Course Manual, (2016), Pulse Australia Limited

14 G Hollaway, F Henry, M McLean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Diseases in pulses: lentil. In 'Identification and Management of Field Crop Diseases in Victoria' Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch08.php

Photo 3: *Botrytis grey mould (BGM) patch in lentil.*

Photo: W. Hawthorne, formerly Pulse Australia via Southern lentil best management practices training course, (2016), Pulse Australia.

Photo 4: *Botrytis grey mould (BGM) sclerotia on lentil stems.*

Photo: SARDI via Southern lentil best management practices training course, (2016), Pulse Australia

Photo 5: *Botrytis grey mould (BGM) sporulation on lentil stem.*

Photo: J. Davidson, SARDI via Southern lentil best management practices training course, (2016), Pulse Australia.

Photo 6: *Botrytis grey mould (BGM) on lentil pods.*

Photo: J. Davidson, SARDI via Southern lentil best management practices training course, (2016), Pulse Australia

10.13.2 Economic importance

A 2012 GRDC survey estimated the incidence of BGM is 34% of years and 40% of lentil crops in the southern region.[15]

BGM is a very serious disease in areas where lentil is grown in wet, humid conditions, particularly in crops with dense canopies. The disease is predominant in seasons with wet springs, and warm night temperatures over 10°C. High yield losses have been recorded and seed quality may be affected.

Discoloured seed may be rejected or heavily discounted when offered for sale. If seed infection levels are <5% then purchasing new seed is recommended or at least grading the seed to remove small seed, which is more likely to be infected.

10.13.3 Disease cycle

The *Botrytis* fungi survive on alternate hosts: *B. cinerea* on over 138 genera of plants including lentil and chickpea and to a lesser extent lupin, field pea and vetch, and *B. fabae* on lentil, vetch, and faba and broad bean.[16]

Seed that is infected with *Botrytis* can suffer seedling blight soon after emergence and plants die.

15 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

16 R Ford (2008) UM00015 Epidemiology and control of Botrytis grey mould of lentils 2003-2008. Project Final Report, The University of Melbourne, http://finalreports.grdc.com.au/UM00015

Spores from infected plants spread to other plants by wind or rain-splash.[17] Spores may blow long distances from trash or other crops. Moisture is essential for infection; leaves need to remain wet for at least 12–18 hours. Once the disease becomes established it rapidly spreads within the crop. BGM is favoured by warm (15–25°C), humid conditions (>70%) that extend for 4–5 days, particularly at flowering time and after canopy closure when the crop environment is most humid. Early sown crops or those with high sowing rates where crop canopy closure is earlier are usually more affected. Occurrence is worse in wet seasons

Yield loss due to BGM results from stem collapse and plant damage, flower loss and reduced seedset, as well as pod abortion. The disease starts in the leaves and stem and progresses to the pods under prolonged wet conditions.

The disease cycle is shown in Figure 4.

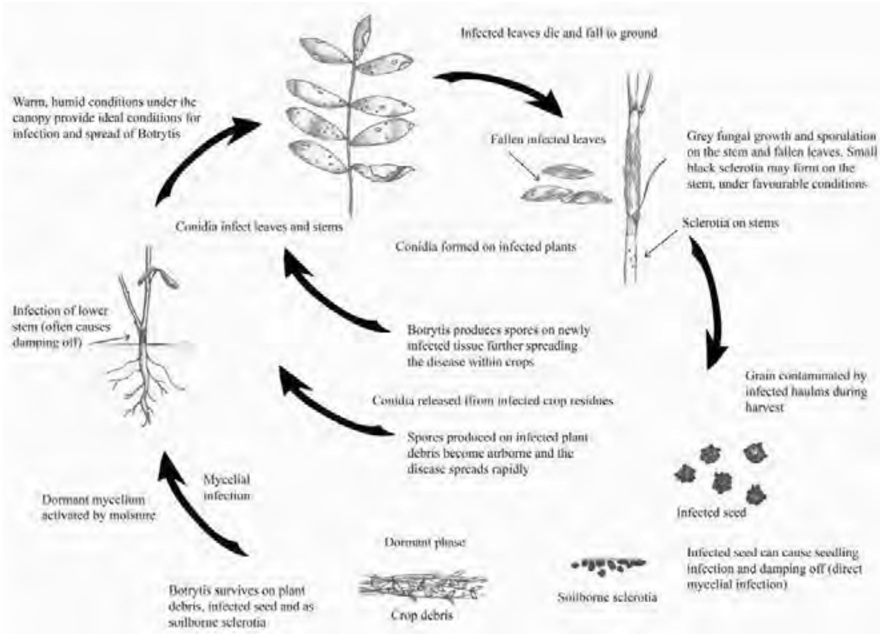

Figure 4: *Disease cycle of Botrytis grey mould (BGM) on lentil*

Illustration by Kylie Fowler.
Source: Diseases in pulses: lentil. In 'Identification and Management of Field Crop Diseases in Victoria', (2015), Department of Economic Development, Jobs, Transport and Resources, http://www.croppro.com.au/crop_disease_manual/ch08.php

Source: G Hollaway, F Henry, M McLean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Diseases in pulses: lentil. In 'Identification and Management of Field Crop Diseases in Victoria' Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch08.php

17 G Hollaway, F Henry, M McLean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Diseases in pulses: lentil. In 'Identification and Management of Field Crop Diseases in Victoria' Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch08.php

10.13.4 Management options

Growers should always assume that BGM inoculum is present, even at low levels. BGM is more dependent on suitable conditions for infection, unlike Ascochyta blight which is more dependent on inoculum, at least in the early phases.

A lentil crop is considered to be at risk of BGM if one or more of the following conditions apply:[18]

- Sown adjacent to lentil, chickpea, faba bean, vetch or lathyrus stubble.
- Is in a high rainfall area.
- Running total of spring rain is >20 mm rain (susceptible variety) or or >45 mm rain (moderately susceptible variety) and more rain is forecast.
- Forecast night temperatures are >8–10°C.
- Was sown early and developed a heavy canopy.
- Sown with a susceptible variety.
- Has a plant population of >120 plants/m2.
- Reached canopy closure by late winter/early spring.
- Has lodged.

Follow the principles of integrated disease management (IDM) which include:

- Use crop rotation and careful paddock selection – allow three years between pulse crops and control self-sown pulses (particularly lentil, faba bean, chickpea, vetch and lathyrus).
- Remove or bury trash (of all pulse crops).
- Select resistant varieties (Table 1 Lentil disease ratings).
- Sow disease-free seed (with no more than five% infection).
- Sow later or at reduced rates to limit crop bulk and delay canopy closure.
- Use fungicide seed dressings (Table 4 Seed dressings registered for use with lentil).
- Canopy management through time of sowing, seeding rate and row spacing.
- Regular crop monitoring.
- Strict hygiene on and off farm.
- Strategic use of foliar fungicides.

While it is important to choose resistant varieties, in areas and years where BGM disease pressure is high all varieties are can become infected.

Crop canopy closure is critical for the development of BGM by providing suitably humid conditions. A more dense canopy is more prone to disease development. Sow at the recommended rate and date for your district. Sowing later or in wider rows can limit disease development, but may also reduce yield. Aim to avoid dense, heavy or lodged canopies in spring.

Always apply fungicides before canopy closure to ensure fungicide penetration of the crop.

Under warm and wet conditions follow-up sprays may be necessary 12–14 days later. Resistant varieties may not need follow-up sprays. Follow-up sprays will be required when:

- BGM is visible within the canopy, or
- relative humidity in the crop is likely to remain high for at least a week, or
- disease in increasing.

Fungicides for BGM control are those containing carbendazim, procymidone, chlorothalonil or mancozeb.

18 W Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015) Lentil: Integrated disease management, Pulse Australia website, http://pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

If BGM pressure or risk is high or the disease is spreading in the crop, then carbendazim or procymidone are more effective than chlorothalonil or mancozeb. Where mancozeb or chlorothalonil is being used primarily for Ascochyta blight control, they have the added benefit of controlling low levels of BGM.

Label regulations limit carbendazim and procymidone to a maximum of two consecutive sprays at 14-day intervals. These are systemic fungicides with single-site specificity so the probability of resistance developing increases with regular use. It is best to alternate carbendazim and procymidone with each other or with either chlorothalonil or mancozeb. Observe the withholding period for grain prior to harvest for all fungicides.

To ensure that BGM is controlled before it has a significant impact on the yield of the crop, the crop should be checked for disease every seven days while the temperature remains below 15°C. If the weather is mild with day temperatures between 15°C and 20°C and humidity over 70% in crop inspections should be made every three days.

Fungicide programs depend on varietal resistance. However, in areas and years of high risk all crops may require foliar fungicides.

For resistant (R) and moderately resistant (MR) varieties[19]:

- These varieties require fewer fungicide applications as the disease moves slower. However, disease can be an issue if left unprotected at canopy closure in high and extended disease pressure situations.
- When disease risk is deemed high, or the disease is detected, apply an early foliar fungicide for BGM control just before canopy closure. The amount of growth, row spacing and erectness of the variety will influence canopy size and when it closes over. Timing of the pre-canopy closure application will vary with the variety, farming system and time of sowing.
- In 2016, when continuing wet conditions promoted BGM growth, even resistant varieties required additional fungicide after canopy closure.

For moderately resistant to moderately susceptible (MR-MS) varieties:

- When disease risk is deemed high, or the disease is detected, apply an early foliar fungicide for BGM control just before canopy closure. The amount of growth, row spacing and erectness of the variety will influence canopy size and when it closes over. Timing of the pre-canopy closure application will vary with the variety, farming system and time of sowing.
- Repeat fungicide application may be needed during flowering and podding depending on the canopy size and seasonal conditions.
- An application at late podding may be required to protect grain quality in high risk situations or if the disease is present. These varieties will have minimal Botrytis in the pods and seeds if the leaf canopy is kept clean of the disease.

For moderately susceptible (MS) varieties:

- If the disease is likely to be present, the risk is deemed high, or the disease is detected, apply an early foliar fungicide for BGM control just before canopy closure. The amount of growth, row spacing and erectness of the variety will influence canopy size and when it closes over. Timing of the pre-canopy closure application will vary with the variety, farming system and time of sowing.
- Repeat foliar fungicide will likely need to be applied during flowering and podding to ensure upper leaves are retained and kept clean of lesions.
- Application at late podding may be required to protect grain quality in high risk situations or if the disease is present. These varieties will have minimal Botrytis in the pods and seeds if the leaf canopy is kept clean of the disease.
- Timing of the pre-canopy closure application will vary with the variety, farming system and time of sowing.

19 Pulse Australia (2016) Southern lentil best management practices training course – 2016. Pulse Australia.

- Varieties with moderate susceptibility to BGM may require no fewer and just as many fungicide applications for botrytis control as a susceptible variety. The disease does move slower in these varieties, but can be devastating if left unprotected in medium to high disease pressure situations.

For susceptible (S) varieties:

- The risk is deemed high for BGM in most situations and so control must start by regularly protecting with foliar fungicide that starts before canopy closure.
- Apply an early foliar fungicide for BGM control just before canopy closure. The amount of growth, row spacing and erectness of the variety will influence canopy size and when it closes over. Timing of the pre-canopy closure application will vary with the variety, farming system and time of sowing.
- Repeat foliar fungicide will likely need to be applied during flowering and podding to protect the crop.
- An application at late podding may be required to protect grain quality. Botrytis in the pods and seeds can occur with minimal disease in the canopy.

The South Australian Research and Development Institute (SARDI) have provided a decision-support model for BGM control in lentil (Figure 5).

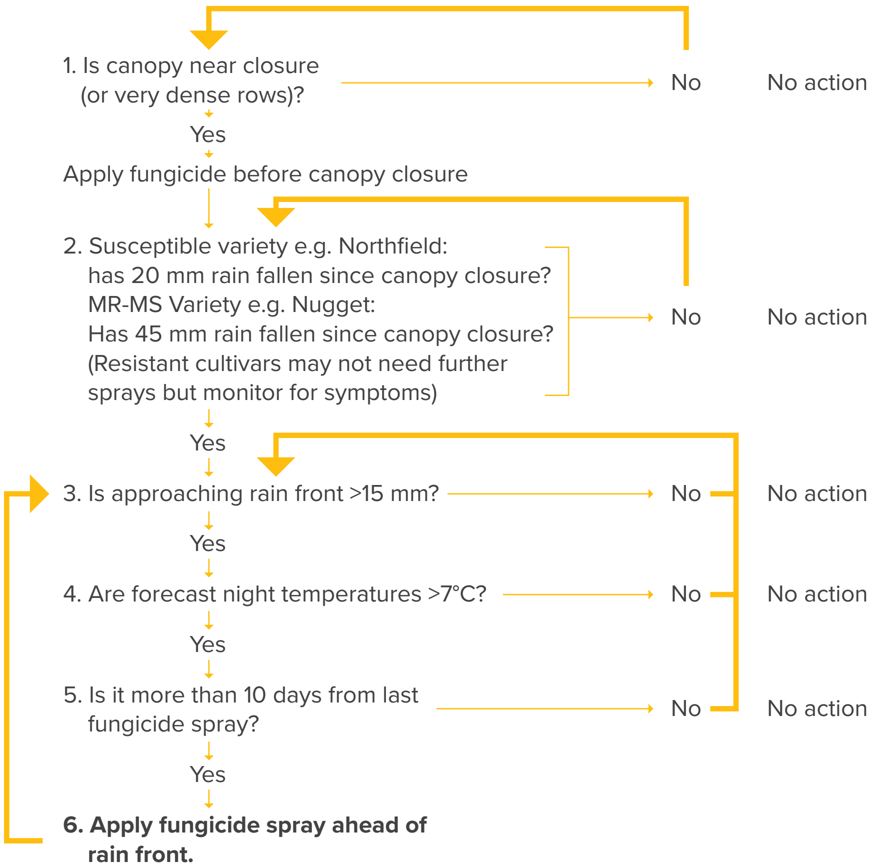

Figure 5: *SARDI decision-support for fungicide applications to control BGM in lentil.*

NB: BGM disease can still develop outside the rainfall and temperature guidelines quoted in the decision model.
Source: J. Davidson, SARDI

10.14 Ascochyta blight

Ascochyta lentis

10.14.1 Symptoms

Ascochyta blight can affect all above-ground plant parts from leaves and stems to flowers and pods (Photo 7).[20] It may appear from seedling to mature stages. Spots start grey but mature to tan, often with a yellow/brown halo. These spots may be small, irregular in shape and are usually scattered over the plant.

The centre of lesions can become speckled with pycnidia, the small black fruiting bodies of the fungus (Photo 8). These pycnidia distinguish Ascochyta blight from other diseases such as BGM or stemphylium blight.

The disease is often inconspicuous and only found by close inspection of the crop (Photo 9).

Sometimes the yellowing may extend to the whole leaf. As the disease develops many of the heavily infected leaflets wither and fall from the plant. Ascochyta blight spots become irregularly shaped, and may merge to cover most of the leaf surface.

Lesions on the stem tend to be elongated, sunken and darker than leaf lesions and usually covered with scattered fruiting bodies i.e. pycnidia. The stems may split and break at the point of infection causing plants to lodge.

On pods, the infected patches are brown and sunken (Photo 10). Well-developed patches can penetrate the pod and infect the developing seeds. Infected seeds may be smaller than normal, shriveled and have purplish-brown patches on the surface reducing quality. Badly infected seeds can have brown or black stains (Figure 11)..

Photo 7: *Ascochyta lesion on a lentil flower*

Photo: Sam Markell, North Dakota State University via Southern lentil best management practices training course, (2016), Pulse Australia.

20 G Hollaway, F Henry, M McLean, P Kant, H Li, S Marcroft, M Rodda, M Aftab, P Trebicki, J Fanning, A Van de Wouw, H Richardson, L Hamilton (2015) Diseases in pulses: lentil. In 'Identification and Management of Field Crop Diseases in Victoria' Department of Economic Development, Jobs, Transport and Resources, CropPro website, http://www.croppro.com.au/crop_disease_manual/ch08.php

Photo 8: *Typical Ascochyta blight lesion showing the pycnidia.*

Photo: SARDI via via Southern lentil best management practices training course, (2016), Pulse Australia

Photo 9: *Ascochyta lesions and leaf necrosis on lentil leaves.*

Photo: W. Hawthorne, formerly Pulse Australia via via Southern lentil best management practices training course, (2016), Pulse Australia.

Photo 10: *Ascochyta lesions on lentil pods.*

Photo: Agriculture Victoria via Southern lentil best management practices training course, (2016), Pulse Australia

Photo 11: *Ascochyta staining on lentil seeds.*

Photo: SARDI via Southern lentil best management practices training course, (2016), Pulse Australia.

10.14.2 Economic importance

Ascochyta blight is a major disease of lentil. It is widespread in southern Australia. A 2012 GRDC survey estimated the incidence of Ascochyta blight is 92% of years and 50% of lentil crops in the southern region are affected when the disease develops.[21]

Severity varies considerably from crop to crop and between seasons. When seasons are favourable for the disease yield losses range from 10–30% in protected crops. Susceptible varieties can suffer significant yield losses and poor seed quality with losses of up to 80% possible in unprotected crops. Discoloured grains may be rejected or discounted.

As the disease is favoured by moist, rainy conditions it is most likely to be a problem in wet seasons and high rainfall areas, particularly where there is a tight history of lentil in the rotation.

The main impact of Ascochyta blight is on seed quality and marketability as discoloured grains may be rejected or discounted. Heavy infection can reduce crop yield but this is less typical.

A change in ascochyta virulence was observed in 2013 with an increase in virulence observed against Nipper⁽ᶦ⁾ and Northfield.[22] This virulent form of ascochyta is now widespread in the southern region.

In 2016 leaf lesions of Ascochyta blight were observed on PBA Hurricane XT⁽ᶦ⁾ lentils in the Maitland and Mallala regions. Testing in controlled environment conditions at SARDI have shown susceptibility of PBA Hurricane XT⁽ᶦ⁾, PBA Ace⁽ᶦ⁾ and PBA Bolt⁽ᶦ⁾, although field reactions have not been confirmed on the latter two cultivars.[23]

There is natural variability in the ascochyta pathogen and the high intensity cropping of a single variety leads to the selection of resistance breaking isolates. The rapid uptake and dominance of PBA Hurricane XT⁽ᶦ⁾ also threatens the longevity of Ascochyta blight resistance in this and numerous other varieties that share a common resistance. Rotation with varieties that have different sources of esistance, e.g. PBA Jumbo2⁽ᶦ⁾, will help the durability of resistance.

21 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

22 J Davidson, R Kimber, C Walela, L McMurray, K Hobson, J Brand and J Paull (2016) Pulse diseases in 2015. GRDC Updates Paper, 9 February 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Pulse-diseases-in-2015

23 S Blake, J Davidson, R Kimber, S Day, L McMurray (2017) Pulse diseases 2016. GRDC Updates Paper https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2017/02/Pulse-diseases-2016

10.14.3 Disease cycle

The ascochyta fungus can survive on infested stubble, self-sown plants and on infected seed. The disease spreads short distances during the growing season when spores produced from diseased plants are spread onto neighbouring plants by rain splash. Airborne spores produced on infested stubble travel over longer distances via wind during autumn and early winter.

Moisture is essential for the spread of Ascochyta blight. Infection can occur at any stage of plant growth following either rain or heavy dew. Infection is likely to occur in environments with prolonged wet, cool (5°C–15°C) conditions and plants become infected early in the growing season. Damage from stem infection often results in serious crop lodging in susceptible varieties.

Heavy rainfall late in the season provides ideal conditions for pod and seed infection. Infection at this stage can cause seed staining and the subsequent downgrading of lentil grain (Photo 11).

The disease cycle is shown in Figure 6.

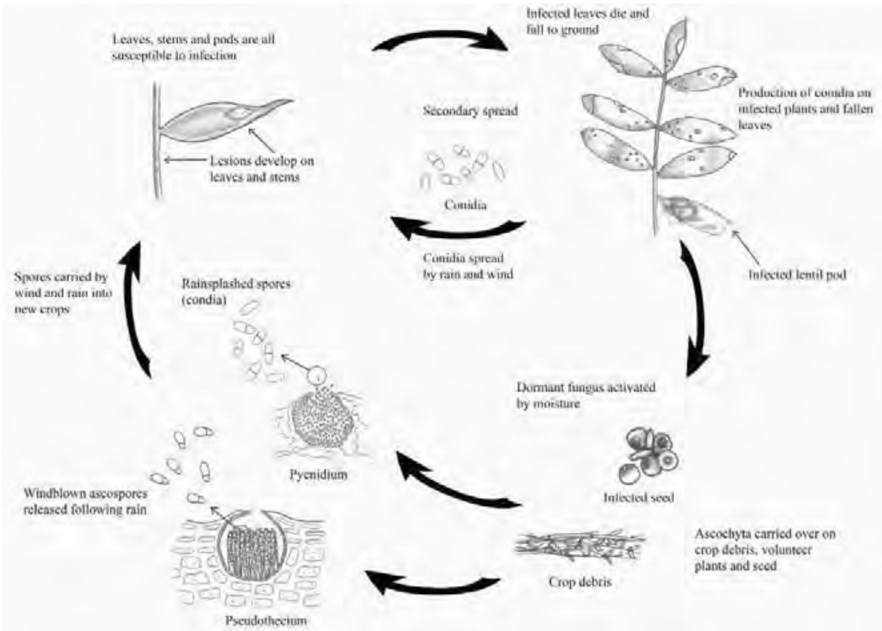

Figure 6: *Disease cycle of Ascochyta blight on lentil.*

Illustration by Kylie Fowler.

Source: Diseases in pulses: lentil. In 'Identification and Management of Field Crop Diseases in Victoria', (2015), Department of Economic Development, Jobs, Transport and Resources, http://www.croppro.com.au/crop_disease_manual/ch08.php

10.14.4 Management options

A lentil crop is considered to be at risk of Ascochyta blight if one or more of the following conditions apply.[24]

- sown adjacent to old lentil stubble
- sown with a susceptible variety
- has been sown early
- history of numerous lentils in the rotation
- ascochyta blight is present at commencement of flowering in a susceptible variety
- Ascochyta blight is present at flowering in a resistant variety during a wet spring

24 W Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015) Lentil: Integrated disease management, Pulse Australia website, http://pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

Integrated disease management (IDM) can minimise the presence of inoculum and protect against potential infection as the crop develops:

- Use crop rotation and careful paddock selection – allow three years between lentil crops and control self-sown lentil.
- Select resistant varieties (Table 1).
- Sow disease-free seed (or with no more than five% infection).
- Sow at the optimum time, not early.
- Use fungicide seed dressings (Table 4). S
- Monitor crops regularly.
- Use fungicides strategically.

Chemical seed treatments reduce the risk of transferring disease to seedlings from infected seed. They only protect the emerging seedling from seedborne ascochyta and botrytis. Seed dressings with thiabendazole will provide a small amount of protection to the emerged seedling from rain-splashed ascochyta or windborne botrytis, but this will only last approximately 6–8 weeks.

Fungicides used in lentil are protectants only. They generally have no systemic action, and they will not eradicate an existing infection. To be effective they must be applied before infection, hence before rain. The key to a successful Ascochyta blight spray program is regular monitoring combined with timely application of registered fungicides.

Target Ascochyta blight in all critical periods, particularly in susceptible varieties and when conditions favour disease spread.

If Ascochyta blight is present during pod formation and filling, seed staining can occur in many older varieties. In a wet spring even resistant varieties may require a spray during podding to prevent seed staining. Severe disease pressure from Ascochyta blight can result in yield loss in some varieties due to seed abortion. Monitoring is essential.

If Ascochyta blight risk is high, or it persists and continues to spread in the lentil crop, then chlorothalonil is considered more effective than mancozeb. Beware of the grazing withholding period (14 days) and the export slaughter interval (ESI) restriction (63 days) with chlorothalonil. The withholding period for grain prior to harvest is 28 days for mancozeb and 14 days chlorothalonil.

Most new lentil varieties for the southern region are resistant to Ascochyta blight at the time of their release. However, variety resistance status can change over time. There is natural variability in the the Ascochyta blight pathogen and the high intensity cropping of a single variety leads to the selection of resistance breaking isolates.

In 2013 an increase in virulence was observed against Nipper⁽ᵀ⁾ and Northfield. This virulent form of Ascochyta blight is now widespread in the southern region. These varieties may require spraying during the vegetative period in disease prone areas and will definitely require a podding spray ahead of rainfall during spring.

In 2016 leaf lesions of Ascochyta blight were observed on PBA Hurricane XT⁽ᵀ⁾ lentils in the Maitland and Mallala regions of South Australia. Testing in controlled environment conditions at SARDI have shown susceptibility of PBA Hurricane XT⁽ᵀ⁾, PBA Ace⁽ᵀ⁾ and PBA Bolt⁽ᵀ⁾, although field reactions have not been confirmed on the latter two cultivars. In 2017, growers in these regions should manage these cultivars as a potentially higher risk for ascochyta, in particular thiram-based seed dressing should be used and growers should be prepared for a fungicide spray during podding. Crops should also be monitored closely in case an additional spray is required during the season to control Ascochyta blight, especially in a wet season.

Differing spray programs have been developed based on each variety's foliar Ascochyta blight rating. Note though that some varieties with good foliar resistance have less resistance to pod Ascochyta blight and are more vulnerable to seed staining (e.g. PBA Jumbo⁽ᵀ⁾, PBA Giant⁽ᵀ⁾).

For resistant (R) and moderately resistant (MR foliar) varieties:[25]

- The presence of Ascochyta blight at an early stage on varieties with moderate resistance in the foliage is unlikely to cause significant yield loss.
- A foliar fungicide applied during podding is unlikely to be required to protect grain quality in most situations unless significant Ascochyta blight is present and rainfall is significant.
- Early monitoring and control of BGM is still critical in Ascochyta blight resistant varieties as they require fewer and later fungicide applications for Ascochyta blight control if at all. This may result in the early development of BGM infection which would have normally been controlled as a result of an earlier fungicide application for Ascochyta blight.
- The Ascochyta blight pathogen can mutate to overcome plant resistance and all varieties should be monitored regardless of nominated resistance ratings.

For moderately resistant to moderately susceptible (MR-MS foliar) varieties:

- Foliar fungicides applied during flowering and podding are likely to be required to protect grain quality particularly in higher rainfall situations, and where Ascochyta blight is present.

For moderately susceptible (MS foliar) varieties:

- Foliar fungicide applications for Ascochyta blight control may be necessary 10–14 weeks after emergence, before canopy closure.
- If Ascochyta blight is present fungicides will be necessary through flowering and podding, ahead of rain events.
- Starting early with protective applications is critical, as control is often ineffective if fungicides are applied after the disease spread.

MORE INFORMATION

For more information visit CropPro webpage: Ascochyta of lentils http://www.croppro.com.au/crop_disease_manual/ch08s02.php

10.15 Sclerotinia stem rot

Sclerotinia trifoliorum, S. sclerotiorum, S. minor

10.15.1 Symptoms

Plants can be attacked at any stage of growth. In young plants the infection usually begins close to ground level and a slimy, wet rot extends into the stem and down into the roots. Affected plants are easily pulled from the soil. They usually have a blackened base that is covered with cottony, white fungus growth (Figure 18).

However, Sclerotinia mainly appears on older plants, which can get the infection on any part of their stems, leaves or pods. At first, water-soaked lesions appear on the stems and leaves, and later affected areas develop a soft, slimy rot which exudes droplets of brown liquid. The infected tissues dry out and become covered with a fine white web of fungus growth.

Sclerotia develop on stems alongside the white fungal growth and are larger (usually 2–5 mm in diameter) than the sclerotia associated with BGM. These sclerotia are usually white at first, then turn black. Sclerotinia in lentil is often found in association with BGM.

Affected plants wilt and die rapidly, without losing their leaves. A late infection can affect the pod and seeds. Infected seeds are smaller than normal and discoloured. Usually isolated plants rather than patches of plants are affected in crops.

25 Pulse Australia (2016) Southern lentil best management practices training course – 2016. Pulse Australia.

Photo 12: *Sclerotinia white hyphae in lentil.*

Photo: Unknown, South Australia 2015 via Southern lentil best management practices training course (2016), Pulse Australia

10.15.2 Economic importance

Crop losses in Australia have been small so far. However, the disease poses a potential threat, particularly with canola in the rotation, and is more likely to be severe in wet seasons. A 2012 GRDC survey estimated the incidence of Sclerotinia stem rot is 5% of years and 3% of lentil crops in the southern region are affected when the disease develops.[26]

MORE INFORMATION

GRDC updates on 2017 pulse diseases are at: 'The watch outs for pulse diseases in 2017' https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/the-watch-outs-for-pulse-diseases-in-2017

10.15.3 Disease cycle

The fungus may be present in the soil or may be introduced with contaminated seed. It can survive in the soil for several years. It has a wide host range (including most pulse and oilseed crops) and may survive on other plants even if lentil is not grown.

Sclerotinia may act as either a leaf or root disease. The fungus in the soil may invade the plant directly or may produce airborne spores which attack the above-ground parts of the plant. Cool, wet conditions are essential for the progress of the disease. Once established, the fungus can move rapidly to neighbouring healthy tissue. A few days after infection, plants start to wither and die. The fungus is carried over to the next year in the infected plants or as sclerotes directly in the soil.

The foliar form of the disease may be spread by airborne spores. While damage to the foliage encourages infection, the fungus can infect uninjured tissue.

Root disease occurs when soilborne spores directly invade the root tissue. A slimy, wet root rot develops and the infected plants suddenly wilt and die.

10.15.4 Management options

Crop rotation prevents rapid disease build-up, but once established in a crop it is difficult to control. Rotations with other legumes and oilseed crops will not break the disease cycle. Cereal crops are not hosts and can be used in the rotation to reduce the risk of infection. Cereals should be grown for several seasons before returning to lentil, other pulses or canola. Broadleaf weeds such as capeweed also host sclerotinia.

The disease risk can be reduced by using disease-free seed. It is also important to avoid sowing lentil on areas where the disease is known to be present. If severe infection occurs, the area should be burnt and ploughed deeply to kill the fungus in the soil.

26 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

Lower seeding rates, wider row spacing and good weed control give a more open crop, which remains drier and is less prone to disease.

10.16 Alternaria

Alternaria alternata

10.16.1 Symptoms

Alternaria appears as dark brown leaf spots which often have a zoned pattern of concentric brown rings with dark margins. Symptoms can be confused with other diseases as infection often follows insect damage or other leaf spots caused by BGM or Ascochyta blight.

10.16.2 Economic importance

Alternaria alternata is a fungus causes leaf spot and other diseases on over 380 host species of plant. It is an opportunistic pathogen of numerous hosts causing leaf spots, rots and blights on many plant parts.

Alternaria occurs late in the season and is a minor disease.

A 2012 GRDC survey on disease incidence did not estimate the incidence of Alternaria.

10.16.3 Disease cycle

Alternaria is a weak pathogen of many hosts and often infects following damage by other fungi or insects. Alternaria leaf spot develops late in the season as the plants start to mature. The fungus probably survives on crop residues and on other hosts.

10.16.4 Management options

Control of alternaria alone is not warranted. Fungicide sprays for other major fungal pathogens should give control.

MORE INFORMATION

For more information see GRDC fact sheet: Pythium root rot www.grdc.com.au/GRDC-FS-PythiumRootRot

10.17 Root rots and Damping off

Fusarium, Rhizoctonia, Pythium spp., *Sclerotium rolfsii*

10.17.1 Symptoms

Root rot can be caused by a range of fungal pathogens including Rhizoctonia, Fusarium and Pythium. Lesions on the stems below soil level are black. Infected plants are stressed.

Seedlings affected by root rot gradually turn black and leaves droop. The plants usually don't collapse completely. The taproot may become quite brittle, except in Pythium root rot when it becomes soft. When plants are pulled from the ground the lower portion of the root snaps off and remains in the soil. The upper portion of the taproot is dark, shows signs of rotting and may lack lateral roots. Distinct dark brown to black lesions may be visible on the taproot.

The leaves and stems of affected plants usually start turning black. Older plants dry-off prematurely and are often seen scattered across a field. In some cases seeds may rot before they emerge.

10.17.2 Economic importance

Root rot can occasionally be a serious disease especially when soils are wet for prolonged periods.

Severe pod infection can result in reduced seedset and infected seed. A 2012 GRDC survey estimated the incidence of root rots is 5% of years and 3% of lentil crops in the Southern Region are affected when the disease develops depending on the causal agent.[27]

10.17.3 Disease cycle

All the fungi responsible for root rot are soil dwellers. They can survive from crop to crop in the soil, either on infected plant debris or as resting spores.

Soilborne fungi invade the roots and stem base of young plants, particularly under wet conditions. Wet conditions also encourage the spread of disease within a field. However, recent research has shown that Pythium does not require high rainfall or cold waterlogged soils.[28] The reduced root development causes the plants to die when they are stressed.

10.17.4 Management options

The disease can be reduced by crop rotation. As this disease may also affect other pulses it is recommended to rotate with non-legume crops.

Disease risk can be reduced by using fresh, undamaged and robust seed treated with a seed dressing to prevent disease build-up. Avoid areas subject to waterlogging as these conditions reduce the vigour of lentil and encourage root rot fungi. Damping off can be controlled using fungicide seed treatment.

Pythium root rot can be detected with a SARDI PreDicta B soil test (http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b) prior to sowing.

27 GM Murray, JP Brennan (2012) The current and potential costs from diseases of pulse crops in Australia. GRDC Report, https://grdc.com.au/resources-and-publications/all-publications/publications/2012/06/the-current-and-potential-costs-from-diseases-of-pulse-crops-in-australia

28 GRDC (2010) Pythium root rot. Root disease fact sheet, GRDC, May 2010, https://grdc.com.au/GRDC-FS-PythiumRootRot

10.18 Stemphylium blight

Stemphylium botryosum

10.18.1 Symptoms

Stemphylium blight is characterised by large, grey-black necrotic lesions restricted to the leaves, often starting from the leaf edge.[29] In North America leaf drop can leave the plant defoliated with only the top-most leaves remaining.[30]

It can be confused with other diseases of lentil such as aschochyta (look for pycnidia). In Canada the disease is increasingly found in seed tests in the lab, but researchers say it can be misdiagnosed in the field, with symptoms mistaken for Sclerotinia (white fluffy mould or black sclerotia) or botrytis (grey fuzzy mould under a magnifying glass).[31]

10.18.2 Economic importance

A 2012 GRDC survey on disease incidence did not estimate the incidence of Stemphylium in lentil. Stemphylium is considered a minor disease of lentil in Australia, although there have been epidemic or sporadic incidences in Bangladesh and Canada.[32]

It is common in lucerne and can cause severe defoliation.[33] In 2016 the mild, wet winter led to an unusually high number of reports of Stemphylium on faba bean in northern NSW.[34]

10.18.3 Disease cycle

Stemphylium botryosum occurs on lucerne, clovers, lupin, beans and tomato.[35] In lucerne, Stemphylium can be carried over on infected plant debris, seed and in soil. The disease is favoured by warm, moist conditions and spores are spread by wind or rain splash.

10.18.4 Management options

As it is a minor disease no control is generally required.

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29 S Jeffrey (2016) Mild, wet winter leads to emergence of leaf blight. GRDC media release, 18 August 2016, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/pests-diseases/winter-crops-lupins-chickpeas-other-pulses/stemphylium-blight-in-faba-bean

30 M Wunsch (2013) Management of Stemphylium blight of lentils. North Dakota State University website, https://www.ag.ndsu.edu/carringtonrec/documents/plantpathologyrd/noyeardocs/LENTILStemphyliummgmt.pdf

31 J Isaacs (2014) Lentils with blight can be misdiagnosed. Grainews, 20 May 2014, http://www.grainews.ca/2014/05/20/lentils-with-blight-can-be-misdiagnosed/

32 P Kant (2013) Stemphylium blight. Pulse Breeding Australia newsletter, Issue 12, Summer 13/14, p15, https://grdc.com.au/~/media/Documents/Major-Initiatives/PBA/Newsletters/Issue-12-PBA-Summer-13-14-Newsletter-pdf.pdf?la=en

33 R Clarke (1999) Diseases of lucerne: fungal leaf diseases. AG0727. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/pastures-diseases/diseases-of-lucerne-2-fungal-leaf-diseases

34 S Jeffrey (2016) Mild, wet winter leads to emergence of leaf blight. GRDC media release, 18 August 2016, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/pests-diseases/winter-crops-lupins-chickpeas-other-pulses/stemphylium-blight-in-faba-bean

35 R Clarke (1999) Diseases of lucerne: fungal leaf diseases. AG0727. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/pastures-diseases/diseases-of-lucerne-2-fungal-leaf-diseases

MORE INFORMATION

For more information see:

Plant Health Australia fact sheet: Stem nematode http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf

APPS fact sheet: Ditylenchus dipsaci http://www.appsnet.org/publications/potm/pdf/Mar11.pdf

10.19 Stem nematode

Ditylenchus dipsaci

10.19.1 Symptoms

Stem nematode damage can be similar to the effects of some herbicides: poor emergence and establishment, stunting and distortion of plants, swollen stem bases, premature plant death, lodging and fewer seed heads. In heavy infections there is poor germination and emergence with patches of malformed and stunted plants (Photo 13).

Symptoms in lentil, faba bean, canola, field pea and chickpea are first seen in seedlings and plants may show signs of recovery later in the season.

Symptoms in oats can persist throughout the season. Lucerne can exhibit 'white flagging' of leaves. Symptoms usually occur in patches, but the entire crop can be affected in severe cases.

The nematodes multiply rapidly on susceptible plants under cold, wet conditions. Sometimes the stem will die back, turning reddish brown from the base and stopping at a leaf.

Photo 13: *Stem nematode causes stunting and twisting of leaves, Black streaks down stems are also a symptom.*

Photo: S. Taylor, formerly SARDI via Southern lentil best management practices training course, (2016), Pulse Australia

10.19.2 Economic importance

Stem nematode is a soilborne pest of oat, pulse and some pasture crops.[36] In South Australia and Victoria there are three different races of the nematode: the oat, lucerne and clover races. The oat race infects the cultivated and wild oat, faba bean and field pea and has been recorded on lentil, chickpea and canola seedlings.

The 2012 GRDC survey on disease incidence did not estimate the incidence of stem nematode in lentil crops.

A heavy infestation of this nematode can cause large yield losses, but this has occurred only rarely.

Access to some international and domestic markets requires seed to be tested and found free of stem nematode.

36 Plant Health Australia (2013) Stem nematode fact sheet. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Stem-nematode-FS.pdf

10.19.3 Life cycle

Stem nematode is spread by infested hay, straw, weeds and other plant material, and as a contaminant of seed. It is transferred in soil by machinery, humans and stock. Stem nematode is highly resistant to desiccation, and can survive in a dehydrated state for many years.

It infects above-ground parts of plants and can multiply many times during the growing season. Disease build-up is worse in wetter situations and at temperatures less than 15°C.

It is more common in high rainfall areas on clay soil.

10.19.4 Management options

There are no chemical options for managing nematodes. Hygiene is very important. Do not introduce the nematode onto the farm or into clean paddocks. Test seed for the presence of stem nematode with a SARDI seed test. Do not bring oaten hay or straw from infested areas onto the property.

Rotate with non-host crops such as wheat and barley to reduce nematode numbers.

Soilborne disease risk can be assessed through the SARDI PreDicta B soil test.

10.20 Root-lesion nematodes (RLN)

Pratylenchus neglectus, P. thornei and other *Pratylenchus spp*.

Lentil is grown as a rotational crop to reduce the population of root-lesion nematodes in the soil.

10.20.1 Symptoms

Root-lesion nematode (RLN) can impair root function, limiting water and nutrient uptake by the plant. Affected plants generally do not thrive or show symptoms of nitrogen deficiency. Symptoms are increased when plants are subjected to water and nutrient stress, or when combined with root damage caused by fungi.

Root symptoms are often difficult to diagnose in the field and are usually not seen until plants are older than eight weeks. Root symptoms are generally more obvious in plants grown in sandier soils. Root symptoms include:

- disintegration of outer layers of root tissue;
- reduction in root hairs and/or nodules;
- a lack of/or stunting of side (lateral) roots; and
- brown lesions and discoloration of roots

Diagnosis can be difficult and the presence of RLN in the soil can only be confirmed with a SARDI PreDicta B soil test to identify the particular RLN species.

10.20.2 Economic importance

Most lentil varieties are resistant to RLN and suffer minimal yield loss.

Root-lesion nematodes can cause large grain yield losses in susceptible crops such as wheat and chickpea.[37] At least 20% of cropping paddocks in south-eastern Australia have populations of RLNs high enough to reduce yield. The extent of yield loss is directly related to the nematode population density at sowing.

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

Worldwide, the genus *Pratylenchus* is the second most important group of plant-parasitic nematodes with more than 90 species of RLN known worldwide. The two main species of RLN in the southern region are *Pratylenchus neglectus* and *P. thornei*.

P. teres and *P. penetrans* are found in the western region.

More than one RLN species can be found in the roots of an individual crop, although one species usually dominates.[38] Identification is important as different crops have different resistance or susceptibility depending on the *Pratylenchus* type. All species of *Pratylenchus* have a wide host range.

The estimated incidence of root-lesion nematode in lentil was not quantified in the 2012 GRDC study on the cost of diseases in Australia. However, SARDI have published results of recent PreDicta®B soil tests for root-lesion nematode.

10.20.3 Life cycle

Nematodes are small, worm-like organisms <1 mm in length and are able to move freely through moist soils and young root tissues. As the females move through plants they feed on the plant roots, causing lesions, and depositing eggs.

There may be three to five generations of nematodes within a growing season. Nematodes are likely to multiply under a range of host crops such as wheat and chickpeas. Barley is only moderately susceptible. Many grass weeds and legumes can also host the nematode.

The nematode survives over the summer months in dry soil and root residues to become active again when the winter rains start.

Nematodes will not move great distances unless they are spread by surface water, soil on farm machinery or wind-blown soil in summer.

10.20.4 Management options

There are no chemical options for managing nematodes. Rotation with resistant crops such as lentil, faba bean, field pea or lupin is the most important management tool for RLN.

Resistant crops reduce the population of nematodes in the soil. Tolerant crops do not reduce the population, but are less vulnerable to damage from nematodes.

Resistant crop species can reduce nematode populations by up to 50% per year. A two or more year break from susceptible crops may be necessary to minimise yield loss if nematode numbers are high. Resistant varieties of susceptible crop species should be grown in the following years.

With the exception of chickpea, pulses tend to have good resistance to *P. neglectus* and *P. thornei*, so can reduce nematode populations in cropping rotations (Table 8).

Resistant crops may differ in their capacity to host *P. neglectus* or *P. thornei* so tailor rotations to manage the predominant species. Crops such as field pea and lentil provide some control for *P. thornei*, while faba bean, field pea and lentil provide control for *P. neglectus*.

Controlling volunteer crops and host weeds is also important. Weeds that can host nematodes include wild oat, barley grass, brome grass, wild radish and *Brassica tournefortii*.

Nematode numbers increase where susceptible crops like chickpea and wheat are grown in rotation.

Reducing the nematode population can lead to higher yield in subsequent cereal crops. Yield loss in south-eastern Australia from RLN is lower than in northern Australia.

MORE INFORMATION

For more information see:

GRDC fact sheet: Plant parasitic nematodes http://www.grdc.com.au/GRDC-FS-Plant-Parasitic-Nematodes-SW

Soil Quality fact sheet: Root-lesion nematode http://soilquality.org.au/factsheets/root-lesion-nematode

SARDI webpage: PreDicta B testing http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

GRDC Video: Root-lesion nematodes https://youtu.be/Ntf08QGXPI0

GRDC Video: Root-lesion nematodes. Resistant cereal varieties have surprising impact on RLN numbers https://youtu.be/1dt64MfUmOc

DAFWA video: How to diagnose root-lesion nematode https://youtu.be/ttFltE-B4qA

38 J Isaacs (2014) Lentils with blight can be misdiagnosed. Grainews, 20 May 2014, http://www.grainews.ca/2014/05/20/lentils-with-blight-can-be-misdiagnosed/

The simplest way to identify a nematode problem is with a SARDI PreDicta®B soil test (http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b) prior to sowing.

Table 8: Resistance and tolerance of pulses to the major *Pratylenchus* species.

Crop	***Pratylenchus* neglectus**		***Pratylenchus* thornei**	
	Resistance	**Tolerance**	**Resistance**	**Tolerance**
Faba bean	R	-	MR	MI
Chickpea	S - MR*	MI - T*	VS - R*	MI - T*
Field pea	R	-	R	T
Lentil	R	T	R	MT
Vetch - Blanchefleur	MR	T	S	I - MI
- Languedoc	MR	T	MS	I - MI
- Morava⁽ᵇ⁾	MR	T	MS	I - MI

* Chickpea varieties have a range of resistances and tolerances to *Pratylenchus* species
Source: Southern lentil best management practices training course, (2016), Pulse Australia

10.21 Viruses

10.21.1 Viruses in pulses

Lentil is infected by many viruses worldwide. Fortunately only a few are currently of major economic importance in Australia (Table 9).

Major viruses that are known to infect lentil in Australia include[39]:

- Cucumber mosaic virus (CMV)
- Alfalfa mosaic virus (AMV)
- Beet western yellow virus (BWYV), also known as Turnip yellows virus (TuYV)
- Bean yellow mosaic virus (BYMV)
- Pea seedborne mosaic virus (PSbMV)
- Bean leafroll virus (BLRV)

Less common viruses that occur on lentil in Australia are:

- Soybean dwarf virus (SbDV), syn Subterranean clover red leaf virus (SCRLV)
- Subclover stunt virus (SCSV)
- Clover yellow vein virus (ClYVV)
- Tomato spotted wilt virus (TSWV)
- Broad bean wilt virus (BBWV)

39 Pulse Australia (2016) Southern lentil best management practices training course – 2016. Pulse Australia.

Table 9: Virus categories and general symptoms.

Virus	Aphid transmission	Seed transmission*	Visual symptom type	Visual symptoms	Virus type (genus)
AMV	Non-persistent	Yes	Shoot tip	Necrotic or chlorotic local lesions, sometimes mosaics that do not necessarily persist.	alfamovirus
BBWV	Non-persistent	No	Mosaic, shoot tip	Vein clearing, mottling and necrosis of shoot apex, plant wilts, mottled, malformed and stunted.	fabavirus
BLRV	Persistent	No	Top yellowing	Upward leaf-rolling accompanied by interveinal yellowing of older leaves and flowers abscised.	luteovirus
BWYV/PhBV	Persistent	No	Top yellowing	Interveinal yellowing of the older or intermediate leaves. Mild chlorotic spotting, yellowing, thickening and brittleness of older leaves.	luteovirus
BYMV	Non-persistent	Yes	Mosaic	Transient vein chlorosis followed by obvious green or yellow mosaic. Usually no leaf distortion.	potyvirus
CMV	Non-persistent	Yes	Shoot tip	Mosaics, stunting and possibly some chlorosis.	cucumovirus
ClYVV	Non-persistent	No	Shoot tip, mosaic	Mosaics, mottles or streaks, vein yellowing or netting.	potyvirus
PSbMV	Non-persistent	Yes	Mosaic	Systemic dark and light-green zonal leaf mottle, slight to moderate downward rolling of leaf margins. Distortions of leaf shape associated with mottle patterns. Seed markings.	potyvirus
SCRLV	Persistent	No	Top yellowing	Mild yellowing, stunting and reddening.	luteovirus
SCSV	Persistent	No	Top yellowing	Top yellows, tip yellows or leaf roll. Leaf size reduced, petioles and internodes shortened.	nanavirus
TSWV	Persistent	No	Shoot tip, mosaic	Necrotic and chlorotic local lesions, mosaic, mottling, leaf shape malformation, vein yellowing, ringspots, line patterns, yellow netting and flower colour-breaking.	tospovirus

*Seed transmission in lentil is significant for some viruses and minimal for others, but of no epidemiological significance. However, it is important for quarantine to keep foreign virus strains out of Australia.
Source: Southern lentil best management practices training course, (2016), Pulse Australia

In 2013 a virus that was earlier thought to be a strain of BWYV was identified in Australian pulse crops: Phasey bean virus (PhBV), which causes causes symptoms that are similar to BLRV and SbDV. It has been found on lentil, but its current economic importance is not yet clear.

Cucumber mosaic virus (CMV) is present in most lentil crops surveyed in South Australia and Victoria. It occasionally causes heavy losses, usually when high populations of aphids have infested the crop at an early stage. Combinations of CMV, Alfalfa mosaic virus (AMV) and Beet western yellow virus (BWYV) are often present in plants tested from these surveys.

There are several other viruses of economic importance on lentil globally that are not present in Australia. Strict quarantine regulations are in place in order to keep the country free of these and other exotic pathogens.

Seasonal variation in virus infection is quite common. The South Australian Research and Development Institute (SARDI) found relatively low virus infection rates in lentil in SA in 2014 (Table 10).[40] BWYV infected canola crops across Victoria, SA and NSW in 2014, but was only detected at a high infection rate in one lentil crop in SA.

Table 10: Results of virus testing in South Australia in 2014.

Crop type	Number of crops or trials tested	Test period	Number of crops with positive virus tests (average % infection rate in brackets)					
			BWYV	PSbMV	CMV	AMV	BLRV	BYMV
Lentil	10	Jul–Aug	3 (4%, 1 at 92%	0	3 (1%, 1 at 100%)	0	0	0
	4	Sep–Oct	3 (2.7%)	0	2 (6.5%)	1 (4%)	0	0

Source: Diseases of pulse crops in 2014, (2015), GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Diseases-of-pulse-crops-in-2014.
Source: R Kimber, J Davidson, M Rodda, M Aftab, J Paull (2015) Diseases of pulse crops in 2014. GRDC Update Papers, 10 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Diseases-of-pulse-crops-in-2014

10.21.2 How viruses spread

Viruses need aphid vectors to spread from infected to healthy plants. The exception is Tomato spotted wilt virus (TSWV), which is transmitted by specific thrip species. None of the persistently transmitted viruses are seed-transmitted. Pea seedborne mosaic virus (PSbMV) strains that can be seed-transmitted in lentil are reported overseas, but not in Australia. Aphid activity is the most important factor for virus development in lentil crops.

The most important factors that predispose pulse crops to severe virus infection are:

- Infected seed.
- Close proximity to a substantial virus reservoir (e.g. lucerne, summer weeds).
- A wetter than average summer–autumn with green material to allow uncontrolled multiplication of aphids during the time when numbers are usually low. When aphids are present early in the season epidemics are more likely to occur and the level of damage will be higher.
- Early spring flights of the aphids.

Viruses can be classified by the manner in which they are transmitted by insect vectors – persistent and non-persistent.

Persistent transmission

These viruses are ingested by the insect and are passed to healthy plants through the saliva. It can take more than a day for these insects to become infectious, but the insect will remain infectious for the rest of its life.

40 R Kimber, J Davidson, M Rodda, M Aftab, J Paull (2015) Diseases of pulse crops in 2014. GRDC Update Papers, 10 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Diseases-of-pulse-crops-in-2014

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Not all aphid species are vectors of this kind of virus in pulses so the identification of aphid species is very important. The main vectors of these viruses are pea, cowpea and green peach aphids. Viruses include BWYV, BLRV and SCSV. Infection will start with random plants and increase as the vectors colonise the crop. Aphids generally only become visible in the crop once they have colonised.

Insecticides that kill aphids can work in suppressing the spread of these types of viruses as transmission rates increase dramatically when the aphids fly.

Non-persistent transmission

Insects transfer these viruses on their mouth parts directly by carrying it from an infected plant to a healthy one. It can only infect one or two more plants at a time.

Many aphid species are vectors of this type of virus including ones that do not colonise legumes but just land and probe while searching for their preferred hosts (e.g. oat and turnip aphids). Viruses include PSbMV, AMV, CMV and BYMV.

Insecticides are less effective at suppressing these types of viruses as they do not act fast enough. They may make the situation worse as the insecticide can agitate aphids and increase virus spread.

10.21.3 Symptoms

Initially, virus transmission from seed leads to scattered diseased plants (Figure 20). but by the time the crop matures, luteoviruses may have been spread by aphids across the entire crop. When primary infection occurs via aphids colonising the lentil crop, infections occur in patches. Plants infected late in the season are able to produce viable seed that can be a source of infection if the virus is seed-transmitted.

Cucumber mosaic virus (CMV) on lentil causes chlorosis, leaf distortion and stunting of the plant (Figure 21).[41]

CMV is more commonly found in lentil and lupin that in other crop types, but has a wide host range that also includes chickpea, field pea and faba bean, as well as minor pulse crops such as lathyrus and narbon bean.

Alfalfa mosaic virus (AMV) on lentil causes a necrotic tip growth, twisting and deformation of leaves and stunting (Figure 22).

Beet western yellows virus (BWYV) also known as Turnip Yellows Virus (TuYV) on lentil causes mild mosaic, light green or yellow leaves (Figure 23). A reduction in leaf size and stunting may occur. Infected plants produce very little seed.

Beet western yellows virus (BWYV) on lentil causes yellowing on lower and middle leaves, but tips grow out green (Figure 24 and Figure 25), high incidence near bare areas in lentil). Stunting may occur.

Pea seedborne mosaic virus (PSbMV) does not generally cause symptoms in lentil, but there may be some chlorosis in new shoots, mottling on leaves, shoot tip necrosis and stunting of plants.

Tomato spotted wilt virus (TSWV) on lentil causes tip necrosis and plant death. Economically significant incidences have been found in the northern region in pulses, especially since the introduction of Western flower thrips, a highly efficient TSWV vector. However, it does not appear to be a major problem as yet in the southern region. Note that other diseases and symptoms can be confused with TSWV, including frost damage.

41 M Aftab, A Freeman, F Henry (2013) Temperate Pulse Viruses: Cucumber Mosaic Virus (CMV), AG1207, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/temperate-pulse-viruses-cucumber-mosaic-virus-cmv

Photo 14: *Virus patches in lentil Note initial infection area (dead plants) and spread from there.*

Photo: W. Hawthorne, formerly Pulse Australia via Southern lentil best management practices training course, (2016), Pulse Australia.

Photo 15: *Cucumber mosaic virus (CMV) in lentil.*

Photo: Southern lentil best management practices training course, (2016), Pulse Australia.

Photo 16: *Cucumber mosaic virus (CMV) and Alfalfa mosaic virus (AMV) in lentil Note the bare area around the infected plants.*

Source: W. Hawthorne, formerly Pulse Australia via Southern lentil best management practices training course, (2016), Pulse Australia

Photo 17: *Bean yellow mosaic virus (BYMV) in lentil.*

Photo: R. Jones, DAFWA via Southern lentil best management practices training course, (2016), Pulse Australia

Photo 18: *Beet western yellows virus (BWYV) in lentil.*

Photo: W. Hawthorne, formerly Pulse Australia via Southern lentil best management practices training course, (2016), Pulse Australia

Photo 19: *Beet western yellows virus (BWYV), high incidence near bare areas in lentil.*

Photo: W. Hawthorne, formerly Pulse Australia via Southern lentil best management practices training course, (2016), Pulse Australia

10.21.4 Economic importance

Viruses are generally not considered a devastating problem of lentil in the southern region, but should not be ignored. A 2012 GRDC study estimated incidence of lentil viruses ranged from 5–100% of crops depending on the virus and the season (Table 11). Infection can reduce yield and seed quality.[42]

Table 11: Incidence and faba bean crop area affected by virus.

Virus	Incidence (%)	Area of crop (%)
Alfalfa mosaic virus	100.0	19.0
Bean leafroll virus	30.0	13.5
Bean yellow mosaic virus	24.0	7.0
Beet western yellows virus	30.0	55.5
Cucumber mosaic virus	100.0	67.5
Pea seedborne mosaic virus	24.0	7.0
Soybean dwarf virus	5.0	0.0
Tomato spotted wilt virus	5.0	0.0

Incidence as a proportion of years when the disease occurs and area as a percentage of crop area affected when the disease develops. No incidence was listed for Clover yellow vein virus or Subterranean clover stunt virus

Source: Murray and Brennan (2012)The current and potential costs from diseases of pulse crops in Australia, (2012), GRDC, https://grdc.com.au/Resources/Publications/2012/06/The-Current-and-Potential-Costs-from-Diseases-of-Pulse-Crops-in-Australia

Viruses are usually present to a certain extent in all crops. Whether they damage the crop or not depends on the growth stage at infection and the number of plants infected. Viruses rarely affect all plants in a crop; more typically individual plants or clusters are affected.

42 K Perry, P Mangano, P Umina, A Freeman, R Jones, W Hawthorne, J Davidson (2010) Aphids and viruses in pulse crops fact sheet. GRDC, Western and Southern regions, July 2010, http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

Detections and damage from virus in lentil in southern Australia include:

- The BWYV (synonym: TuYV) outbreak in 2014 damaged canola crops in SA, Victoria and NSW. While there was concern that it could spread to pulse crops including lentil, the cold conditions over winter substantially reduced the spread of virus by aphids.[43]
- BWYV appears to be present in many lentil crops grown. In 2009 there was significant crop damage and patchiness due to BWYV in lentil crops that were thin or affected by herbicide or nutritional disorders. That year there was considerable aphid activity following earlier summer–autumn rains and a mild winter–early spring
- In 2006, BLRV occurred at high levels in southern NSW and some SA and Victorian crops.
- In 2006 and 2007, a minority of lentil crops in Victoria and SA had very high levels of CMV.
- In SA in 2006, AMV was found at high levels in all crop types but not in 2007.
- Both CMV and AMV have been detected in seed lots of lentil.
- BYMV occurs commonly at a low frequency in lentil crops and has not caused any serious losses.
- ClYVV caused plant death in spring-sown lentil grown adjacent to irrigated white clover in South Australia in the late 1990s. Similar symptoms are seen in lentil crops on occasions, but can be confused with other causes.
- PSbMV has infected lentil grown near PSbMV infected field pea crops in SA, but harvested grain does not seem to show the characteristic seed markings typically seen in field pea or faba bean.

Virus studies in Western Australia have measured the impact of infection on individual lentil plants:[44]

- AMV decreased shoot dry weight by 74–76% compared with asymptomatic plants, as well as reduced seed yield (81–87%) and individual seed weight (10–21%).
- CMV decreased shoot dry weight by 72–81% compared with asymptomatic plants, as well as reduced seed yield (80–90%) and individual seed weight (17–25%).

While viruses occur in all states, they are a more of a problem in northern NSW and southern Queensland, occasionally causing total crop failures in chickpea.

Damage caused by viruses varies greatly from season to season and depends on the prevalence of aphids. Infection is more likely to cause yield loss when infected seed stock is sown, and aphids arrive early in the season. When aphids arrive late other plants can compensate for individual plant losses.

10.21.5 Disease cycle

Aphids bring viruses into lentil crops from surrounding plants, mostly legumes (like lucerne or clovers). Some viruses, like BWYV, AMV, CMV, BYMV and TSWV, have a host range that includes non-legume species. Hence other plant species (e.g. sow thistle, turnip weed) can act as a virus source at the start of the season.

CMV and AMV are non-persistently transmitted by a range of aphid species. The luteoviruses are persistently aphid-transmitted, but are more vector specific. Correct identification of the aphid is important for effective management. TSWV is spread by thrips.

Probing and feeding needs to be prolonged for persistently transmitted viruses (0.1–4.0 hours for luteoviruses), but only needs to be brief for non-persistently

43 B Coutts, R Jones, P Umina, J Davidson, G Baker and M Aftab (2015) Beet western yellows virus (synonym: Turnip yellows virus) and green peach aphid in canola, GRDC Updates Paper, 10 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Beet-western-yellows-virus-synonym-Turnip-yellows-virus-and-green-peach-aphid-in-canola

44 LJ Latham, RAC Jones, BA Coutts (2004) Yield losses caused by virus infection in four combinations of non-persistently aphid-transmitted virus and cool-season crop legume. Australian Journal of Experimental agriculture 44, 57-63

transmitted viruses. Eventually aphids colonise the lentil plant and become very visible in the crop.

Crop loss depends on the growth stage at infection and the number of plants infected. Early and widespread infections lead to the greatest losses.[45]

Aphid activity is influenced by seasonal conditions and will require early monitoring in nearby crops and pastures. See 7.1 for more information on monitoring and managing aphids.

10.21.6 Management options

There are no proven methods for controlling viruses.

Virus management in pulses aims at prevention through integrated pest management, that involves controlling the virus source, aphid populations and minimising virus transmission into and within the pulse crop.

While a large population of aphids is required to inflict feeding damage, virus transmission can occur before aphids are seen to be present. Pre-emptive management is required.

Management options at the planning stage:[46]

- Suppress the virus source within the crop by purchasing virus-tested seed. Only retain seed from crops with no visible symptoms. Grade out smaller grain, which is more likely to be infected. PSbMV, CMV, BYMV and AMV survive through seed transmission. A threshold of 0.1% seed infection is recommended for sowing in high-risk areas, and <0.5% for low-risk areas.
- Distance crops from lucerne, weeds or other species that act as a reservoir for viruses, diseases and aphids.
- Control volunteer weeds and self-sown pulses that are a green-bridge host for viruses and a refuge for aphids and their multiplication during summer and autumn.
- Rotate pulse crops with cereals to reduce virus and vector sources (aphids or other insects) and where possible avoid close proximity to perennial pastures (e.g. lucerne) or other crops that host viruses and aphid vectors.

Management options at sowing and in-crop:

- Use a seed treatment of Gaucho 600 Red® (imidacloprid), which is registered for early aphid protection to control persistently transmitted viruses.
- Retain cereal stubble, as aphids are less likely to land in stubble.
- Sow at recommended times to avoid autumn aphid flights.
- Sow at recommended plant densities to achieve early closure of the crop canopy. Closed canopies deter aphids.
- Note that high seeding rates and narrow row spacing to provide early canopy closure assists in aphid control, but conflicts with management of fungal diseases.
- Manage crops to minimise seedling stress through disease, herbicide damage and poor nutrition. Stressed crops are more attractive to aphids.
- Insecticides after emergence may be effective for persistently transmitted viruses. However, they may not be effective for non-persistently transmitted viruses as the insecticide can agitate aphids and increase virus spread.
- Monitor lentil and nearby crops and pastures for aphids. Be prepared to use insecticide when there may be localised flights.

45 K Perry, P Mangano, P Umina, A Freeman, R Jones, W Hawthorne, J Davidson (2010) Aphids and viruses in pulse crops fact sheet. GRDC, Western and Southern regions, July 2010, http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

46 W Hawthorne, M Materne, J Davidson, K Lindbeck, L McMurray, J Brand (2015) Lentil: Integrated disease management, Pulse Australia website, http://pulseaus.com.au/growing-pulses/bmp/lentil/idm-strategies

MORE INFORMATION

For more information see:
GRDC fact sheet: Aphids and viruses in pulse crops http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

Pulse Australia webpage: Managing viruses in pulses http://pulseaus.com.au/growing-pulses/publications/manage-viruses

Agriculture Victoria webpage: Managing viruses in pulse crops http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/managing-viruses-in-pulse-crops

Insecticide resistance is becoming more common in aphids. Growers should only consider applying insecticide for virus control if they consider their crops to be at high risk. Insecticides aimed at controlling damage from aphid feeding are normally too late to control virus spread and damage.

10.21.7 Virus testing

Diagnostic testing is available for plant viruses. Only some tests can be performed with relative ease in the field. Current testing options may not detect the less common viruses.

Detection of virus n one or two plants is not proof that the virus is causing a problem. It is important to check for a range of viruses, as the one detected by a test may not be the virus actually causing symptoms.

Detection of a seedborne virus does not mean there will be virus present in progeny seed. Seed samples from the crop require testing to determine if seed infection has occurred.

Serological testing for viruses is available through DDLS Seed Testing and Certification (formerly AGWEST Plant Laboratories), TASAG ELISA and pathogen testing service or Agrifood Technology.

TASAG also sell Agdia Immunostrips test kits. A result can be obtained in minutes.

DAFWA Diagnostic Laboratory Services (DDLS) Seed Testing and Certification

DDLS conduct seed tests for CMV.

Department of Agriculture and Food
Reply Paid 83377
3 Baron Hay Court, South Perth, WA 6151
Ph: 08 9368 3721
Email: DDLS-STAC@agric.wa.gov.au
https://www.agric.wa.gov.au/plant-biosecurity/ddls-seed-testing-and-certification-services

TASAG

TASAG offer in-house virus testing of plants or seed and test kits that can be used in the field (Agdia Immunostrips test kits, US website www.agdia.com).

Contact: Peter Cross
New Town Laboratories
13 St John's Ave, New Town, Tasmania, 7008
Ph: 03 6165 3252
Email: Peter.Cross@dpipwe.tas.gov.au
http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/tasag-elisa-testing

Agrifood Technology

Agrifood conduct testing for CMV and AMV.

Contact: Robert Rantino or Doreen Fernandez
260 Princes Highway, Werribee, VIC 3030, Australia
Postal: PO Box 728, Werribee, VIC 3030, Australia
Phone: 1800 801 312
http://www.agrifood.com.au/index.php/services/food-safety

MORE INFORMATION

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

DDLS Seed Testing and Certification (formally AGWEST Plant Laboratories) https://www.agric.wa.gov.au/plant-biosecurity/ddls-seed-testing-and-certification-services

TASAG ELISA Testing Services: http://dpipwe.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-health-laboratories/tasag-elisa-testing

MORE INFORMATION

For more information see:

Plant Health Australia: Lentil anthracnose http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Lentil-anthracnose-FS.pdf

CropPro webpage: Victorian disease manual – Lentil anthracnose http://www.croppro.com.au/crop_disease_manual/ch08s04.php

10.22 Exotic diseases with potential to impact on Australian crops

If you suspect an exotic disease, immediately contact Plant Health Australia's Exotic Plant Pest Hotline on 1800-084-881.

10.22.1 Lentil anthracnose

Colletotrichum truncatum

Importance

Lentil anthracnose is an exotic disease for Australia as it has not been observed here in lentil.[47] It has devastating effects on lentil crops in Canada, and current Australian lentil varieties are susceptible to this disease.

Anthracnose on lentil is caused by *Colletotrichum truncatum*, while Lupin anthracnose is caused by *Colletotrichum gloeosporoides*.

C. truncatum has a very wide host range, affecting other legumes including field pea, bean species, vetch, soybean and peanut. While strains of the *Colletotrichum truncatum* fungus have been found on other pulse crops in Australia, the strain that attacks lentil has not been recorded.

Necrotic lesions on stems, leaves and pods result in plant damage and dead patches in the crop. Yield reductions can be as high as 60–70%.

Symptoms

The first symptoms are green-white lesions on leaves after the first tendril forms, but before flowering, when plants have 8–12 nodes on the main stem (Photo 20). Irregular shaped, light-brown lesions develop on the base of stems and progress up to leaves and pods in the canopy (Photo 21 and Photo 22).

Infected plants lodge and have abnormally dark brown stems. As infection advances and the plant matures, lesions become brown in colour and this is often followed by leaf drop with similar lesions on the stems.

Microsclerotia (black, pinhead-sized structures) form from older lesions and blacken the stems, with stem lesions eventually girdling the stem, causing wilting. Defoliation of lower leaves and ultimately death of affected plants may occur (Photo 23).

There are a number of other infections that result in lesions and wilting in lentil, including Botrytis grey mould and Sclerotinia stem rot. The distinguishing feature of Lentil anthracnose is the blackened lesions which girdle the stems and ultimately kill the plant. Plant samples showing suspected Anthracnose-like symptoms should be sent for diagnosis.

47 Plant Health Australia (2013) Lentil anthracnose. Plant Health Australia fact sheet, http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Lentil-anthracnose-FS.pdf

Photo 20: *Early stages of Lentil anthracnose leaf lesion development.*

Photo: R. Morrall, University of Saskatchewan via Southern lentil best management practices training course, (2016), Pulse Australia.

Photo 21: *Lentil anthracnose.*

Photo: J. Davidson, SARDI via Southern lentil best management practices training course, (2016), Pulse Australia.

Photo 22: *Early Anthracnose stem lesion development prior to development of microsclerotia.*

Photo: G Chongo, Agriculture and Agri-Food Canada via Southern lentil best management practices training course, (2016), Pulse Australia.

Photo 23: *Heavy anthracnose infection in lentil.*

Photo: R. Morrall, University of Saskatchewan via Pulse Australia (2016) Ref 30.

Spread

Anthracnose is spread by spores that are small and light. These may be present on infected stubble and spread to new plants by rain splash, or can be spread longer distances by wind, particularly as trash during and after harvest. Spores and infected soil can also be spread by machinery, clothing and animals, and seed may also be infected. Spores can be viable for five years or longer in the soil, infecting subsequent lentil or other host crops.

Disease management

The disease can be managed with foliar fungicides.

Methods to quickly detect any possible incursion and to positively identify the Anthracnose fungus have been established using molecular marker technology to distinguish the lentil-attacking strain from any other related fungus species.

Entry potential: Medium. Entry through infected seed or via seed lots contaminated with infected lentil trash or soil.

Establishment and Spread potential: High as evidenced by the climatic conditions similar to those in overseas countries where *C. truncatum* is a serious problem. Also other races/strains of *C. truncatum* already occur in Australia on other crop host species.

Economic impact: High. All of the current Australian varieties are susceptible. Anthracnose could have a dramatic effect on production.

Overall risk: High.

10.22.2 Rust

Uromyces viciae-fabae

Importance

The *Uromyces* pea and lentil rusts are major fungal pests affecting *Vicia* spp. (faba bean, vetch and lentil) as well as *Pisum* spp. (field pea, garden peas, etc)[48] and other members of the pea family. Each strain of *U. viciae-fabae* is host-specific with the two strains that affect lentil and pea not found in Australia.

Strains of *Uromyces viciae-fabae* occur in Australia on faba bean and vetch. *U. viciae-fabae* is considered a high economic threat to lentil and field pea because of potential yield losses through reduced production.

Symptoms

Rusts can build up rapidly and are mostly seen as the weather warms above 20°C. Leaves, stems and pods can be infected (Photo 24).

48 Plant Health Australia (2013) Pea and lentil rust. Plant Health Australia fact sheet, http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Field-pea-and-Lentil-rust-FS.pdf

MORE INFORMATION

For more information see Plant Health Australia: Pea and lentil rust http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Field-pea-and-Lentil-rust-FS.pdf

The first symptoms are minute, whitish, slightly raised spots that, as they enlarge, change to orange-brown in colour, often surrounded by a light coloured halo (Photo 25).

Photo 24: *Lentil rust.*

Photo: K. Lindbeck, NSW DPI via Pulse Australia (2016) Ref 30.

Photo 25: *Lentil rust.*

Photo: K. Lindbeck, NSW DPI via Pulse Australia (2016) Ref 30.

Surveillance

Characteristic rust spots on the leaf surfaces and other plant parts are an obvious indicator that rust is present.

The *Uromyces* lentil and pea rusts could be confused with other rusts. The strains of *U. viciae-fabae* that infect faba bean and vetch are present in Australia. If faba bean infestation is high, *U. viciae-fabae* may also infest adjacent field pea crops. If resistant varieties show symptoms, samples should be taken for further testing.

Neither lentil nor pea rust has been recorded on field peas in Australia. If rust symptoms are seen on lentil or field pea a sample should be sent for further testing to identify the species.

Entry potential: Medium. Entry potential via contaminated seed (rust is not seedborne, but spores may travel alongside seed). High establishment and spread potential, economic impact considered medium.

Establishment and spread potential: High. Rust spores are small, light and may survive for several days. They can be spread large distances by windblown infected plant debris during harvest into adjacent paddocks or easily attach to clothing, machinery and tools, allowing movement and spread between farms and regions.

Economic impact: High. A destructive disease of lentil considered to be a high economic threat due to potentially high yield losses through reduced production.

Overall risk: Medium

10.22.3 Fusarium wilt

Fusarium oxysporum f. sp. *Lentis*

The primary host of *Fusarium oxysporum* f. sp. *lentis* is lentil and it is host-specific.[49] Fusarium wilt affects stems, roots, growing points, flowers and seeds. Seedling wilt is characterised by sudden drooping and drying of leaves and whole seedling. Adult symptoms appear at flowering to late pod-fill, with sudden drooping of top leaflets, leaflet closure without premature shedding, and dull green foliage followed by wilting of the whole plant or individual branches. Root systems will appear normal, with a slight reduction in lateral roots.

The pathogen has a low entry potential but high, however high establishment and spread potential. It is viable in soil and debris for up to three years and spores spread by mechanical means and on seed.

Australian breeding lines are screened overseas for resistance to Fusarium.[50]

Entry potential: Low.

Establishment and spread potential: High.

Economic impact: High. A destructive disease of lentil.

Overall risk: Medium.

10.22.4 Aphanomyces root rot

Aphanomyces euteiches

Economic importance

This root rot has been observed in recent years in parts of northern NSW in faba bean.[51] It is unlikely to be a major pathogen of lentil at present. However, the expansion of this crop into regions with heavy soils and high rainfall, or irrigated fields, increases the risk of losses.

Symptoms

Chlorosis and wilting of the plant, associated with necrosis in the roots

Disease cycle

The fungus survives in soil and is exacerbated by waterlogging. It can spread from crop to crop in the soil, either via infected plant debris or as resting spores.

In wet soils these fungi can invade plant roots and cause root rot. Wet conditions also encourage the spread of disease within a field. The reduced root development causes the plants to die when they are stressed.

Control

The disease can be reduced by crop rotation.

It is not known if this strain of the disease can also affect other pulses. A pea-infecting strain is known to occur in Europe.

49 Pulse Australia (2016) Southern lentil best management practices training course – 2016. Pulse Australia.

50 GRDC (2011) DAV00119 PBA Lentil breeding - expansion project. Project outline, GRDC, https://grdc.com.au/research/projects/project?id=708

51 Pulse Australia (2016) Southern lentil best management practices training course – 2016. Pulse Australia.

Pre-harvest treatments

Key points

- **Crop-topping is a form of desiccation, and is common practice in lentil.**
- **Timing of crop-topping is based on the weed stages of development to prevent weed seedset.**
- **Crop desiccation is used to aid in uniform ripening of the crop and to kill green weeds for harvest.**
- **Desiccation enables an earlier harvest.**
- **Do not use glyphosate to desiccate lentil crops if the seed is to be retained for sowing.**
- **Timing of crop-topping or desiccation is more critical than the rate of application of the desiccant.**

11.1 Desiccation

Desiccation is the application of herbicide to a virtually mature crop prior to harvest with the aim of halting further growth and development of the plant. Desiccation is used to aid in uniform ripening of the crop and also to kill green weeds. It also enables an earlier harvest. Desiccation is becoming a common practice, particularly in all pulse crops.

Desiccation is a valuable management tool especially under conditions where:

- There is a problem with green weeds at harvest;
- Improved harvest efficiency is required:
    - » Desiccation eliminates many of the problems associated with green stems and 'gum' build-up causing uneven flow of material through the harvester and 'jamming' problems; and
    - » Minimising the risk of harvester blockages, which enables drum speeds to be reduced in many cases, with a reduction in cracked or damaged grain;
- Early summer rain causes reshooting and re-flowering of lentils;
- Problems of patchy/delayed crop maturity on heavy clay soils; and
- Where 'early harvest management' is being adopted.

Desiccation of lentil has been found to improve yields (Table 1) and harvestability.

Table 1: Lentil yield (t/ha) with and without desiccation in Western Australia.

Harvest method	Merredin 1994	Cunderdin 1996	Merredin 1998	Average
Desiccated	0.86	1.48	1.43	1.26
Normal	0.72	1.26	1.32	1.10
Windrowing	0.45	-	-	-

Source: G Riethmuller, K Siddique, I Pritchard (2005 revised) Successful Lentil Harvesting. Agriculture Western Australia Farmnote 99/99

Benefits of crop desiccation are similar to those from windrowing and include more uniform maturity, reduced problems associated with late weed growth and advanced harvest date. Compared with windrowing, the crop is not placed on the ground so there is less risk of harvest problems due to wet weather.

Timing is critical and is based on crop stage of growth. Timing is either similar to or later than that for windrowing depending on the product used.

Early desiccation should be avoided as it can result in yield and quality losses. The danger of premature desiccation is in causing staining of the seed coat, having excessive green cotyledons in the sample, and/or producing small or wrinkled seed, all of which can create marketing problems.

Crop damage from ground rigs can also be an issue, particularly in tall crops. Tram-lining may help and should be considered at sowing if crop desiccation is likely to be used.

Diquat (Reglone®) is registered for desiccation of lentil. **DO NOT use glyphosate to desiccate lentil crops if the seed is to be retained for sowing.**

Photo 1: *A lentil crop showing different stages of development of pods within the canopy.*

Photo: M. Raynes, formerly Pulse Australia

Photo 2: *A lentil crop that has been desiccated for easier harvest due to the presence of broadleaf weeds.*

Photo: W. Hawthorne, formerly Pulse Australia

11.1.1 Seed and pod development

Pod and seed maturation in lentil is very staggered up each podded branch and between branches. Immature seeds are generally in the top one-third to one-quarter of the canopy. Due to the effects of higher temperatures and varying degrees of moisture stress on the plant at maturity, this period of time is generally more compressed and of shorter duration than flowering.

An issue requiring careful consideration is how to optimise the timing of the desiccation when various stages of seed maturity are present on individual plants, as well as variation across the paddock.

This can be further compounded by soil type variation or irregular land surface with alternating mounds and depressions/hollows (micro-relief), commonly referred to as 'crab hole' country. This can further add to the problem of uneven crop maturity.

Often, inspection of commercial crops nearing potential time for desiccation reveals that while the lower pods have dried to below 15% seed moisture (seeds detached from pod), the upper 25% of pods on each fruiting branch were still at 30 to 40% moisture content, and at varying stages approaching physiological maturity.

11.1.2 Timing of desiccation

The optimal stage to desiccate the crop is when the vast majority of seeds have reached physiological maturity. To assess desiccation timing, walk along a transect through a representative paddock section and randomly sample pods from the top third of the canopy. A minimum of 50 pods should be sampled.

Seed should then be shelled from the pod and the representative seed sample assessed as to the proportion of dark green seed (maximum 50%) and yellow-buff colour seed (minimum 50%). If clear green seed (Photo 3) is present in the sample, then the crop is too immature and should be reassessed at a later date.

Photo 3: *Green kernel (right) due to early desiccation of red lentil. A maximum of 1% is allowable in receival and export standards.*

Photo: W. Hawthorne, formerly Pulse Australia

Timing of desiccation is critical to ensure grain yield and quality are not compromised. Desiccating too early can lead to both significant yield penalties and grain size problems. Results from a trial (Lenaghan & McCann 2003)[1] indicate that desiccation should not occur before 50% of the seeds in the pods present in the top third of the canopy are displaying some colour change (yellow-buff) and the remaining seeds are firm to touch and a deep green colour. (See Table 2 and Photo 1.)

As an indicator this will coincide with 60% of the pods in the top third of the canopy appearing yellow-buff. The rate of desiccant (Reglone® 1.5 L/ha and 1 L/ha) did not

1 L Lenaghan, T McCann (2003) Lentil desiccation – optimum timing and rates. The Lentil Company, http://www.jsaindependent.com.au/publications/lentil_desiccation_report.pdf

have a significant effect on yield or grain quality in this trial. Timing is more critical than the rate, so the rate should be adjusted depending on the target.

Timing of desiccation is more critical than the rate of application of the desiccant.

Whilst it did not happen in this trial, grain colour (seed coat discolouration and/or and green kernel) can be compromised if desiccation is done too early. This can be especially so if rain falls during the dry period before harvest.

Table 2: Desiccation* timing with diquat (Reglone®) and its effect on lentil grain yield and quality.

Timing	Visual symptoms in top third of canopy at desiccation			Grain yield (t/ha)	Grain quality	
	Crop	Pod	Seed		Poor colour (%)	Screenings (% <2 mm slotted screen)
Untreated control	100% ripe brown	100% colour change	100% colour change	1.8	<0.1%	2.0
T1	90% green 10% mottled yellow	No colour change	10% immature (not formed properly) 10% clear green & soft 80% green & firm	1.2	<0.1%	4.0
T2	40% green 60% mottled yellow	20% colour change	5% green & soft 85% green & firm 10% colour change	1.4	<0.1%	2.2
T3	5% green 90% mottled yellow 5% ripe brown	60% colour change	55% green & firm 45% colour change	1.7	<0.1%	1.9
T4	<1% green 60% mottled yellow 40% ripe brown	85% colour change	25% green & firm 75% colour change	2.1	<0.1%	2.6
T5	5% mottled yellow 95% ripe brown	100% colour change	100% colour change	2.1	<0.1%	2.9
lsd					ns	0.7

*Average of desiccant treatments 1.0 & 1.5L/ha Reglone® + 0.1% wetter
Source: L Lenaghan, T McCann (2003) Lentil desiccation – optimum timing and rates. The Lentil Company, http://www.jsaindependent.com.au/publications/lentil_desiccation_report.pdf

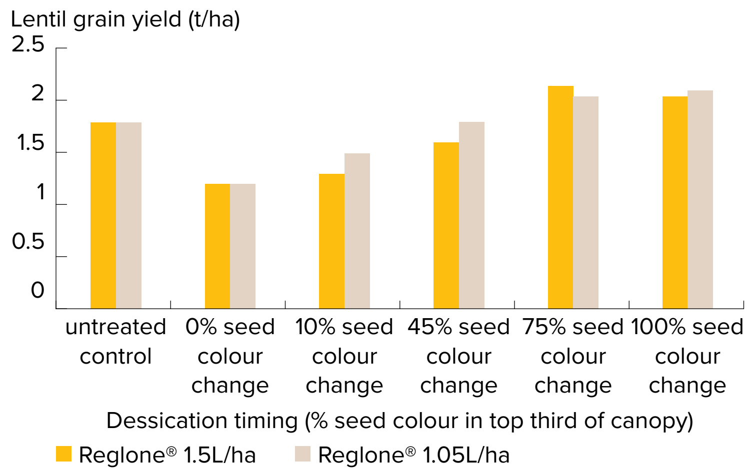


Figure 1: *Desiccation timing and its effect on yield and quality in lentil**.

* Note – More detail of crop stage at desiccation is shown in Table 2. Seed colour changes indicated are from the top third of the canopy only, as these are the most immature grains.
Source: L Lenaghan, T McCann (2003) Lentil desiccation – optimum timing and rates. The Lentil Company, http://www.jsaindependent.com.au/publications/lentil_desiccation_report.pdf

A lentil desiccation trial at Birchip in 2001 showed no yield or quality penalties with early desiccation with Reglone® at 1.5L/ha plus 0.1% wetter (BCG 20011). Four treatments were applied, and all were harvested on the same day.

Treatments (and grain yields) with an lsd ($p<0.05$) of 0.24t/ha were:

Control – not desiccated. Harvested normally (1.38t/ha);

- desiccated when pods were fully formed but still green (1.26t./ha);
- desiccated when pods were fully formed and seed in the bottom pods could be 'rattled' (1.34t/ha); and
- desiccated when pods were fully formed and seed in the mid pods could be 'rattled' (1.24t/ha).

This description of the lentil growth stage as "pods were fully formed but still green" is now known to be less precise than those used by Lenaghan & McCann (2003).[2]

Photo 4: *Lentil during pod-fill and before dry-down.*

Photo: W. Hawthorne, formerly Pulse Australia

2 L Lenaghan, T McCann (2003) Lentil desiccation – optimum timing and rates. The Lentil Company, http://www.jsaindependent.com.au/publications/lentil_desiccation_report.pdf

Photo 5: *Lentil during pod-fill and starting to dry down.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 6: *Lentil starting to dry down.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 7: *Lentil drying down.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 8: *Lentil drying down.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 9: *Green plants on wheel-track edges and also greener parts of a paddock. If desiccated too early issues with grain quality can occur.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 10: *Desiccating lentil. Note the green wheel tracks from previous traffic.*

Photo: M. Raynes, formerly Pulse Australia

11.1.3 Effect of desiccants on green immature seeds

Applying desiccants to seed that is still green and actively filling will result in:

- a reduction in grain size (and yield);
- an increase in a greenish discolouration of the seed coat (if >1%, green kernels (cotyledons) leads to severe marketing problems); and
- a reduction in seed viability (dead or abnormal seed).

In lentil and other pulse crops intended for use as seed or for sprouting markets, glyphosate should not be used as it will affect seed germination even when applied after physiological maturity. See a faba bean example in Table 3.

Table 3: Effects of desiccation timing on seed viability in faba bean.

Treatment	Faba bean crop stage	% Normal seed	% Abnormal seed	% Total germinated
Nil pre-harvest treatment		92	2	94
Desiccated – glyphosate	Seed physiological maturity	27	63	90
	Seed physiological maturity plus 6 days	64	29	93
Windrowed	Seed physiological maturity	89	2	91
	Seed physiological maturity plus 6 days	85	7	92

Source: P Matthews, D Holding (2004) Managing faba bean harvest. in Proceedings of Bean Focus 2004 pp100-103, https://grdc.com.au/Resources/GrowNotes.

11.1.4 Products registered for the pre-harvest desiccation of lentil

Table 4: The following table comprises extracts from the Reglone® and Roundup Ultra Max® product labels.

Active ingredient	Example trade name	Rate	Critical comments
Diquat	Reglone® (200 g/L)	2–3 L/ha	Spray as soon as the crop has reached full maturity. Helps overcome slow and uneven ripening and weed problems at harvest. Add Agral® 200 mL/100 L or BS1000® 160 mL/100 L prepared spray. **DO NOT harvest for 2 days after application.**
Glyphosate*	Roundup Ultra Max® (570 g/L)	0.645–1.7 L/ha	**Apply when physiologically mature and less than 15% green pods.** Use higher rates where crops or weeds are dense and where faster desiccation is required. **DO NOT harvest within 7 days of application.**

Note: Always read the label supplied with the product before each use.

WARNING: DO NOT use glyphosate to desiccate lentil, field pea, faba bean or chickpea that are to be used for seed or sprouting as germination is affected.

MORE INFORMATION

For more information on desiccation go to:
Desiccation and Crop-topping: Risks in Pulse and Canola Crops:
http://pulseaus.com.au/storage/app/media/crops/pulses/20161005_PA-AOF-desiccant.pdf

11.1.5 Practicalities of desiccation

Desiccants work more efficiently when sprayed slightly later than optimal time for windrowing; when the crop is reasonably ripe across the entire paddock. It is important to ensure that good coverage of the desiccant is achieved to ensure that the stems dry down. Desiccants applied by aircraft, due to wet paddock conditions, do not dry down the plant matter as effectively as ground application.

Pulse Australia released an 'Alert' on desiccation and crop-topping in October 2016. (Please note: This alert was from an international marketing perspective.)

Click on the link for the most current information including herbicides and desiccants approved for use in lentil.
http://pulseaus.com.au/blog/post/broadleaf-crop-desiccation

11.2 Crop-topping

Crop-topping is a form of desiccation; however, its timing is based on weed stages of development rather than that of lentil. It is timed to prevent weed seedset, meaning the lentil crop can be compromised if crop-topping is implemented too early. Products used and rates applied differ from that of desiccation.

Table 5: Summary of lentil varietal response to grain yield effects of crop-topping with paraquat at the mid timing (optimum) stage for ryegrass crop-topping in South Australia.

Variety	Maturity of the variety	Yield loss* (No of years) at mid-crop-top timing**	Yield loss range (%) at mid-crop-top timing**
Boomer	Mid/late	2/3	0-24%
Nugget	Mid/late	2/3*	0-22%
Nipper⊕	Mid	1/3	0-20%
PBA Flash⊕	Early/mid	1/3	0-14%
PBA Blitz⊕	Early	1/3	0-10%
PBA Jumbo⊕	Mid	0/3	0

* Number of years' significant yield loss occurred out of the total years tested (x/3)
** The percentage yield loss range compared with Nil treatments.

Source: Grain yield implications of crop-topping pulses for late weed control in south-eastern Australia. "Capturing Opportunities and Overcoming Obstacles in Australian Agronomy", (2012), Proceedings of 16th Australian Agronomy Conference 2012, http://www.regional.org.au/au/asa/2012/weeds/8099_linesml.htm

Timing of crop-topping is critical from both a weed and crop perspective.

Timing of crop-topping in lentil works very well in early maturing varieties like PBA Blitz⊕, PBA Bolt⊕ and PBA Flash⊕. However, timing can be marginal in some years in other lentil varieties that are later maturing (Nugget). Crop-topping is generally not always possible in later varieties due to maturity being so late relative to ryegrass maturity in a lengthy growing season.

11.2.1 Implications of crop topping too early

Growers must be aware of grain quality defects that may occur if crop-topping occurs earlier than the optimal time. These grain quality defects can result in either rejection at delivery or severe downgrading.

Crop topping of lentil too early can cause discoloured seed coat or cotyledons (kernel). Also some of the smaller pods near the top of the plant are more exposed to direct contact by the desiccant spray. Seeds in these less mature pods are not physiologically mature (green kernel) when they dry down. Grain quality issues due to early crop-topping are exacerbated if crop-topping occurs just prior to a significant rainfall event.

Rate of desiccant product or product used can also influence speed of dry-down, hence the potential for more grains that are immature.

Photo 11: *Lentil crop with ryegrass at its optimum stage for crop-topping (2011).*

Photo: Grain yield implications of crop-topping pulses for late weed control in south-eastern Australia. "Capturing Opportunities and Overcoming Obstacles in Australian Agronomy", (2012), Proceedings of 16th Australian Agronomy Conference 2012, http://www.regional.org.au/au/asa/2012/weeds/8099_linesml.htm

Photo 12: *Lentil crop with ryegrass at its optimum stage for crop-topping (2010).*

Photo: Grain yield implications of crop-topping pulses for late weed control in south-eastern Australia. "Capturing Opportunities and Overcoming Obstacles in Australian Agronomy", (2012), Proceedings of 16th Australian Agronomy Conference 2012, http://www.regional.org.au/au/asa/2012/weeds/8099_linesml.htm

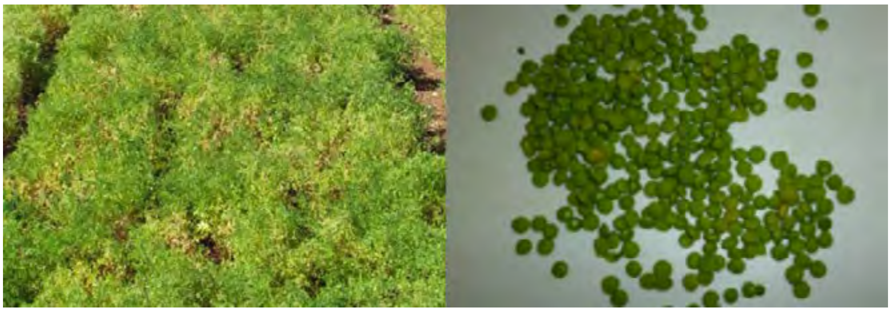


Photo 13: *Lentil crop with ryegrass at its optimum stage for crop-topping (2011).*

Photo: Grain yield implications of crop-topping pulses for late weed control in south-eastern Australia. "Capturing Opportunities and Overcoming Obstacles in Australian Agronomy", (2012), Proceedings of 16th Australian Agronomy Conference 2012, http://www.regional.org.au/au/asa/2012/weeds/8099_linesml.htm

Photo 14: *Lentil crop with ryegrass at its optimum stage for crop-topping (2010).*

Photo: Grain yield implications of crop-topping pulses for late weed control in south-eastern Australia. "Capturing Opportunities and Overcoming Obstacles in Australian Agronomy", (2012), Proceedings of 16th Australian Agronomy Conference 2012, http://www.regional.org.au/au/asa/2012/weeds/8099_linesml.htm

MORE INFORMATION

For further information on this trial go to: http://www.regional.org.au/au/asa/2012/weeds/8099_linesml.htm

MORE INFORMATION

For more information on 'Desiccation and crop-topping of pulses' see Pulse Australia bulletin at http://pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping

MORE INFORMATION

For more information on crop-topping go to:
Desiccation and Crop-topping: Risks in Pulse and Canola Crops: http://pulseaus.com.au/storage/app/media/crops/pulses/20161005_PA-AOF-desiccant.pdf

MORE INFORMATION

Pulse Australia released an 'Alert' on desiccation and crop-topping in October 2016.

Click on the link for the most current information including herbicides and desiccants approved for use in lentil. http://pulseaus.com.au/blog/post/broadleaf-crop-desiccation

Trials on crop-topping

A crop-topping trial was conducted at Arthurton/Melton, South Australia in 2011.[3] Key findings were:

- Reductions in grain yield can occur with early crop-topping (two weeks prior to recommended timing);
- Grain yield is unaffected by late crop-topping (two weeks after recommended timing);
- Grain weight is affected by crop-topping similarly to grain yield; and
- Crop-topping does not have an effect on the occurrence of mould in lentil grain.

Photo 15: *Varying stages of maturity of seeds in pods of PBA Blitz⊕ at the stage of crop-topping.*

Photo: M. Raynes, formerly Pulse Australia

Photo 16: *Varying stages of maturity of pods of PBA Hurricane XT⊕ at the stage of crop-topping.*

Photo: M. Raynes, formerly Pulse Australia

3 M Lines, L McMurray, J Brand (2012) Grain yield implications of crop-topping pulses for late weed control in south-eastern Australia. In "Capturing Opportunities and Overcoming Obstacles in Australian Agronomy". Edited by I. Yunusa. Proceedings of 16th Australian Agronomy Conference 2012, 14-18 October 2012, Armidale, NSW, http://www.regional.org.au/au/asa/2012/weeds/8099_linesml.htm

11.3 Windrowing

Windrowing (or swathing) is when a standing crop is cut then left on the ground for the grain to be harvested at a later date. It is primarily used to bring the harvest date forward, uniformly ripen the crop, protect the crop from shattering where harvest is to be delayed, or be a part of general management to reduce seedset of weeds present.

Windrowing has become common in pulses like faba beans in some areas as growers try to reduce problems associated with direct harvesting, uneven crop maturity, or weed seed management. Windrowing lentil crops is not a common practice in Australia. However, it is possible if done correctly.

11.3.1 Benefits

Windrowing a pulse crop, including lentil can provide a number of benefits:

- Uniform maturity of the crop in paddocks;
- Problems caused by late maturing weeds are avoided. These include delayed harvest which increases the risk of staining caused by the weather and disease, and storage problems from green weed contamination;
- Can advance the harvest date when done as soon as the crop is mature, avoiding clashes with other crops, such as cereals;
- Weed seed is moved into a windrow that can be burnt after harvest;
- Lower pods are harvested rather than being left behind, due to the lower cutting height possible with a windrower;
- Excessively tall crops can be better handled at harvest. When direct harvesting tall crops the reel can be in the way: pushing plants forward and causing problems with feeding material into the harvester and losses on the cutter bar. Direct harvesting very tall and lodged crops is also very slow. Windrowing can dramatically increase harvester efficiency;
- Windrowing reduces damage to harvesters. Harvesters working in 'rougher' country can damage knife fingers and sections, retractable fingers and other components on sticks and stones. Pick-up fronts leave most of these 'undesirables' on the ground; and
- Harvest speed may be increased, particularly if a light crop is made into paired windrows; therefore, increasing the width covered by the harvester pass.[4]

In Canada, windrowing of lentil is prevalent. A key reason is that growers believe the lentil maintains its grain colour with this practice. Improved colour is a key parameter that assists growers in achieving a higher quality grade.

11.3.2 Risks

There are several risks to windrowing crops:

- Windrowing too early (prior to crop maturity) can cause significant yield and quality losses. Small and shrivelled seed will result from drying down of immature seed;
- Windrowing too late can cause shatter losses as the cutter bar hits the crop;
- The seed coat can discolour if left too long in the windrow, especially in wet conditions when mould growth and seed staining can occur;
- Light windrows can be blown; and
- Topsoil can blow if there is very little root system and plant biomass left.

While windowing lentil maintains better colour, it has not necessarily been found to be enough of an advantage for some growers compared to the overall time savings in the harvest program with crop-topping, desiccation and direct harvesting.

4 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Windrowing of lentil crops for uniform ripening and earlier harvest was once considered impractical because lentil windrows often lack bulk, are difficult to pick up from the bare ground, and tend to be blown around in strong winds when left to dry down. However, there has been some success in placing wide windrows doubled into a bulkier windrow and using a 'cotton wheel roller' to compact the windrow. Risk is reduced and harvesting efficiency improved because of the larger, compact windrow and wide windrows covered in the harvesting pass.

A windrowing trial was attempted in 1994 at Merredin in WA; however, issues with picking up the lentil windrow with crop lifters led to a yield reduction of 37%.[5] Even so, windrowing may be an option in medium rainfall areas where growth and biomass production are generally large and good harvest weather is difficult to achieve. A self-propelled windrower is required to cut across the lay of the crop and a pick-up front is ideal.

11.3.3 Timing

The most critical step in windrowing is timing. Windrowing at the correct maturity time reduces the time the lentil plant spends in the windrow. Assessment for timing of windrowing should be based on seed maturity. Lentil seed is considered physiologically mature when the seed is filled to its maximum size, and has changed colour.

The ideal time to windrow is when the seeds in the top third of the lentil plant are at full physiological maturity.

Visual measurements such as leaf colour and drop, or pod colour should not be considered for timing of windrowing as these parameters can be misleading; leaves can be prematurely lost and pods blemished by disease.

If the lentil crop is not at the required level of maturity, then windrowing becomes problematic. Alternatively, windrowing on the later side of required maturity increases grain losses due to shattering. Determining the most appropriate time can be difficult taking into account variation across the paddock.

Snails

Windrowing of some pulses has also been successful when it is done only hours in front of the harvester, and done during the early morning whilst the crop is wet with dew to avoid grain loss. This timing is principally to help reduce snail contamination in the grain sample harvested later that day. Such a late timing does not assist in obtaining uniform and early crop ripening.

11.3.4 How to windrow

The cutting height for windrowing should be just below the bottom pods with the reel following the top of the crop. The reel speed should be quite slow. The delivery opening in the windrower should be large enough to prevent blockages or there will be lumps in the windrow. Windrows should be dense and tightly knit for best results.

Pick-up fronts are the most common type used for harvesting windrows. However, crop lifters used close together on open fronts have been used with some success.

Curing should take about 10–12 hot days. However, heavy infestations of radish, weeds and other green matter could delay drying.

5 G Riethmuller, K Siddique, I Pritchard (2005 revised) Successful Lentil Harvesting. Agriculture Western Australia Farmnote 99/99, http://www.agric.wa.gov.au/objtwr/imported_assets/content/fcp/lp/lent/cp/f09999.pdf

11.3.5 Should lentils be windrowed or direct headed?

In Canada, the practices of windrowing (swathing) lentil and direct harvesting (straight cut) lentil are both commonplace. There is no clear indication as to which method is best.[6]

The key element in choosing between windrowing and direct harvesting lentil is the level of urgency in harvesting the crop and transferring the grain into storage. Lentil must be prioritised at harvest in preference over other grain crops. This has been highlighted in both Canada and Australia where wet, uncooperative weather or extreme heat and winds have made the management of lentil harvest much more difficult than usual.

Timing and logistics are a consideration as the area that can be direct harvested in one day is less than what can be achieved with harvesting windrows. Windrowing green (not fully mature) lentil results in a larger window of time with which to harvest all crops.

Another consideration for choosing windrowing over direct harvesting is the cost of operation. The cost of operating a harvester versus a windrower is significantly higher. Additionally, windrowing and subsequent harvesting can be done at a speed of around 9–10 km/h, whereas direct harvesting is usually slower, around 6.5km/h, a key advantage when timeliness of harvest is critical.

There may sometimes be a time-sensitivity issue around the windrowing of both lentil and canola. In these circumstances the decision needs to be made whether to use desiccation and straight harvesting rather than windrowing.

11.3.6 Direct harvesting

Most Australian and some Canadian lentil growers tend to prefer direct harvesting (straight cutting) of lentil after desiccation (or crop-topping). Growers attribute much of their success in harvesting lentil to having the correct harvesting equipment. Using a flex harvester front with air reels can result in limited shatter on the knife front, provided the speed of the harvester is maintained. If the crop is shorter or thinner, it can be difficult to keep the crop feeding well and the harvester moving at the desired speed. More losses occur in a thin, poor standing crop compared to a thick and bulky crop. Harvest efficiency is improved if lentil has been rolled and/or sown inter-row into standing stubble, especially in a thinner or shorter crop.

A key benefit of direct harvesting lentil for many growers is time management of the entire harvest program (taking into account all crop types). For some, the time taken for lentil windrowing can be too long and can overlap with when canola and faba bean crops needs windrowing. Desiccating lentil can be completed in significantly less time than windrowing, thus allowing time needed for windrowing canola. Some growers employ additional contract harvesters to take off their lentils rapidly, given the dire yield and market consequences of delayed harvest.

6 B Bratrud (2011) To Swath or Not — Harvest Management of Lentils. Grainews 6 June 2011, http://www.agcanada.com/grainews/2011/06/06/to-swath-or-not-harvest-management-of-lentils/

Harvesting lentil

Key points

- **Lentil should be harvested as soon as mature as pods may fall if harvest is delayed.**
- **Early harvested lentil grain is much more resilient against breakage during harvesting and subsequent handling.**
- **Grain quality deteriorates the longer mature lentil is left exposed to weathering in the paddock.**
- **Harvesting grain at high moisture levels up to 14% helps minimise cracking.**
- **There are several modifications and harvest aids that can assist in the harvesting of lentil.**
- **Flexi-fronts enable harvesting close to the ground to pick up shorter plants.**
- **Harvesting lentil can be hazardous for starting paddock or harvester fires.**

12.1 Impact of delayed harvest on profitability

Lentil can be one of the most profitable winter crops, especially when a professional approach to production and marketing is taken. This is as opposed to treating it as a minor, secondary crop where it is 'planted last, harvested last, and sold to the nearest buyer'. Early harvest of lentil crops is critical as delays can cost both growers and the pulse industry a considerable amount of money.

Delays can result in significant yield losses and quality downgrading due to lodging, shattering, pod loss and diseases. Grain quality can also suffer through mechanical damage, or weathering and seed staining. Furthermore, grain moisture levels outside of the optimum range at harvest can adversely affect the quality of the grain in storage.

In any growing area, it is often not unusual for lentil crops planted on the same sowing rain to be harvested several weeks apart. This spread in the harvesting window results in a range of grain moistures. For many late harvested crops grain moisture is often low, around 8%; preferred moisture content is 12% with a maximum of 14% accepted.[1]

The main reasons (or perceptions) influencing a grower's decision to delay lentil harvest include:

- Lentil harvest can clash with cereal harvest. Lentil is still considered 'secondary' by some growers, with wheat or barley taking precedence at harvest time.
- The possibility of achieving premiums for high quality wheat or malting for barley is a major incentive for prioritising the cereal harvest, although in reality the premiums for early harvested lentil are often greater.
- There is a perception that lentils 'weather' reasonably well and/or do not shatter. This is not true.
- Uneven ripening of lentil crops if not desiccated (or windrowed), especially when grown on heavy clay soils or variable soil types.
- Lentils are considered slower or more difficult to harvest than cereals, resulting in less hectares harvested per day. This does not need be so if desiccation is used, and the harvester is modified to suit lentils.
- The risk of a harvester fire is perceived to be greater in lentil than other crops.

Some growers, with a high proportion of lentils in their cropping program, use contractors to assist with a timely harvest, recognising the necessity for an early and efficient harvest to avoid potential losses of both yield and quality.

12.1.1 Yield losses

Yield losses in lentil increase significantly the longer harvest is delayed.

Lentil is very prone to pod splitting and pod drop with delays in harvest. This is especially so when weather events (rain and strong winds) occur after the plant has dried down. Weathering of the grain can also occur in split pods.

Lentil plants that have been affected by rain are also more difficult to thresh out at harvest, and often contain much higher levels of unthreshed pods and pod material.

It is estimated that grain losses due to a 1–3 week delay in harvest range from \$150–\$450 per hectare, depending on seasonal conditions.[2] Most of the losses are due to pod loss and shattering before harvest, as well as pod loss upon intake into the harvester.

1 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

2 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Photo 1: *Yield losses of up to 50% have been recorded in the field after rains or strong winds.*

Photo: W. Hawthorne, formerly Pusle Australia

The incidence of lodging of the lentil plant increases the longer it is left standing once ready for harvest. Furthermore, the risk of lodging is even higher if the crop is high yielding and has been planted on wide rows without stubble trellising.

An example of the difference in dollar value of lentil due to yield loss is as follows:

1. **Timely harvest**
   500 tonnes of lentil @ 14% grain moisture @ $450 per tonne = $225,000.
2. **Delayed harvest**
   500 tonnes of lentil @ 8% grain moisture = 470 tonnes (due to grain losses)
   470 tonnes @ $450 per tonne = $211,500.
   Difference in income: $13,500 (6% loss)

12.1.2 Deterioration in grain quality

Early harvested lentil grain is much more resilient against breakage during harvesting and subsequent handling, even at low moisture contents. Grain quality deteriorates the longer that mature lentils are left exposed to weathering in the paddock.

The seed coat of lentil is very prone to wrinkling if it has been exposed to wetting and drying events due to rain or heavy dew during the harvest months. Expansion of the seed as it absorbs moisture, and then contraction as it dries, weakens the seed coat. This renders it much more susceptible to mechanical damage during harvest and handling operations.

Levels of cracked and damaged grain can be as high as 50% in extreme cases of delayed harvest combined with rain and/or wind events.

Lentil that does not meet the Number 1 Receival Standard of 3% maximum defective grain needs to be graded in order to meet the standard. This cost is incurred by the grower and is between $15 and $25 per tonne. Some receival agencies do have a 'cleaning grade' for lentil that would otherwise achieve Grade 1 standard.

Those defective grains that do not meet the receival standards are termed 'seconds' and are usually sold into the stockfeed market for a significantly lower price.

MORE INFORMATION

For more on lentil cleaning grades, see: https://ezigrain.abb.com.au/quick_links_pdfs/Lentil_cleaning_grade_FINAL.pdf

Most lentil is ultimately processed into dahl or flour by removing the seed coat (hull) and splitting the cotyledons. However, the external and internal appearance is still critical for marketing. Older seed that has darkened with age splits better than new season grain. The milling process uses abrasive type mills to gradually abrade the seed coat from the cotyledons, and is reliant on the seed coat being firmly attached to the cotyledons.

Cracking and weakening of the seed coat prior to processing substantially reduces the recovery percentage of splits, as well as reducing the quality of the final product.

Lentil seeds discolour and darken when exposed to weathering in the paddock.

Darkening of the seed coat is caused by oxidation of polyphenol compounds (tannins). The following conditions play a major role in accelerating seed coat darkening:

- rainfall
- cool to mild temperatures
- high humidity
- sunlight.

While there is usually no direct penalty or discount for a moderate degree of seed coat darkening, it does have a significant impact on the marketability of the product and the reputation of the Australian industry as a supplier of quality product. Quality is becoming increasingly more important as Australian traders attempt to establish market share against Canada, our major lentil exporting competitor.

It is likely that there will be increased segregation and premiums paid for fresh, unstained lentil of good quality. New varieties with quality traits are being developed and the Australian industry is very quality conscious.

Factors that affect the quality of lentil grain include:

Mould infection. Weathering of grain due to delays in harvesting can substantially increase mould infection levels. High levels of mould infection will also cause darkening of the seed coat. Humidity (>70% relative humidity) and wet conditions favour the development of a range of fungi in late-harvested lentil crops. While *Alternaria* spp. usually predominate, *Asperguillus, Gladosporium* and *Penicillium* species may also be present.

- **Ascochyta infection.** Increased risk of late ascochyta infection can develop on dry senescing pods under wet conditions, and can penetrate through to the seed in susceptible varieties. The current Farmer Dressed Receival Standard for visible ascochyta lesions is a maximum of 1% on the seed cotyledon (kernel).
- **Insect-damaged grains.** Native budworm can occasionally attack senescing lentils, particularly when rainfall has softened the pod. Insect-damaged seeds are classified as defective, and cannot exceed the tolerance level of 3% current Farmer Dressed Receival Standard.

12.1.3 Missed marketing opportunities

IN FOCUS

An early harvest provides some degree of control over lentil grain quality, as well as how and when the crop is marketed. Late-harvested lentil can often result in a grower becoming a price-taker in a falling market or encountering delays in delivery.

Delayed harvest can often mean missing out on premiums paid for early harvested crops of good quality. This is often the case, except for seasons where major production problems have been encountered, resulting in a shortfall of grain in the market.

MORE INFORMATION

Detailed information on lentil receival standards is in Section 15 Marketing.

MORE INFORMATION

For the current Australian Pulse Standards for Lentil go to: http://www.pulseaus.com.au/marketing/receival-trading-standards

12.2 Implementing early harvest management

There are a range of management factors that contribute to an early-matured crop, and all can be important at different times and for different reasons. Each factor has its own advantages. Optimal results, in terms of yield, profit and timing for maturity, are due to these factors being applied in the most appropriate and balanced manner. Of course, seasonal conditions will always be a factor influencing decision-making.

These factors include:

12.2.1 Sowing

- Sow at the earliest opportunity within the preferred planting window for your area. This may involve dry sowing by a particular calendar date.
- Moisture-seeking equipment and/or press-wheels can significantly enhance sowing opportunities under marginal soil moisture conditions.
- Use adapted varieties that meet targets for early harvesting.
- Use precision planters or machines with automatic depth control. This will result in more uniform plant establishment and crop development, and, consequently, more even crop maturity. This is particularly so when sowing into marginal soil moisture and dry conditions.

12.2.2 In-crop management

- Control Botrytis grey mould before canopy closure;
- Control native budworm during flowering to maximise early podset; and
- Avoid using herbicides that delay crop maturity, for example flumetsulam (Broadstrike®).

MORE INFORMATION

More information on windrowing, desiccation and crop-topping is in Section 11.3 "Windrowing"

12.2.3 Harvest management

- In a short crop, consider weed-wiping (where possible) to kill tall, late weeds that might otherwise delay harvest (see "8.6 Herbicide types" on page 16 for more information on weed wiping);
- Consider windrowing to enable earlier maturity and harvest date;
- Consider using a desiccant to dry late-maturing plants and any weeds;
- If using glyphosate (or equivalent registered products) to terminate crop growth at the 80–90% black-brown pod stage, be aware of potential impacts on seed quality; and
- Prepare the harvester to operate efficiently at 14% grain moisture content.

A major advantage of high moisture harvesting is that harvest can commence earlier in the season and earlier each day.

Harvesting at 14% moisture content, compared to 12%, can effectively double the harvest period available on any one day in hot environments. Growers can consider blending, aerating and/or drying the grain to achieve the required receival standard of 14% moisture.

12.2.4 Benefits of early harvesting

Early harvesting results in reduced grain losses because the seed pods are less prone to shatter or drop. The crop is also easier to gather because it stands more erect, allowing the harvester front to operate at a greater height, reducing the soil, rocks and sticks entering the harvester.

Early harvesting also means there are fewer summer weeds to clog the harvester.

Early harvesting also plays a role in disease control and crop establishment in the following crop. Early harvested grain is of better quality in terms of colour, weathering and disease.

MORE INFORMATION

Go to Section 11 Pre-Harvest Treatments for further information.

Early harvesting of lentil offers the advantages of:

- reduction in grain losses;
- reduced risk of grain discoloration;
- lower percentage of cracked grain; and
- reduced snail contamination.

Early harvesting of lentil is possible with the maximum moisture level for receival at 14%. This allows significant improvements in lentil quality to be realised, with less cracked and/or stained grain, and lower snail contamination. Lentil stems or weeds, or weeds that are still green, could become a problem in rotary harvesters by wrapping around rotors, reducing rotor speed and overloading rotor drives.

Strategies to aid early harvest of lentil may include desiccation, crop-topping and windrowing.

12.3 Harvesting and harvester settings

Lentil is easily threshed, so concave clearances on harvesters should be opened and the thresher speed reduced.[3]

Lentil is prone to cracking, particularly green lentil types, so thresher speed should be adjusted (300–600 rpm) and also the concave (10–30 mm) to suit conditions (Table 1 and Table 2). Consideration must be given to thresher impact speeds that vary with the thresher diameter (Table 3). Thresher speed should be adjusted to suit the required 12 metres per second impact speed.

Lentil can be harvested with minor adjustments and modifications. Flexi-fronts are best because they can harvest close to the ground whilst flexing with ground contours. Open-front or pick-up fronts are also suitable for harvesting lentil.

Lentil should be harvested as soon as mature as pods may fall if harvest is delayed, especially after rain.

A lentil crop varies in height from 15–80 cm, with pods held up within the canopy. This makes direct harvesting possible with open-front machines without crop lifters.

Harvesting grain at high moisture levels up to 14% should help minimise cracking.

A good sample from the harvester is required as lentil is destined for human consumption. Desiccating the crop will kill summer weeds and ensure even crop ripening. Alternatively, direct harvesting early prevents green weeds clogging the harvester, staining the grain and contaminating the sample.

If there are summer weeds present, thresher speed may need to be increased to ensure that weeds do not clog or block the harvester. Maximum wind settings and barley sieve settings should ensure a good sample. Furthermore, the rake at the back of the sieves should be blanked-off to stop summer weeds entering the returns. Summer weeds may cause walkers and sieves to block completely resulting in high grain losses.

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

Table 1: Harvester settings for pulses.

	Chickpea	Faba bean	Green lentil	Red lentil	Lupin	Field pea	Vetch
Reel speed	medium	slow	slow	slow	slow	medium	slow
Spiral clearance	high	high	low	low	high	standard	low
Thresher speed	400–600	400–600	350–450	350–450	400–600	400–600	400–600
Concave clearance	10–30 mm	15–35 mm	20–30 mm	10–20 mm	10–30 mm	10–30 mm	10–30 mm
Fan speed	high	high	high	high	high	high	medium
Top sieve	32	32–38 mm	32 mm	16 mm	32 mm	25 mm	25 mm
Bottom sieve	16 mm	16–19 mm	8–16 mm	3–10 mm	16 mm	16 mm	10–16 mm
Rotor speed*	700–900	700–900	350–450	350–450	700–900	700–900	slow

* Rotary machines only.
Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Table 2: Suggested harvester settings for lentil.

Component	Red lentils	Green lentils
Reel speed	slightly faster than ground speed	slightly faster than ground speed
Table auger clearance	7–10 mm	8–12 mm
Drum or rotor speed	300–600 rpm*	300–600* rpm
Concave clearance	10–20 mm (start at 10 mm)	13–20 mm (start at 13 mm)
Fan speed	60.75% (start at 75%)	70.85% (start at 85%)
Top sieve	10–20 mm (start at 20 mm)	13–25 mm (start at 25 mm)
Bottom sieve	5–10 mm (start at 10 mm)	8–16 mm (start at 16 mm)

* Drum or rotor diameter (mm) influences the rotational speed (rpm).
Drum or rotor rotational speed and diameter for 12 metres per second peripheral speed are:
400 mm drum = 570 rpm; 500 mm = 460 rpm; 600 mm = 380 rpm; 700 mm = 330 rpm; 800 mm = 290 rpm.
Source: Successful Lentil Harvesting (1999), Agriculture Western Australia Farmnote 99/99, http://agric.firstsoftwaresolutions.com/fullRecord.jsp?recno=10735

MORE INFORMATION

To view a video on harvesting lentil go to: http://www.youtube.com/watch?v=RnFDgpqUI38

12.3.1 Harvester thresher size and rotor speed

It is impact forces that easily damage lentil. It is important to minimise any mechanical damage of lentil grain because the appearance of the grain is a very important quality parameter. Ease of threshing and the amount of seed splitting differs between varieties, so some testing is necessary.

The outside or peripheral speed of the harvester thresher, or rotor, impacts the grain to thresh it out of the pods. This speed depends on the thresher or rotor revolution speed and its diameter. Keeping this impact speed to around 12 metres per second (the same as for lupin) will reduce the chance of grain damage.

An experiment at Merredin, Western Australia, using a specially designed grain impact tester, showed that grain damage was greater at higher impact speeds (Table 3). Grain with low moisture content is most prone to damage and this is another reason to harvest the crop as soon as it is ripe.

Table 3: Red lentil seed damage with impact speed (seed moisture at 12.7%).

Impact speed (m/s)	Seed damage (%)
9.2	0.5
13.7	0.9
18.9	8.3
23.4	18.4
26.9	30.0

Source: Successful Lentil Harvesting, (1999), Agriculture Western Australia Farmnote 99/99, http://agric.firstsoftwaresolutions.com/fullRecord.jsp?recno=10735

12.4 Modifications and harvest aids

There are a number of modifications and harvest aids to assist in the harvesting of lentil. Growers must assess the cost-benefit ratio of modifications and harvest aids as growing a small area of lentil may not justify the cost.

12.4.1 Flexible cutter-bar fronts (flexi-fronts)

The cutter-bars of flexi-fronts are hinged in short sections, allowing the whole front to flex and closely follow the ground contour. Flexi-fronts use skid plates and are particularly good for short crops like lentil and field pea, but can also be used on cereals by locking the hinged sections together.

Flexi-fronts are ideal for harvesting lentil, particularly when used in association with some air assistance to blow the plant material into the comb front.

Photo 2: *A harvester set up for lentil with a flexi-front and air assist.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 3: *Harvesting lentil with a flexi-front and air assist.*

Photo: T. Bray, formerly Pulse Australia

12.4.2 Aussie-Air

Aussie-Air directs an air blast through the reel fingers, and is suitable for both heavy and light crops.[4]

12.4.3 Harvestaire

A Harvestaire replaces the reel with a manifold that directs a blast of air into the front of the harvester.[5] The manifold causes some interference with the incoming crop, meaning correct orientation of air blast is very important. An optional secondary fan to increase the air blast is worthwhile and the device is more effective in light crops.

12.4.4 Vibra-mat

Vibra-mat is a vinyl mat that vibrates with the knife, thereby stopping bunching of plant matter at the knife of open-front harvesters. The Vibra-mat also helps the table auger to clear out plant matter. Its main advantage is that the device is inexpensive. The Vibra-mat is more effective in light crops.

With the Vibra-mat it is important to match ground speed to table auger capacity and crop density. If the ground speed is too slow, plant material will not have enough momentum to carry to the harvester front. If the ground speed is too fast, the cut crop will not be cleared from behind the knife.

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

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

Photo 4: *Harvestaire front combined with extension fingers and a blue Vibra-mat.*

Photo: G. Cumming, formerly Pulse Australia

12.4.5 Crop lifters

Crop lifters are an attachment to the knife that extend forward and are designed to lift lodged crops above the knife to reduced grain losses at harvester front. They are used in situations where crop height is low to the ground and harvesting with a standard front would result in a large amount of plant material being unable to be picked up by the harvester.

Most cereal crop lifters can be used. However, since lentil plants have many thin stems, a slim crop lifter is recommended to reduce the sideways movement of the plant (Photo 5).

Photo 5: *Light crop lifters that can be used in lentils.*

Photo: G Reithmuller

In two experiments at Merredin in 1995 and 1996, crop lifters spaced at 230 mm increased lentil yields by an average of 26% (0.38 t/ha) (Table 4).

Table 4: Average lentil yields from two experiments in 1995 and 1996 with and without slim crop lifters at Merredin (Western Australia).

Harvest attachment	Yield (t/ha)	% yield of no lifters
Slim lifters at 23 mm	1.87	126
No lifters	1.49	100

Source: G Riethmuller, K Siddique, I Pritchard (1999) Successful Lentil Harvesting. Agriculture Western Australia Farmnote 99/99, http://agric.firstsoftwaresolutions.com/fullRecord.jsp?recno=10735

It is best to avoid crop lifters if there are high numbers of sticks on the ground. Also, lifters can result in an increased intake of soil into the harvester; therefore, height control is important.

Soil intake can wear harvester parts and so is best avoided if possible. However, soil can be separated from the grain by fitting screens to the bottom of the clean grain elevator. Elevator screens can also help remove small, damaged or frosted grain.

Crop lifters can dig into wheel ruts left by spraying vehicles, so avoid spraying when the soil is very wet or use low-pressure tyres.

A flexible cutter-bar is ideal because it has the best height control.

12.4.6 Extension fingers

Plastic extension fingers collect lentil pods that would have fallen off in front of the knife resulting in grain losses. The pods are caught on the fingers and pushed into the comb by the incoming crop. The fingers are approximately 30 cm long and fit over existing fingers. They are relatively inexpensive.

Photo 6: *Plastic extension fingers fitted to a draper front.*

Photo: G. Cumming, formerly Pulse Australia

12.4.7 Extended fronts

Extended fronts are now available for some harvesters. They reduce losses at the knife by increasing the distance between the knife and auger to a maximum of 760 mm. This helps stop losses from plant material bunching in front of the auger, where pods can fall over the knife and be lost.

12.4.8 Platform sweeps

Platform sweeps are used in conjunction with extended fronts. They consist of fingers that rake material towards the auger to help eliminate bunching. They can also be used on conventional fronts.

12.4.9 Draper fronts

Draper fronts such as JohnDeere, CaseIH, MacDon® and Honeybee® have large clearances behind the knife and carry the crop to the elevator. These fronts can also be used for cereals without modification.

12.4.10 Other modifications and harvest aids

A **straw chopper** may be of value to chop up stubble and spread it uniformly across the paddock.

Set the **finger tyne reel** to force the lentil material down onto the front.

Moving the **broad elevator auger** forward can improve the feeding in of light lentil material.

Vibration due to cutter-bar action, plant-on-plant or reel-on-crop impact, and poor removal of cut material by the auger all cause shattering and grain loss. Grain loss can be reduced by **harvesting in high humidity or at night** to minimise pod shattering, and avoid harvesting in extreme heat.

Finger reels are less aggressive than bat reels and cause fewer pod losses.

Double-acting cutter-bars reduce cutter-bar vibration losses.[6]

Four finger guards with open second fingers also reduce vibrations (Figure 7).

Figure 1: *A four finger guard.*

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

A **lupin breaker** is a cheap and simple device that can increase harvesting capacity to reduce grain loss. It is a small, serrated plate which attaches to the front spiral and creates an aggressive, positive feed action to clear cut material from the front of the knife.

There are other options available to improve lentil harvesting.

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

Photo 7: *Belt front fitted with cross auger.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 8: *Short fingers on a flexi-front.*

12.5 Snails

Snails can be a major issue in some areas. Snails can accumulate in the lentil canopy, climb up standing stubble of the previous crop, migrate into lentil windrows, and are eventually collected by the harvester.

Snails cause a whole range of problems:

- damage to the lentil plant
- damage to the seed pods (Photo 8) affecting grain quality
- clogging and damaging harvesting machinery
- causing delays while snail pulp is removed
- contaminating the grain sample.

The receival standard for 'farmer-dressed' lentil is one snail per 200-gram sample.

There is no quick and easy way to control snails, but a combination of a number of strategies and modifications to harvesting equipment can help.[7]

Before sowing:

- burning or cabling stubbles; and
- baiting snails.

Before harvest:

- baiting snails. Complete all baiting by end of August to avoid the risk of bait entering grain samples at harvest (refer to Section 9 "Pest management");
- harvest crops early: the later they are left, the more difficult they will be to harvest; and
- leave badly infected areas until cool or damp weather when snails are more likely to be down on the ground and off the plants.

At harvest:

- minimise the entry of soil into the harvester by using a grate in the bottom of the front elevator;
- use a smaller top sieve, or 10 mm punch hole or octagonal top sieve;
- weld a lip onto the front of the top sieve to stop snails falling off;
- add removable panels to the harvester to allow easy cleaning;
- add a steel slat in the elevator to keep the elevator clean;
- slow down the speed of the grain elevators; and
- harvest with the repeat door open, but monitor losses.

After harvest:

- burning stubbles in autumn is effective, particularly when a complete burn of the paddock is achieved;
- control grass along fence lines where snails can remain undisturbed; and
- roll, slash, cable or trash harrow stubbles so snails cannot get above 5 cm off the ground. Beware of erosion.

Photo 9: *Snail damage to a near-mature pea pod.*

Photo: M. Raynes, formerly Pulse Australia

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

Photo 10: *Snails accumulate under the lentil canopy, but can also climb upstanding cereal stubble or lentil plants.*

Photo: M. Raynes, formerly Pulse Australia

12.5.1 Harvester modifications to minimise snail contamination

A number of harvester modifications have been tested to address the issue of snail contamination when harvesting **faba bean** early;[8] these modifications may have some relevance to lentil.

Disrupter kit (faba bean)

A disrupter kit fitted to a rotary harvester can lead to further improvements at early harvest, including reduced cracked grain. However, increased cracking of mature bean stalks with the disrupter has the potential to cause higher grain losses, unless the harvester wind and sieve settings are adjusted more finely to suit harvest conditions.

- Harvesting beans at close to the maximum moisture receival level improves grain quality and reduces losses, providing temperatures are not excessive. Earlier harvesting reduces snail contamination.
- A disrupter kit allows early harvest of bean crops with immature green bean stalks with minimum rotor speed loss. Adjust disrupter settings to minimise excessive shattering of bean stalks.
- As bean stalks mature and harvest temperatures increase, machine settings need careful adjustment to prevent significant losses from the excess flow of shattered material over the sieves.
- The disrupter kit should be removed for harvesting mature bean canopies.
- Frontal harvest losses are more affected by temperature and humidity at harvest than by early or late harvest timing.

Photo 11: *Disrupter peg (left) and disrupter bar (right) fitted to harvester for early bean harvest.* Photo: M. Richards

8 M Richards, S Wentworth (2004) Managing early harvest and white snails in beans. Proceedings of Bean Focus 2004 pp105-107

Snail dislodgers (faba bean)

Either pusher bars with dangling belts, or a rotary brush, can be effective in reducing snail contamination when harvesting bean crops with high snail numbers. However, the reduction in snails in the grain sample is at the expense of increased grain losses. The rotary brush is used at low revolutions per minute (rpm) brushing against the direction of travel. A fixed pusher bar with dangling belts can increase frontal grain losses by up to 5% while dislodging up to 60% of round snails from the harvested zone.

Photo 12: *Pusher bar with dangling belts fitted to harvester to reduce snail contamination.*

Photo: M. Richards

Photo 13: *Rotary brush fitted to harvester to reduce snail contamination.*

Photo: M Richards

12.6 Achieving a clean grain sample

Harvesting lentil can be costly if stones, sticks or too much soil are picked up with the lentil. As well as reducing the quality of the grain sample, damage can be incurred to the harvester.

12.6.1 Rolling for harvest efficiency

MORE INFORMATION

Refer to Section 5 "Post planting" for detailed information on rolling lentil.

Harvesting efficiency can be increased and harvester damage reduced by rolling paddocks after sowing to flatten and firm soil and depress obstacles like stumps and stones. It is said that harvesting efficiency with lentil starts with the surface condition of the paddock after sowing.[9]

Photo 14: *Clods formed at sowing need to be rolled to enable easier harvest.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 15: *Stones left unrolled create harvest difficulties and losses.*

Photo: W. Hawthorne, formerly Pulse Australia

9 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

12.6.2 Perforated screens

Perforated screens fitted on the bottom of the broad elevator of the front, and cross augers, grain and second's elevators in the harvester all reduce the amount of soil in the grain sample.

The perforated screen at the broad elevator is quite large and removes the soil before it enters the main working mechanism of the harvester.

12.6.3 Harvester speed

Excessive harvester speeds will cause large grain losses and force more soil into the harvester. Generally, speeds greater than 6–8 km/h are not recommended, irrespective of the type of harvester front used.

12.6.4 Harvesting in high humidity

Harvesting in humid conditions, when pods are less prone to shatter, can reduce grain losses. However, more unthreshed pods may appear in the grain sample. Care should be exercised when harvesting lentil at night, unless using a flex-front or a pick-up front with some positive height control to stop the front from digging into the ground. Some growers have fitted wheels on the outer end of their fronts, as a depth stop. Others have used ultra-sonic automatic depth controls to control the height of the harvester front.

12.6.5 Pick-up fronts

Pick-up fronts, the same as, or similar to, those used for picking up windrows, can be used to harvest lentil. Pick-up fronts greatly reduce the amount of soil entering the harvester and make harvesting easier because harvesting height is not as critical as with a front fitted with lifters. This allows harvesting at night. The fingers on the pick-up fronts are closely spaced and will gather the entire crop, so crop losses are reduced.

There are different types of pick-up fronts. Some have fingers attached to rotating belts (draper pick-ups) and others have fingers attached to rotating threshers (peg roller pick-ups). The peg roller types are similar and less expensive but tend to shatter pods and cause slightly higher grain losses than the draper type. The draper types are more expensive but will reduce losses if harvesting later in the day.

12.7 Lodged crops

If the crop has lodged it is usually best to harvest in the opposite direction, or at right angles, to the direction the crop has fallen. Crop lifters may help.

If sown on wide rows, crop lifters should be used and the direction of travel of the harvester up and back in the rows. The crop usually feeds in better over the knife section, and also provides the harvester operator with a better view of any rocks or sticks in the paddock.

12.8 Harvesting for seed

Lentil seed kept for sowing in the following season should be harvested from an area that is as free as possible from diseases, pests and weeds. Contaminant weeds can be hard to control in lentil, and seed infected with Ascochyta blight will transfer the disease into the next crop.[10]

If harvesting grain for seed, germination rates can be maintained if the grain is harvested at 12–14% moisture and then stored in aerated silos or immediately graded and bagged. Crop-topping with herbicides prior to crop maturity may reduce grain quality and seed viability. Retaining crop-topped seed is not recommended.[11]

Extra care must be taken when harvesting lentil for seed, to reduce grain cracking even if this means making a poorer sample (including limited unthreshed pods). Gentle harvesting will give the best seed quality. Rotary harvesters are gentler on the crop and will generally cause less grain damage than conventional harvesters.

10 J Carter, M Materne (1997) Lentil Growers Guide: A Guide to the Production of Lentils. Victorian Department of Natural Resources and Environment, Horsham.

11 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

12.9 Harvester fires

Harvesting lentil can be hazardous for starting paddock or harvester fires, perhaps more so than in other crops.

With hot, dry conditions in Australia's southern cropping region each summer, harvester fires are an extreme risk to life, crops and property. Growers and contractors need to make ensure harvesters are well-maintained and cleaned regularly to reduce fire risk, especially when harvesting lentil.

Flammable material can collect on the exhaust manifold and turbocharger in a harvester's engine bay, which is the most common cause of harvester fires. When these materials ignite, they can blow around the machine and into nearby crops, where they can cause spot fires.

Keeping the harvester clean and well-maintained is the best way to prevent harvester fires. Taking steps to prevent harvester fires should be a priority in all crops. Lentil, chickpea, sunflower and lupin are more flammable than other broadacre crops grown in the southern region.

Harvester fires can be prevented by undertaking the following:

- Keep at least two fire extinguishers accessible on each harvester;
- Perform regular blow downs on the harvester. In extreme conditions this might be every half hour or every time after filling the harvester box;
- Keep equipment clean and well-maintained;
- Ensure the manifold, turbocharger and exhaust are free of flammable material; and
- Do not overload electrical circuits.

Harvesting, and any other paddock activity, should be halted in high-fire-risk periods which typically have low humidity, high winds and vulnerable crop conditions.

MORE INFORMATION

For more information on harvester fires go to: https://grdc.com.au/news-and-media/news-and-media-releases/south/2014/11/take-simple-steps-to-reduce-harvester-fire-risk
and watch: https://www.youtube.com/watch?v=WqTfR2ifM1l

Photo 16: *A harvester fire in a safflower crop. Like lentil and chickpea, harvesting safflower produces a fine dust, meaning the risk of fire is great.*

Photo: Denise McLellan

12.9.1 Harvest checklist

1. Recognise the five factors that contribute to fires:

- relative humidity
- ambient temperature
- wind
- crop type
- conditions.

Stop harvest when the danger is extreme.

1. Redouble efforts for **service, maintenance** and **machine hygiene** at harvest on the days more hazardous for fire. Follow systematic preparation and prevention procedures.
2. Use every means possible to **avoid the accumulation of flammable material** on the manifold, turbocharger or the exhaust system. Be extra wary of side and tailwinds that can disrupt the radiator fan air blast that normally keeps the exhaust area clean.
3. Be ultra-alert for areas on the harvester where **chafing** can occur: fuel lines, battery cables, hot wires, tyres, drive belts etc.
4. Avoid **overloading electrical circuits**.
5. Regularly **check bearings** on the harvester; both the front and the machine body. Use a hand-held digital heat-measuring gun for temperature diagnostics on bearings, brakes etc.
6. Drag chains, drag cables or grounding conductors, may help dissipate **electrical charge** but are not universally successful in all conditions. In certain conditions a drag chain could even start a fire from rock strikes.
7. The **battery isolation switch** must be used when the harvester is parked. Use **vermin deterrents** in the cab and elsewhere, as vermin chew certain types of electrical insulation.
8. Observe the **Grassland Fire Danger Index** (GFDI) protocol on high-fire-risk days.
9. It should not be assumed that static electricity is a cause of fires; current evidence does not support this as a prime cause of harvester fires.
10. Maintain **two-way contact** with all harvest workers. Remain vigilant for hazards on machinery during the fire season.[12]

MORE INFORMATION

For further information on harvest fires go to: https://grdc.com.au/GRDC-BPG-ReducingHarvesterFireRisk

or see the Combine harvester fire hazard reduction checklist, http://www.grdc.com.au/Media-Centre/Hot-Topics/Harvester-Fires/Details#sthash.5a7xgzkY.dpuf

12 Grains Research and Development Corporation (2014) Take simple steps to reduce harvester fire risk. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Media-News/South/2014/11/Take-simple-steps-to-reduce-harvester-fire-risk

MORE INFORMATION

The Chickpea Book
https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-24/The-Chickpea-Book

12.10 Assessing grain harvest losses

Grain can be lost at a number of places during harvest and each loss needs to be assessed so that corrective action can be taken. Figure 18 shows the three places where grain can be lost:

- before harvest due to pod shedding;
- at the harvester front due to the type of harvester front or set-up; and
- in the threshing system of the harvester, due to drum, concave and sieve settings.

To determine grain losses, the following action should be undertaken:

- Harvest a typical area then stop and allow the machine to clear itself of material;
- Reverse the harvester about 10 m and shut down the machine;
- Check for grain in each of the three areas:
  - » in the standing crop in front of the harvester (A);
  - » in the cut crop in front of the harvester (B); and
  - » in the cut crop behind the harvester including trash (C).

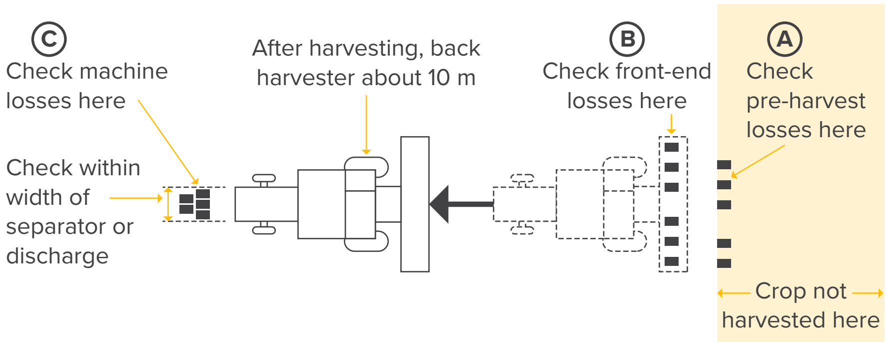


Figure 2: *Sampling places for grain losses at harvest.*

Source: Southern Lentil Best Management Practices Training Course Manual, (2016), Pulse Australia

Sampling is best done using a quadrat with an area of 0.1 m^2.

- Count the number of grains lying within each of 10 quadrats in each of the three locations; and
- Average the 10 samples in each area.

Example:

Grain losses on the ground at each location (A, B and C) can be calculated, using the 100 seed weights from the sowing rates in Section 4 "Planting".

Lentil: 100 seed weight	= 5 grams
Grain on the ground	= 96 per quadrat (average of 10 quadrats)
Grain loss	= (seed/m^2) X (100 seed weight)
	= (96 X 5)
	= 480 kg/ha (or ~0.5t/ha)

12.11 Receival standards

The national receival standards for lentils are set by the pulse industry via Pulse Australia, and reflect the market requirements for a quality food product. Receival standards are set in order to achieve the export standards used by marketers and buyers internationally.

Variety types are segregated with only 1% off-type varieties allowed. Delivery requires low discolouration or staining of grain seed coat (1% maximum) and lentil kernel (maximum 1% poor colour), as well as low insect damage and breakages (defectives 3% maximum) and minimal foreign material or impurities (3% maximum).

Sizing through round and slotted screens may also occur. Failure to achieve these receival standards may mean price discounts, necessitate re-cleaning or even market rejection if severe. Local buyers may accept lentils that are 'out of specification', but only by arrangement and when it suits.

Table 5: Summary of Lentil receival standards.

	Maximum moisture content (%)	Minimum purity (%)	Maximum defective plus poor colour (%)	Screen size for defective (mm)	Poor colour maximum (%)
Red lentil receival standard	14	97	4	2.00 or 2.2 slotted	1 seed coat 1 kernel
Green lentil receival standard	14	97	4	2.0 or 2.2 slotted	1 seed coat 1 kernel
	Unmillable material maximum	**Snail maximum**	**Insect maximum**	**Nominated weed seed maximums (maximums for each type)**	
Red lentil receival standard	0.5 (0.3% soil)	1 per 200g	15 per 200g	See nominated weed list below for weeds and amounts allowable	
Green lentil receival standard	0.5 (0.3% soil)	2 per 400g	30 per 400g	See nominated weed list below for weeds and amounts allowable	

Source: http://pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide#marketing,-enduses-and-standards

Nominated foreign weed examples

- Type 1 (4 per 200 g): three-cornered Jack
- Type 2: (nil per 200 g): wild garlic, coriander and any other tainting agents
- Type 3a (1 per 200 g in total): Bathurst burr, caltrop
- Type 3b (2 per 200 g total): vetches (tares)
- Type 3c (4 per 200 g total): heliotrope
- Type 4a (10 per 200 g total): cut leaf mignonette, melilotus (if no taint), nightshades, skeleton weed, variegated thistle
- Type 5 (20 per 200 g in total): knapweed, salvation Jane
- Type 6 (5 seeds or pods total per 200 g) medic pods, marshmallow pods, saffron thistle, wild radish pods
- Type 7a (10 seeds per 200 g total): other pulses
- Type 7b (10 seeds per 200 g total): cereals, turnip weed, bindweed
- Type 7c (1 seed in total per 200 g): safflower, sunflower
- Type 8 (100 seeds per 200 g): bellvine.
- Small foreign seeds (0.6% by weight): amsinkia, canola, charlock, marshmallow seeds, hedge mustard, etc

MORE INFORMATION

The 2017/18 Pulse Standards Review Industry Consultation Paper is available here: http://pulseaus.com.au/blog/post/pulse-standards-review

Definitions:

- **Defective grains:** includes poor coloured grains, broken, damaged and split, shrivelled, distorted, grub eaten, sprouted and affected by field mould. Do not include contrasting colours in designated varieties.
- **Poor colour:** if seed coat or cotyledon colour is distinctly blemished and/or off-colour from the characteristic colour of the predominate class, including the 1% visible ascochyta.
- **Contrasting colours:** For designated varieties, contrasting colour of seed coat is seeds of the same variety that genetically has contrasting colours of seed coats.
- **Foreign material:** includes unmillable material and all foreign vegetable matter (includes cereals, wild oats, oilseeds, other legumes and weed seeds not otherwise specified).
- **Unmillable material:** includes soil, stones, metal and non-vegetable matter.

Standards

The most recent standards are available at Pulse Australia. Please see http://pulseaus.com.au/storage/app/media/markets/20160801_Pulse-Standards.pdf

Pulse Standard Review

The Pulse Standards Review Industry Consultation Paper was updated following a review of submissions and suggestions received by the Pulse Australia Standards Committee following the 2016 harvest.

This details various proposed changes to the Pulse Trading Standards, for implementation in the 2017/18 season.

Most changes are minor and directed at improving/clarifying interpretation.

Visual quality charts

Visual quality charts are available for growers to download at http://pulseaus.com.au/marketing/receival-trading-standards#current-standards

These charts are designed to be used as a guide in conjunction with the current Australian Pulse Trading Standards

Additional grade – cleaning grade

Some buyers or bulk storage operators offer a cleaning grade.

The cleaning grade allows:

- an increase in the maximum for total defective material to 11%
- a higher tolerance for foreign seed contaminants

Storage and handling

Key points

- Lentil, especially green lentil types, are very prone to mechanical damage during harvest, handling and storage.
- Re-cleaning lentil after harvest is sometimes necessary.
- Lentil stored above 12% moisture requires aeration cooling to maintain quality.
- Lentil will darken in storage.
- Meticulous hygiene and aeration cooling are critical in preventing pest incursions.
- Fumigation is the main option available to control pests in stored lentil; this requires gas-tight, sealable storage.
- Avoiding mechanical damage to the grain will maintain market quality and seed viability, and deem the grain less attractive to insects.

13.1 Handling lentil

Lentil, especially green lentil types, are very prone to mechanical damage, particularly during rough handling. This applies to:

- overly dry grain (<10% moisture content); and
- crops that have been exposed to weather damage prior to harvest.

Grain could be handled up to six times before delivery to receival points, so it is important:

- the number of handling stages are minimised wherever possible; and
- efficient handling techniques that minimise damage are used.

The use of tubulators or belt conveyors can reduce damage compared to conventional spiral augers.[1]

If using augers:

- operate slow and full;
- use large diameter augers;
- the flight pitch should be greater than the auger diameter;
- length of the auger should be no longer than necessary: the shorter the better;
- keep auger incline as low as practical;
- check flight casing clearance. Optimal clearance is typically 50 percent of grain size to minimise grain becoming wedged between the auger spiral and the casing, causing cracking; and
- auger drives should be at the discharge end, and not on the intake.

13.2 Grain cleaning

Re-cleaning lentil after harvest is sometimes necessary. Although cereals can be cleaned from most other pulses, the similar size of lentil to cereal grain means this is not possible. It is preferable to clean cereals out of lentil in the paddock with the use of herbicides. This is done when lentil and the cereals are still plants, and prior to the production of any grain.[2]

Vetch (and tare) seeds are difficult to remove from lentil grain by cleaning. Prior to planting, if the proposed lentil paddock has a potential vetch or tare problem, a suitable sized variety to assist with grading should be chosen. For example, a small-seeded variety e.g. PBA Hurricane XT⟮ⁱ⟯, might be chosen so that the vetch is retained on top of the sieve. Alternatively, a large-seeded variety like PBA Jumbo2⟮ⁱ⟯, PBA Jumbo⟮ⁱ⟯ or PBA Giant⟮ⁱ⟯ might be chosen so the vetch falls through the screen.[3]

When cleaning, screens or paddles can be damaged beyond repair if the grain jams in rotary screens. Fitting the screens with a spacer will provide additional clearance, thus avoiding the problem.

Milk thistle bud can be difficult to separate, contaminating the lentil sample as it is similar in size and weight to peas. However, if desiccated, or given time to dry, the bud will disintegrate when put through an auger and can then be easily separated.

Soil and most small weed seeds can be separated in rotary screens; however, the soil will increase wear on the components of the cleaner.

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

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

3 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

MORE INFORMATION

Go to Section 15: Marketing for detailed information on the following:
- Marketing, end-use and standards;
- National pulse standards; and
- Visual quality charts.

MORE INFORMATION

Refer to Section 12: Harvest for information on how to minimise damage to lentil grain during and before harvest.

Photo 1: *Grain cleaning to remove vetch and tare seeds.*

Photo: M. Raynes, formerly Pulse Australia

13.3 Grain quality in storage

Monitoring the quality of grain before and during harvest is extremely important. The lentil seed coat and kernel (cotyledon) can be discoloured by crop-topping or premature desiccation if sections of the paddock have uneven maturity. Staining of seed caused by green plants in the crop or admixture of splits, weeds, stones etc., will reduce the value of the grain and result in deductions to the final price received.

Visual appearance of lentil is critical. Human food markets demand a quality sample without cracking, staining, de-hulled grain or insect damage. Grain samples indicating no mechanical damage from harvesting will always be more acceptable to a buyer. The smaller seed of lentil makes it less prone to mechanical damage than larger-seeded crops like faba bean; however, damage can still occur with poor handling. Minimising the number of times grain is transferred in augers will greatly reduce the chances for damage to the grain.[4]

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

4 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

MORE INFORMATION

The Stored Grain information hub has more information: http://storedgrain.com.au/

As do the following videos:

GRDC Video: Stored Grain Storing Pulses https://youtu.be/CeWA-OdhhSk

GRDC Video: Oilseed & Pulse Storage https://www.youtube.com/watch?v=JvzfJ2Xo6Sg

GRDC Video: Stored grain: Stay safe around grain storage https://grdc.com.au/archive/video/cm2mgmo3jwu

Case studies:

GRDC Video: Over the Fence: On-farm storage pays in wet harvest - May 2011 https://www.youtube.com/watch?v=ejywX-WytTs

GRDC Video: On-farm storage delivers harvest flexibility and profit https://www.youtube.com/watch?v=UWr7CTMxVMg

GRDC Video: On-farm storage in the SA Mallee with Corey Blacksell https://www.youtube.com/watch?v=fFKJYylp0hk

GRDC Video: On-farm storage in SA – Lindon Price https://www.youtube.com/watch?v=V9pSYmh_cO0&feature=youtu.be

Refer to the GRDC Factsheet: Storing pulses. www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

Refer to GRDC factsheet: Vigilant monitoring protects grain assets. http://storedgrain.com.au/monitoring-protects-grain

13.3.1 Basic storage principles

Key points to remember with regard to storing pulses are:

- Pulses stored above 12% moisture require aeration cooling to maintain quality.
- Meticulous hygiene and aeration cooling are critical in preventing pest incursions.
- Fumigation is the main option available to control pests in stored lentil; this requires gas-tight, sealable storage.
- Avoiding mechanical damage to the grain will maintain market quality and seed viability, and deem the grain less attractive to insects.[5]

Growers contemplating medium-long term storage (6–12 months) need to be aware that lentil continues to age and quality will deteriorate over time, especially in sunlight with high temperatures and humidity.

Lentil will darken in storage, although not as dramatically as faba bean or desi chickpea. Rate of seed coat darkening (deterioration in grain colour) will be accelerated by:

- high seed moisture content;
- high temperatures;
- high relative humidity;
- condition of the grain at harvest; and
- sunlight.

To maintain lighter seed coat colour and minimise darkening of seed, any pulses stored above 12% moisture content will require aeration cooling to maintain quality.

Mature grain, subject to field weathering in the paddock prior to harvest, will deteriorate at a more rapid rate in storage compared to non-weather grain, even if stored under ideal conditions for temperature and relative humidity.

Avoid short to medium storage of weather-damaged lentil.

Stored lentil, with high germination and vigour, can remain viable for at least three years providing the moisture content of the grain does not exceed 11%.[6]

The storage life of pulses is determined by temperature, moisture content, insects and diseases. Careful management of these factors is critical to avoid deterioration during storage.

When grain enters storage, it requires regular monitoring to allow early action and intervention if insects or grain quality issues arise. **Monitoring grain at least monthly for insects, moulds, grain temperature and moisture should be standard practice.**

Moisture

Pulses harvested at 14% moisture or higher must be dried before entering storage to preserve seed germination and viability. As a rule, every 1% rise in moisture content above 11% will reduce the storage life of pulse seed by one-third and Figure 1. Any pulse stored above 12% moisture content will require aeration cooling to maintain quality.[7]

5 Grains Research and Development Corporation (2012) Storing Pulses. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

6 Grains Research and Development Corporation (2012) Vigilant monitoring protects grain assets. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/03/Vigilant-monitoring-protects-grain-assets

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

MORE INFORMATION

Refer to Section 13.4 Grain Storage Principles in this chapter for information on preventing moisture migration and drying grain.

Temperature

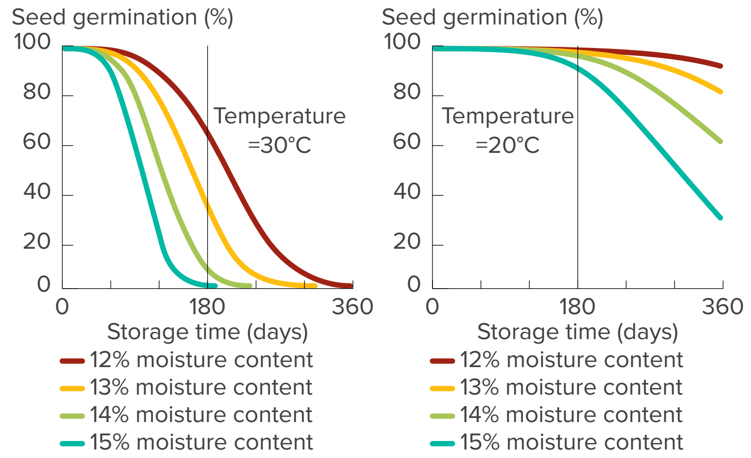


Figure 1: *Generalised graph of storage temperature and moisture effect on seed vigour. The left graph shows effects of moisture content on wheat germination when stored at 30°C. Right graph is when stored at 20°C.*

Source: Stored Grain Information Hub, (2016) GRDC, http://storedgrain.com.au

High temperatures in storage will cause deterioration in grain viability. Temperatures of stored pulse grain should not exceed an average of 25°C and preferably the average temperature should be below 20°C. In general, each 4°C rise in average stored temperature will halve the storage life of the grain. See Table 1 and Figure 1.

One practical way of reducing temperatures is to paint the silo white, as dark coloured silos will absorb more heat.

Grain in large silos (>75 t) will remain cooler as grain is a poor conductor of heat and day to night temperature fluctuations rarely reach 15 cm beyond the silo wall. Small silos (<20 t) and field bins will have larger temperature fluctuations and can cause deterioration in grain quality.

Table 1: Maximum recommended storage periods by temperature and moisture.

Grain moisture (%)	Grain temperature (°C)	
	20°C	30°C
14	3 months	n/a
13	9 months	3 months
12	>9 months	9 months

MORE INFORMATION

Refer to the GRDC Grain Storage: Storing Pulses Fact Sheet. www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

13.4 Grain storage principles

IN FOCUS

Key storage principles for lentil include:

- Lentil grain should only be stored if it is clean and dry;
- Moisture content of all grain entering storage must be accurately assessed with a moisture meter;
- Moisture content of grain during harvest can change during the day and evening;
- Sealable gas-tight silos should be fumigated immediately after filling to stop any insects that are present from creating moisture; and
- Grain must be maintained at low temperatures and moisture content for maximum storage time.

Silo capacity

Approximate weight of grain stored in a cubic metre of silo is shown in Table 2. The actual figures can vary as much as 6–7% in wheat and barley and 15% in oats. In pulses, the variation is likely to be less (3–4%), and will vary with the grain size, variety and season.

Table 2: Calculating silo capacities.

Grain	Cubic metres	Kilograms	3-bushel bags
Lentil	1	800	9.2
Chickpea	1	750	9.2
Faba bean	1	750	9.2
Broad bean	1	645	9.2
Field pea	1	750	9.2
Lupin	1	750	9.2
Vetch	1	750	9.2
Wheat	1	750	9.2
Barley	1	625	9.2
Oat	1	500	9.2
Example: Silo of lentils.	67.4	53,920	620

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

Calculating silo capacity

Calculating the volume of a cylinder:
Volume = area of base (diameter squared X 0.7854) X height

Calculating the volume of a cone:
Volume = 1/3 (area of base X height)

Photo 2: *On-farm storage enables a timely harvest and a planned marketing strategy.*

Photo: M. Raynes, formerly Pulse Australia

Photo 3: *On-farm storage is becoming more sophisticated with aeration facilities and sealing capability to enable a quality product to be out-turned.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 4: *A range of on-farm storage options for both short and long-term prospects.*

Photo: W. Hawthorne, formerly Pulse Australia

13.4.1 Cooling grain and aeration cooling

Cooler temperatures of grain in storage have several advantages:

- seed viability (germination and vigour) is maintained longer;
- moist grain can be safely stored for a short time before blending or drying;
- moisture migration is reduced;
- insect breeding cycles are slowed (or cease in some instances) and 'hot spots' are prevented;
- mould growth is reduced; and
- darkening of the seed coat is slower.

Aeration cooling is a vital tool when storing lentil. It allows for longer-term storage of low-moisture grain by creating cool, uniform conditions. These conditions maintain seed quality, protect seed viability, and reduce mould and insect development. Aeration cooling also allows grain to be harvested earlier, and at higher moisture levels, capturing grain quality and reducing mechanical seed damage.

Aerated silos are fitted with fans that push air through the grain, to cool the grain and equalise the moisture and temperature throughout the silo. With an aeration system, a waterproof vent on the top of the silo allows the air to escape as it is forced from the base of the silo. This vent needs to be replaced with a sealed lid or a capped venting tube during fumigation.

It is important to know the capacity of an existing aeration system. Aeration cooling can be achieved with airflow rates of 2–3 litres per second per tonne delivered from fans driven by 0.37 kilowatt (0.5 horsepower) electric motor for silos of around 100 t capacity. Always ensure this amount of air will be pushed through the column of grain, and is directly related to how the fans perform under 'back pressure' from the grain. Reputable suppliers of aeration equipment will ensure fans recommended will meet this requirement.

Correctly controlled aeration should aim to reduce grain temperature to 20°C or lower. Controlling aeration cooling is a three-stage process: continual, rapid and then maintenance. Cooling achieved during storage depends on both the moisture content of the grain, and the humidity and temperature of the incoming air.

An understanding of the effects of relative humidity and temperature when aerating stored grain is important. Automatic aeration controllers that select optimum fan run times provide the most reliable results and are deemed best for convenience.

MORE INFORMATION

Refer to GRDC Booklet: *Aerating stored grain, cooling or drying for quality control*: www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

GRDC factsheet: Performance testing aeration systems: https://grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

13.4.2 Preventing moisture migration

Moisture migration is where convection currents cause moisture to concentrate in the top centre of the silo/storage. Moisture also moves from warmer to cooler grain on the sidewall of bins when warm grain goes into winter storage. Grain affected by moisture migration often feels damp or tacky at the surface and may form a crust when grain warms in the spring.

Grain stored in sealed silos must be of sufficiently low moisture content to prevent moisture migration. Grain with excess moisture should not enter a sealed store where there is no escape of moisture. An exception is where the silo is aerated and has adequate ventilation fitted.

In a sealed silo, there is no free venting and therefore no escape for moisture into the headspace. This means that moisture can migrate to the upper grain layers causing condensation. There will also be some loss of moisture to the atmosphere. This top area of the grain is at high risk from mould and insect colonisation.

MORE INFORMATION

Refer to GRDC Booklet: *Aerating stored grain, cooling or drying for quality control*. www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

GRDC Performance testing aeration systems Fact Sheet. https://grdc.com.au/resources-and-publications/all-publications/factsheets/2012/08/grdc-fs-grainstorage-performancetestingaerationsystems

GRDC Dealing with high-moisture grain Fact Sheet. www.grdc.com.au/GRDC-FS-HighMoistureGrain

For general information on handling, drying and cooling see: Agridry Rimik Pty Ltd http://www.agridry.com.au

Watch GRDC Groundcover TV Episode 16 Stored Grain: Stay Safe Around Grain Storage https://www.youtube.com/watch?v=CM2mgmo3jWU

Moisture sources

Grain: Grain and seed are living and release moisture as they respire. This moisture moves upwards by convection currents created by the temperature difference between the grain in the centre of the silo and the walls, which can be either warmer or cooler.

Grain insects: Insects or mites in the grain release moisture and heat into air spaces as they respire. If grain in storage is less than 14% moisture, and is free of insects, moisture content increase in the upper layers of the grain will be insignificant.

If grain in storage is above 14% moisture content, then enough moisture may be carried into upper grain layers to place that grain at risk of mould. Moisture from insects builds up faster than moisture from grain respiration and to higher levels. There is no moisture migration in an aerated silo as the entire stack is normally cooled to one temperature (20°C or less).

Condensation impact: Moisture carried into the silo headspace can condense on a cold roof and fall back as free water. This can then cause a circle of mould or germinated grain against the silo wall. Moist grain can also contain greater numbers of insects.

Leaks: Water entering through structural damage will increase grain moisture content to a level where there is a greater incidence of mould and insect growth.

13.4.3 Drying grain and aeration drying

The purpose of drying grain is to remove excess moisture to prevent spoilage during storage.

Continuous-flow or batch dryers provide reliable drying, although they can reduce quality if run at too high a temperature. **Temperature should not exceed 45°C when using heat to dry lentil.** Check the specifications or talk to the manufacturer about safe conditions for drying lentil.[8]

High capacity aeration systems can also be used to dry grain, and are ideally suited for drying grain harvested at 15–16% moisture content. Aeration drying has a lower risk of cracking and damaging lentil, which can occur with hot-air dryers. Aeration drying requires a larger capacity fan to move high volumes of air through the grain at a faster rate than that required for cooling only.

Flow rates of at least 15–25 L/sec/tonne are required for aeration drying. By comparison, an air-flow rate of as little as 2–3 L/sec/tonne can achieve aeration cooling.

Careful selection of conditions using dry ambient air (using an automated controller) can remove moisture from the stored grain over a period of weeks.

8 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

MORE INFORMATION

Refer to the exotic pests section in Section 9: Insect and pest control.

A GRDC video on stored grain is at 'Stored grain: managing sealed & unsealed storage' https://youtu.be/TIs0S-7DwxA

MORE INFORMATION

GRDC Video: Grain silo hygiene https://youtu.be/3VU7qJCoCwI

13.5 Insects in storage

Insects are not considered a major problem in stored lentil. While seed beetles or Bruchids (*Bruchinae*) are considered primary pests of pulse crops, very few Bruchid species (present in Australia) attack lentil.

It is important to note that there are exotic Bruchids (not present in Australia) that do attack lentil.

One exception appears to be in cases where lentil is loaded into storages containing residues of cereal grain already infested with cereal insect pests such as flour beetles (*Tribolium* spp.) and grain borers (*Rhyzoptherha* spp.) These prior infestations can develop and spread in lentil. Removal of these residues prior to loading is essential. In some cases, grain insects can cross-contaminate lentil storage from cereal storage. Monitoring and minimising the potential for infestations should prevent this from happening.

13.5.1 Farm and grain hygiene

Maintaining good farm hygiene, in and around storage facilities, plays a crucial role in overcoming many problems associated with storage pests. Prevention is much easier than cure.

Good hygiene practices, combined with aeration cooling, should prevent infestations developing.

Good hygiene practices include:

- removing all grain residues from empty storage facilities. Residues from all grain-handling and carriage equipment must also be removed before new grain is stored and equipment used;
- cleaning up spillages around silos and destroying all residues to prevent re-infestation;
- once storages and equipment have been cleaned, treat them with an inert dust treatment;
- ensure insects or weeds are not carried onto the property via farm equipment (i.e. harvesters); and
- all equipment should be thoroughly cleaned after use.

Insect development

Most insect development ceases at temperatures below 20°C. Freshly harvested grain usually has a temperature of around 30°C and above, which is an ideal breeding temperature for many storage pests. Silos with aeration rapidly reduce grain temperatures, reducing insect breeding and aiding grain quality.

Table 3: The effect of grain temperature on insects and mould. .

Temperature (°C)	Insect and mould development
40-55	Seed damage occurs, reducing viability
30-40	Mould and insects are prolific
25-30	Mould and insects active
20-25	Mould development is limited
18-20	Young insects stop developing
<15	Most insects stop reproducing, mould stops developing

Source: Aerating stored grain: Cooling or Drying for Quality Control a Grains Industry Guide (2013), GRDC, www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

Insect-control programs should principally aim to control insects in the growing crop. However, fumigating grain in sealable gas-tight storages will control infestations in stored grain.

MORE INFORMATION

For more information, refer to GRDC factsheets: Hygiene and structural treatments for grain storage: www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

Storing pulses: www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

GRDC Video: Applying Diatomaceous Earth Demonstration https://youtu.be/L-lyCgstkc0

MORE INFORMATION

Refer to Section 13.6.1 Testing silos for seal in this chapter; and

GRDC factsheet: Pressure testing sealable silos http://elibrary.grdc.com.au/ark!!33517/x4vcv2x/t1xe5ja

Treatment options for controlling insects in stored lentil

If treatment is required for insects in stored lentil, the only control options are:

- phosphine fumigation;
- an alternative fumigant such as nitrogen gas; or
- controlled atmosphere (aeration cooling).

Phosphine fumigation is the main method for insect control of grain in storage.

No insecticide sprays are currently registered for use on lentil. Markets are particularly sensitive to insecticide residues, so detection of any residues on lentil could result market loss, not just the rejection of a contaminated delivery.

Residual sprays should not be used on storage and handling equipment that is to be used for lentil.

Using diatomaceous earth as a structural treatment is possible if the storage and equipment is washed and dried before using pulses. This will ensure the diatomaceous earth does not discolour the grain surface. If unsure, the grain purchaser must always be consulted regarding delivery standards and/or allowances.

13.5.2 Fumigation

Phosphine is the only fumigant currently registered for use in pulses.

Fumigation basics

Effective fumigation is both the control of all insect life stages and the reduction in risk of resistance development. To achieve this, fumigation must be undertaken in a sealable, gas-tight silo.

New silos purchased should comply with Australian Standard AS 2628 to ensure they are sealable to a gas-tight standard. Once erected, silos purchased as gas-tight should be checked by performing a standard pressure test. When they are filled they should be checked again, prior to fumigation. An annual silo maintenance routine, when the silo is empty, should include pressure testing, as well as checking and replacing worn or damaged seals and carrying out any repairs.

Conduct a pressure test to ensure the silo is gas-tight before fumigating.

Minimum fumigation times following application of phosphine are:

- 7 days at grain temperatures above 25°C; and
- 10 days at grain temperatures 15–25°C.

Grain below 15°C should not be fumigated with phosphine as insects are very hard to kill at low temperatures.

It is important to note that fumigant takes longer to distribute in storages with more than a few hundred tonnes capacity, unless forced circulation is used.

When not to fumigate

Not all silos can be sealed adequately to enable fumigation. An unsealed silo will not hold the fumigant for more than a few minutes, even using a high dosage rate. However, aeration can be added to all silos.

Fitting aeration cooling will help immensely with insect control. Aeration coupled with excellent hygiene can overcome many potential insect problems in grain storage. Having at least one sealable gas-tight silo as a 'hospital' bin enables the grower to correctly and effectively manage any insect infestations when detected.

It is illegal and highly dangerous to put phosphine into unsealed systems.

Fumigation success

Provided fumigation is carried out correctly, the fumigant will penetrate the grain and destroy all stages of insects in the treated grain at the time of fumigation: adults, eggs, larvae and pupae. This also includes insects that may have developed resistance to phosphine.

Effective fumigation with phosphine needs a concentration (chemical to air ratio) of:

- 300 parts per million (ppm) for 7 days at grain temperatures above 25°C; or
- 200 ppm for 10 days at grain temperatures 15–25°C.

Poor fumigations may appear to have been successful when dead adults are observed; however, many of the eggs and pupae are likely to survive and will continue to infest the grain. In addition, insects that survive are more likely to carry phosphine-resistance genes, which has serious consequences for future insect control across the entire industry.

When to fumigate?

Storages should be cleaned prior to filling with new grain (see Section 13.4 Grain storage principles). However, if there is reason to believe there are stored grain insects in a silo, fumigation should be carried out as soon possible. This will ensure that all insect stages are eliminated before any grain damage or weight loss occurs.

Early harvesting and immediate fumigation will reduce the number of insects in stored pulses.

Using phosphine

Phosphine is a highly toxic substance (Schedule 7). To purchase and use phosphine a relevant chemical user registration must be held relevant to the state (or territory) of operation.

Caution should always be used when dealing with phosphine gas as it is, not only toxic but also highly explosive. Observe all ventilation and withholding periods for handling and grain use.

Gas respirators suitable for protection against phosphine must be worn. Always open containers of phosphine preparations in the open air. When opened, use the entire contents or dispose of excess chemical. Do not reseal leftover tablets as once they have been exposed to air they will begin to evolve into gas and may become explosive.

Face masks must fit properly for protection. This may be difficult for those with bearded faces, but is essential to avoid poisoning. Appropriate mask maintenance is also essential. For safety reasons, it is best not to work alone when applying phosphine tablets, or inside structures that have been fumigated.

Warning signs must be clearly displayed when fumigation is in process (Figure 2). These should have details of when the fumigation commenced, the end date, and information on ventilation. Entry into the silo is prohibited during both fumigation and ventilation. Signs should be placed at all storage access points during fumigation.

MORE INFORMATION

Refer to GRDC Fumigating with phosphine, other fumigants and controlled atmospheres Fact Sheet: http://storedgrain.com.au/fumigating-with-phosphine-and-ca

MORE INFORMATION

For fumigation product information, hazardous substance database and protective equipment also see: www.draeger.com.au

Figure 2: *Phosphine warning sign.*

This phosphine warning sign can be downloaded from the Stored Grain Information Hub website (www.storedgrain.com.au).

Phosphine application and dosage rates

REFER to LABEL INSTRUCTIONS.

Phosphine is slightly heavier than air and spreads rapidly. As grain does not absorb phosphine well, phosphine circulates through the stack effectively.

There are two forms of phosphine available for use on-farm; bag chains and tablets. **Bag chains** are the safest form, and ensure there is no residue spilt onto the grain. **Tablets** are the more traditional form and can be purchased in tins of 100. Phosphine **blankets** are also available; however, these are designed for bulk storages of 600 tonnes or more.

The same amount of phosphine must be applied regardless of the amount of grain in the silo. When using fumigants, the volume of space determines the required amount of fumigant, not the grain in the storage.

The rate of application is the same for all crops:

- using a standard bag chain = 1 bag chain per 75m^3
- using tablets = 1.5 g/m^3 (equivalent to three tablets per 2m^3).

Always read the product label to confirm recommended application rates.

Bag chains may be hung in the head space, or rolled out flat in the top of a gas-tight silo, so air can pass freely around them.

Tablets should be spread out evenly on trays and then hung in the head space or placed level on the grain surface.

Table 4: Recommended rates of phosphine tablets (sealable gas-tight silo only).

Cubic metres	Bushels	Tonnes	Number of tablets
18	500	14	28
37	1000	28	56
56	1500	42	84
74	2000	56	111
92	2500	70	138

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Some silos may also be fitted with purpose-built facilities to apply phosphine from the ground. These must have a passive or active air-circulation system. This is so the phosphine gas is carried out of the confined space as it evolves, otherwise an explosion can occur.

Timing

Minimum fumigation times following application of phosphine are:

- 7 days at grain temperatures above 25°C; and
- 10 days at grain temperatures 15–25°C.

The fumigation period varies from 7 to 20 days depending on temperature and product used.

It is important to follow concentration and exposure instruction carefully, as overdosing may reduce the fumigants effectiveness.

Do not use phosphine when the grain temperature is below 15°C or when grain moisture is below 9%.

Ventilation after fumigation

If there is only natural air-flow moving over the grain, a minimum period of 5 days' ventilation is required to allow the phosphine concentrations to drop to safe levels below 0.3 ppm time weighted average (twa).

The concentration of phosphine can be measured with a multigas detector pump, fitted with a Draeger testing tube for phosphine. This equipment can detect levels of phosphine as low as 0.01 ppm in the air.

The detector is available from Draeger Australia, 8 Acacia Place, Notting Hill, VIC 3168, telephone (03) 1800 647 484. See https://www.draeger.com/en_aunz/Home

Disposal

Tablet residues and expended sachets should be swamped with dilute acid or soapy water in open air until bubbling ceases and then buried at least 30 cm below the soil surface. The expended tablets should not be piled together as there is a risk they may catch fire.

First aid

If a person is exposed to phosphine gas, they should immediately be moved into the open air and given oxygen treatment if possible. Standard first aid emergency procedures (DRSABC) must be implemented.

This may include some to all of the following:

- **Danger** – ensure area is safe
- **Response** – check for alertness
- **Send** for help – dial 000
- Clear **airway**
- Check for **breathing**
- Start **CPR**.

If a phosphine tablet is swallowed, vomiting should be induced as soon as possible. Milk, butter, oils (castor oil) or alcohol should not be consumed.

Accidents are always possible so an emergency plan should be prepared in advance. Ensure all personnel understand first aid treatment for phosphine poisoning. Standard first aid emergency procedures should be displayed as well as emergency phone numbers.

Other fumigants

There are other fumigants for the control of insect pests in grain storage.

Methyl bromide fumigation

The Australian government phased out most uses of methyl bromide from 1 January 2005. Methyl bromide may only be used on pulses for an approved quarantine or pre-shipment use.

Methyl bromide fumigation is an essential requirement for pulse exporters to comply with shipments of grain to India. This can only be done by licensed personnel. A certificate of fumigation is required by the Australian Quarantine and Inspection Service (AQIS). AQIS inspectors complete a phyto-sanitary certificate stating that the grain shipment leaving Australia does not contain live insects.

Carbon dioxide fumigation

If a silo meets test levels, carbon dioxide can be added, under pressure, from a cylinder. This provides a rapid initial purge to quickly achieve high carbon dioxide levels.

For thorough protection, a carbon dioxide concentration of 34% or more must be maintained for 10 days.[9]

13.6 Sealing silos

MORE INFORMATION

For more information on sealing silos go to GRDC Performance testing aeration systems Fact Sheet: https://grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

GRDC Hygiene and structural treatments for grain storage Fact Sheet: www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

GRDC Pressure testing sealable silos Fact Sheet: http://storedgrain.com.au/pressure-testing

The Australian Standard (AS 2628-2010) allows growers to refer to an industry benchmark when purchasing a gas-tight, sealable silo. This standard provides assurance that the silo will perform in the intended manner.

Growers may choose to retro-seal existing farm silos rather than buying new gas-tight silos. Always ensure any retro-sealed silos comply with Australian Standard AS 2628. It is illegal to put phosphine into unsealed systems, hence the importance of retro-sealing. It is important to note that not all silos can be made gas-tight.

Sealing a silo must be carried out with care and attention to achieve a successful outcome. A haphazard approach will be costly in terms of time required to locate and repair any leaks.

Silos that are inadequately sealed lose gas through small holes. This prevents the fumigant reaching and maintaining concentrations necessary for an effective insect kill (Photo 5).

Figures 3 and 4 show how gas is lost from inadequately sealed silos, due to the effects of wind and sun.

Information on sealing and testing silos, cited in this section, is sourced from the *Grain Legume Handbook* (2008).

Techniques have been developed which allow farm silos to be sealed to gas-tightness for effective fumigation. Any retro-sealing work undertaken must meet the Australian standards and pass the standard pressure test.

Retro-sealing of silos is not usually recommended. It is recommended to aerate older silos and purchase new silos that have been constructed from start to finish to be gas-tight and meet the standard.

Even if a silo can be sealed gas-tight for fumigation purposes, fitting aeration cooling will help immensely. Aeration, coupled with excellent hygiene, can overcome many potential problems.

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

MORE INFORMATION

See the GRDC Grain storage Fact Sheet *Pressure testing sealable silos*: http://storedgrain.com.au/pressure-testing

Photo 5: *An unsealed silo.*

Photo: DAFWA

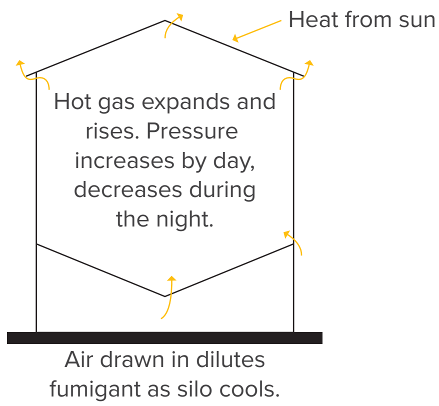


Figure 3: *Gas loss through heat effects.*[10]

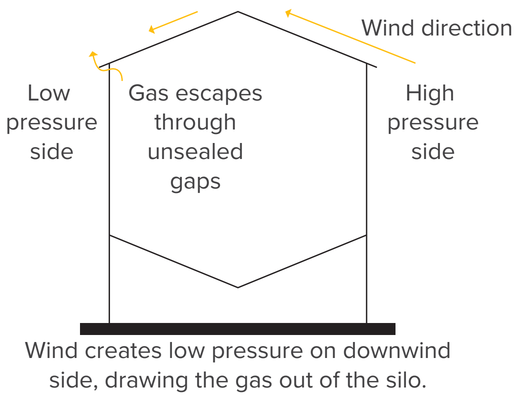


Figure 4: *Gas loss through wind effects.*

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

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

13.6.1 Testing silos for seal

A relief valve fitted to sealable, gas-tight silos can also be used as a gauge for pressure testing. This allows for easy and regular seal tests. The relief valve should be filled to the second line (Figure 11) with light engine oil. Don't use water as it will evaporate. Vegetable oil is also unsuitable as it may react with the phosphine.

Test the silo for gas-tightness using the pressure relief valve (Figures 5 and 6) by applying a '5-minute half-life pressure test'.

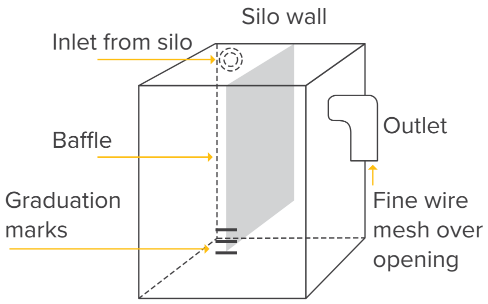


Figure 5: *Pressure relief valve.*[11]

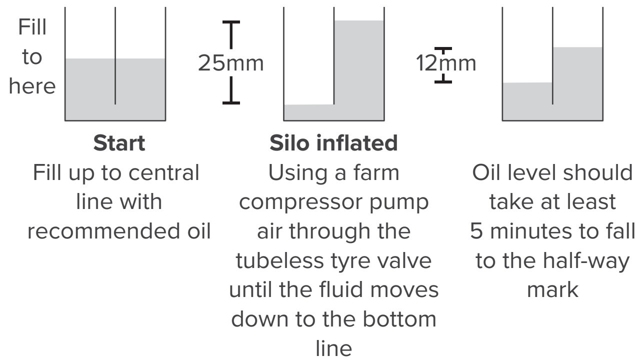


Figure 6: *Testing the silo with the pressure relief valve.*

Source: Grain Legume Handbook (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

Key points to note are:

- A silo sold as a 'sealed silo' needs to be pressure tested to ensure it is gas-tight.
- Check new sealable, gas-tight silos for Australian Standard pressure sealing compliance (AS2628).
- Pressure test sealed silos upon erection, annually and before fumigating with a '5-minute half-life pressure test'.
- Maintenance of a quality, sealable, gas-tight silo is the key to ensuring a silo purchased as gas-tight maintains its gas-tight status.

Method of testing

Pressurise the silo using an air compressor, along with a tubeless tyre valve that is fitted to the silo wall.

This is done until a 25 mm difference is achieved in the heights of the fluid columns (or 250 pascals); this should only take a few minutes.

The pressure fall to 12 mm (125 pascals) is then timed; it should not be less than 5 minutes.

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

This seal test should only be conducted when weather conditions are stable, as fluctuations in the temperature, strength of sunlight, or windy conditions can affect the readings. The best times for testing are early morning before heating or between between 1 p.m. and 3 p.m. when temperatures are usually stable.

If the difference in fluid levels falls to 12 mm in less than 5 minutes, then this indicates an air leak. This will need to be found and sealed before fumigation can be effective.

All hatches should be checked first to ensure they are sealing properly. Then leaks in other parts of the silo can be located by applying a soapy solution to suspect areas: bubbles will indicate an air leak.

Alternatively, a boat flare may be released inside the silo (Photo 5). It is important to ensure the silo is free of grain dust as it is explosive.

When pressurising the silo, care must be taken to not exceed a difference of 30-mm in fluid levels. This high level of relief valve operation could damage the structure.

Every time sealing of a silo is undertaken, pressure testing must be done by following the above method.

When a sealable, gas-tight silo is not being used for fumigation, leave the top lid slightly open. When empty, leave the top lid and bottom hatch slightly open.

When retro-sealing, any sealing or modifications to a silo must be done by a qualified and reputable contractor who guarantees their work meets Australian Standards AS 2628 – 2010.

13.7 Silo bags

Silo bags (also known as grain bags, sausage bags or harvest bags) are becoming increasingly popular. However, **silo bags for lentil storage should be considered as temporary only, due to the likelihood of quality issues arising.**

There are success stories with silo bags when used to temporarily store grain, including pulses. There have also been failures when appropriate precautions were not taken.

Pulses are risky grains to store in silo bags.[12] Pulse grain has been rejected by markets because of objectionable taints and odours derived during improper storage in a silo bag.

Silo bags are a sealed storage with no aeration. To maintain grain quality in storage it is essential to bag the grain at the correct moisture content and to ensure that the bag remains sealed throughout the entire storage period to prevent moisture access.

High moisture grain, condensation, water aggregation under the film or leaks can cause localised mould and widespread spoilage in pulses.

Even with adequate seals, hermetic conditions to protect against insects and mould (low oxygen, high carbon dioxide) are difficult to achieve consistently. This is due to either high grain temperatures or low grain moisture content at the time of storage.

12 W Hawthorne, A Meldrum, G Cumming (2010) Grain Bags for Pulse Storage – Use Care. Pulse Australia, http://www.pulseaus.com.au/storage/app/media/crops/2010_APB-Pulse-grain-bag-storage.pdf

Photo 6: *Silo bags for lentil storage should be considered as temporary only.*

Photo: W. Hawthorne, formerly Pulse Australia

Lentil quality risks and silo bags

There are risks associated with storing lentil in silo bags:

- lentil grain may not retain its quality, colour or odour, especially if the seal is breached;
- contamination and moisture can enter bags from vermin and other pests that create holes in the bag;
- excessive grain moisture can result in condensation within the bag causing localised areas of mould and objectionable odours;
- pockets of mouldy grain can develop in silo bags, along with an offensive, distinctive 'mouldy' odour throughout. There is a nil tolerance of this in receival standards;
- marketers have rejected pulse grain in the past due to objectionable moulds, taints and odours acquired through storage in silo bags;
- removing taints and odours in affected grain is not necessarily possible, even with further aeration;
- grain stored in silo bags can develop an overall offensive, distinctive 'plastic' odour that requires considerable periods of aeration to remove. There is nil tolerance of odours in receival standards;
- achieving and keeping hermetic conditions under Australian conditions is rarely achieved. Hermetic conditions should not be relied upon as the only source for control of insects in storage; and
- grain moisture of stored lentil is critical, and difficult to control in silo bags.[13]

MORE INFORMATION

Refer to Pulse Australia Bulletin: Grain Bags for Pulse Storage – Use Care: http://www.pulseaus.com.au/growing-pulses/publications/grain-storage-bags

GRDC Successful storage in grain bags Fact Sheet: https://grdc.com.au/resources-and-publications/all-publications/factsheets/2012/03/grain-storage-fact-sheet-successful-storage-in-grain-bags

13 W Hawthorne, A Meldrum, G Cumming (2010) Grain Bags for Pulse Storage – Use Care. Pulse Australia, http://www.pulseaus.com.au/storage/app/media/crops/2010_APB-Pulse-grain-bag-storage.pdf

Environmental issues

Key points

- **Heat waves and moisture stress can affect lentil.**
- **Lentil is most sensitive to waterlogging, particularly at flowering.**
- **Lentil seedlings are tolerant of frost.**
- **Frost can cause flower, pod and seed abortion**

14.1 Drought and heat stress

Lentil is like other cool-season pulses in its susceptibility to extreme hot (or cold) conditions, especially at flowering. Heat waves (temperatures >35°C) and water deficiency (moisture stress) can affect lentil.

Canopy development in lentil is quite rapid, especially during early sown and warmer winter conditions. At any location, seasonal variations in temperature can bring about a significant shift in flowering times for the same time of sowing (i.e. ± 10 days is possible).

On hot days, the leaves of the lentil plant fold and the stomata close in order to reduce evapotranspiration. Plants take on a 'wilted' appearance and look more blue-grey in colour. A common coping mechanism is increased pod and leaf drop.[1]

Lentil is considered a moderately drought-tolerant crop. However, it can suffer through lack of height, and hence, harvestability in drought conditions.[2] Its inability to handle moisture stress is greatest if its rooting depth is impeded by compaction or subsoil constraints (for example boron or salt). Farming systems with lentil in low or medium rainfall areas now tend to use stubble retention and, occasionally, wider row spacing to minimise moisture loss from soil before canopy closure.

When heat stress occurs during flowering and pod-filling, significant reductions can occur in yield, seed quality and subsequent profitability to the grower.

Photo 1: *Lentil showing signs of moisture stress due to competition from early weeds.*

Photo: W. Hawthorne, formerly Pulse Australia

MORE INFORMATION

GRDC Update Paper: Improving lentil tolerance to heat stress
https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/improving-lentil-tolerance-to-heat-stress

1 A Delahunty, J Nuttall, M Nicolas, J Brand (2015) Genotypic heat tolerance in lentil. Proceedings of the 17th ASA Conference, Hobart, http://agronomy2015.com.au/1107

2 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

14.2 Moisture stress

Moisture stress in lentil influences plant height. Hence, it can affect yield and harvestability when the crop height is too short (to harvest). Timing of moisture stress relative to growth stage is important. Lentil varieties can respond individually to moisture stress depending on their general tolerance (to moisture stress), specifically at flowering.

Abortion of pods, caused by moisture stress, is usually noted on the last-formed pods in the upper parts of the plant.

Several trials have been conducted examining the effects of moisture stress on lentil, and at various stages of growth.

A stubble-management trial in South Australia showed early-maturing varieties were unable to re-flower significantly after rain.[3] Varieties with a maturity classified as anything other than 'early' were in the early-flowering stage or not flowering when the moisture deficit occurred. This meant they were less responsive to soil moisture differences related to stubble presence.

In pot experiments, water deficits reduced seed yield by up to 60% in some lentil genotypes.[4] Withholding water at flowering or podding reduced leaf area (48–55%), total dry matter (32–50%), flower production (22–55%), and number of pods and seeds (27–66%), with significantly higher flower drop and empty pods when water was withheld.

However, in some genotypes in the same trials, seed yield was increased by a temporary water deficit. This is because more flowers were produced when those genotypes were re-watered after a period of water deficit. In other genotypes, increased seed yield came as a result of podset and seedset being maintained when those lentil plants were re-watered after their period of water deficit during podding.

Photo 2: *Lentil showing signs of moisture stress.*

Photo: W. Hawthorne, formerly Pulse Australia

3 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

4 R Shrestha, N Turner, K Siddique, D Turner (2006) Physiological and seed yield responses to water deficits among lentil genotypes from diverse origins. Australian Journal of Agricultural Research, 57(8), 903-915 https://repository.uwa.edu.au/R/-?func=dbin-jump-full&object_id=17455&local_base=GEN01-INS01

14.3 Waterlogging

Lentil is the most sensitive of all pulse crops to waterlogging.[5] Lentil will generally not survive after periods of waterlogging, especially in cool conditions of winter. Mild waterlogging is an issue, even when foliar disease is kept under control.

Lentil is most sensitive to waterlogging at flowering. The response of lentil to waterlogging is similar to its response to low light and low temperatures; all result in flower and pod abortion and leaf senescence (drying off).[6]

This high sensitivity to waterlogging means that paddock selection with lentil is critical to minimise risks of losing the crop to 'wet feet.'

Photo 3: *Waterlogging in lentil.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 4: *Lentil dying under waterlogged conditions.*

Photo: M. Raynes, formerly Pulse Australia

5 Grains Research and Development Corporation (2016) Lentils: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

6 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Photo 5: *Lentil growing poorly in waterlogged conditions.*

Photo: W. Hawthorne, formerly Pulse Australia

14.4 Frost

Yield losses from frost damage can be severe for a high-value crop like lentil.

Frost damage occurs when the plant is at a vulnerable stage of growth at the time of the frost. Timing is critical[7], and the level of damage depends on severity of the frost, crop sensitivity, variety maturity and sowing time. Any subsequent frosts can lead to further damage.

Frost can cause flower, pod and seed abortion. It will normally affect the smallest pods first; despite the fact they are the higher pods on the plant. Pods at a later stage of development are generally more resistant to frost than flowers and small pods. However, pods may suffer some mottled darkening of the seed coat.

Lentil has some ability to recover from frost damage by being able to regenerate new branches in severe cases. New regrowth occurs from the base of the frost-affected plants if moisture conditions are favourable.

In severe frosts, leaves are killed and the stem is wilted. If the plant is at the 1–5 node stage, there can be quick recovery from underground axillary buds. If the lentils are at the 7th node stage or beyond, plants will most likely die because axillary bud initiation will most likely not occur as the plant is moving into reproductive stages.

As well as damage to the plant and seed, frost damage can also result in an increased vulnerability to entry of pathogen (e.g. Botrytis grey mould).

Frost tolerance for lentil at flowering is –2°C to –3°C (Table 1).

Frost frequency and intensity is unpredictable. When managing frost risk, one can only work on the likelihood of a frost occurring, without knowing exactly when, or if, it will happen. On the plus side, variety specific management packages consider the probability of frost when setting out advisory planting dates.

Compared to other pulses, the lentil plant flowers later and can escape some early frosts. Lentil is a short crop and hence, can be sensitive to poor pod set or grain fill when frosts do occur. Sowing too late (to avoid frost during flowering) can lead to short crops, harvest difficulties and poor quality, if the season finishes quickly. This is

7 F Stoddard, C Balko, W Erskine, H Khan, W Link, A Sarker (2006) Screening techniques and sources of resistance to abiotic stresses in cool-season food legumes. Euphytica 147:167–186, http://www.google.com.au/

a trade-off the grower must make, between sowing early to maximise yield potential, but with a greater risk of frost affecting the flowering plant.

Frost risk is influenced by a variety of factors including:

- crop type (sensitivity, flowering date);
- crop variety (flowering date and duration);
- sowing time;
- soil type and condition;
- canopy management and row spacing;
- stubble presence;
- atmospheric and soil moisture levels;
- crop nutrition and nodulation;
- crop stress level;
- topography of land; and
- frost severity, number and timing.

Importantly, unlike chickpea, low temperatures (<2°C) are not known to cause pollen sterility in lentil.

Diagnosing frost damage

Frost damage in lentil is relatively easy to recognise and identify. Pods take on a different, 'mottled' appearance, and the grain inside becomes black and shrivelled. Damage on well-developed grains may appear 'frost burnt', leaving a stain on the sides of the grain that were exposed to the pod wall.

Severe frosts can cause a characteristic bend in the stem of the lentil plant.

Keys to success for minimising frost damage in lentil

Although it is difficult to totally minimise frost risk it is important to:

- know the period of highest probability of frost incidence;
- map the topography to show areas of greatest risk and specifically manage these areas to minimise frost damage;
- aim to reduce exposure to frost or impact at vulnerable growth stages;
- choose the appropriate variety and time of sowing;
- manage the pulse canopy. Row spacing, retained cereal stubble and small changes in temperature around the critical trigger point can assist in avoiding frost damage;
- consider planting in rows up and down a slope to increase air-flow and cool air drainage;
- understand the impact of soil type, condition and moisture status; and
- manage crop nutrition and minimise crop stress level to lessen frost damage.[8]

MORE INFORMATION

Two valuable sources of information for frost damage are:

The GRDC *Pulse & Canola – Frost Identification: the Back Pocket Guide:* https://grdc.com.au/resources-and-publications/all-publications/bookshop/2012/01/pulse-canola-frost-identification-the-back-pocket-guide-grdc046

Minimising frost damage in pulses: http://www.pulseaus.com.au/growing-pulses/publications/minimise-frost-damage

8 W Hawthorne (2007) Managing Pulses to Minimise Frost Damage. Australian Pulse Bulletin PA 2007 #01, http://www.pulseaus.com.au/storage/app/media/crops/2007_APB-Pulses-frost.pdf

Photo 6: *Lentil frosted and healthy flowers.*

Photo 7: *Frosted spots on lentil pods.*

Photo 8: *Frosted lentil pods.*

Table 1: Range of critical damage temperatures (°C) for grain and other crops.

Crop	Germination	Flowering	Fruiting
Spring wheat	-9,–10	-1,–2	-2,–4
Oats	-8,–9	-1,–2	-2,–4
Barley	-7,–8	-1,–2	-2,–4
Lentil	-7,–8	-2,–3	-2,–4
Field pea	-7,–8	-2,–3	-3,–4
Vetchling	-7,–8	-2,–3	-2,–4
Coriander	-8,–10	-2,–3	-3,–4
Lupin	-6,–8	-3,–4	-3,–4
Spring vetch	-6,–7	-3,–4	-2,–4
Faba and Broad Bean	-5,–6	-2,–3	-3,–4
Sunflower	-5,–6	-2,–3	-2,–3
Safflower	-4,–6	-2,–3	-3,–4
Sugar beet	-6,–7	-2,–3	--
Fodder beet	-6,–7	--	--
Soybean	-3,–4	2,–3	2,–3
European yellow lupine	-4,–5	2,–3	--
Buckwheat	-1,–2	-1,–2	-0.5,–2
Rice	-0.5,–1	-0.5,–1	-0.5,–1
Tomato	0,–1	0,–1	0,–1

Source: Frost damage: Physiology and critical temperatures (undated), FAO Corporate Document Repository, http://www.fao.org/docrep/008/y7223e/y7223e0a.htm

Photo 9: *Frosted lentil pod.*

Photo 10: *Damaged lentil seed in frosted pod.*

14.5 Lack of sunlight

Lack of sunlight can be a major factor in determining the level of podset in pulses in southern Australia. A Mediterranean climate with winter rainfall dominance and a dense canopy can lead to poor podset through lack of sunlight. Total radiation, rainfall, evaporation, temperature, humidity and wind strength are all contributing factors to the level of podset.

In faba bean at least, the amount of radiation hitting the flower from when it opens and for the following 3 days is the overwhelming contributing factor to level of podset. This is regarded as likely, also, in lentil and other pulses.[9]

14.6 Soil erosion

Poor emergence is more likely with lentil on hard-setting soils and this can lead to a higher potential for soil erosion. Rolling lentil after sowing can also leave some soils prone to erosion and in these situations post-emergent rolling is preferred where possible.

Pulses make slow early growth and consequently leave the soil more susceptible to the effect of wind and water erosion than cereals. This is particularly true for lentil. Consequently, the benefits of stubble retention and limited tillage are key in growing pulses.

On light soils, pulse stubbles require careful grazing management. Stubble residues can break easily from the roots and tend to collect in heaps leaving the paddock prone to wind erosion.

On heavier soils overgrazing can create dust problems, affecting clean fleece yields.[10]

9 F Stoddard (1993) Limits to retention of fertilized flowers in faba beans (Vicia faba L.). Journal of Agronomy and Crop Science 171 (4): 251-259, http://onlinelibrary.wiley.com/doi/10.1111/j.1439-037X.1993.tb00137.x/abstract

10 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

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.

NOTE: Port Adelaide lentil values have varied between A$125/t and A$800/t over the past 7 years (representing variability of 30–100%). For a property producing 200 t of lentils this means $25,000–$160,000 difference in income depending on timing of sales.

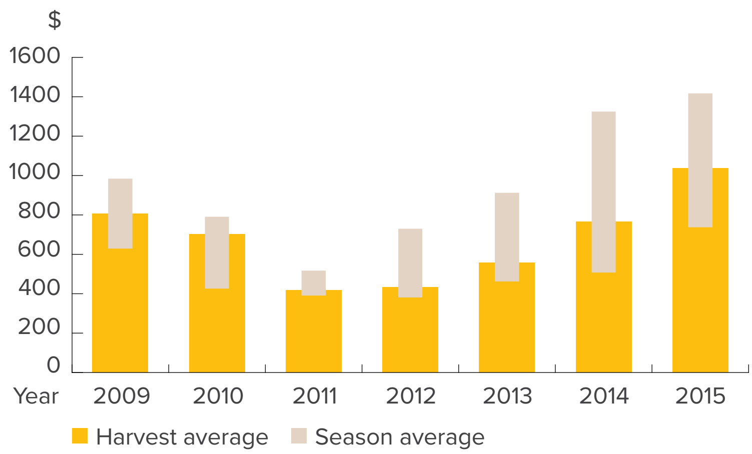


Figure 1: *Intra-season variance of Port Adelaide Lentil Values.*

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 the target price and then work towards achieving that target price.

Unknowns include the amount of grain available to sell (production variability), the final cost of that production, and the future prices that may result. Australian farm-gate prices are subject to volatility caused by a range of global factors that are beyond our control and difficult to predict.

The skills growers have developed to manage production unknowns can be used to manage pricing unknowns. This guide will help growers manage and overcome price uncertainty.

15.1.1 Be prepared

Being prepared and having a selling plan are essential for managing uncertainty. The steps involved are forming a selling strategy and a plan for effective execution of sales.

MORE INFORMATION

The Australia Bureau of Agricultural and Resource Economics and Sciences (ABARE) released its latest report in mid June 2017.

The 'Australian Crop Report: June 2017 No. 182' is a quarterly report with a consistent and regular assessment of crop prospects for major field crops, forecasts of area, yield and production and a summary of seasonal conditions on a state by state basis.

It reports that the area planted to cereal crops is expected to decrease, but the area planted to canola, chickpeas and lentils is forecast to increase.

Please see: http://data.daff.gov.au/data/warehouse/aucrpd9abcc003/aucrpd9aba_20170614_uPOax/AustCropRrt20170614_v1.0.0.pdf

A selling strategy consists of when and how to sell.

1. When to sell

This requires an understanding of the farm's internal business factors including:

- production risk
- a target price based on cost of production and a desired profit margin
- business cash-flow requirements.

2. How to sell?

This is more dependent on external market factors including:

- time of year determines the pricing method
- market access determines where to sell
- relative value determines what to sell.

Figure 2 lists the following diagram lists key selling principles when considering sales during the growing season.

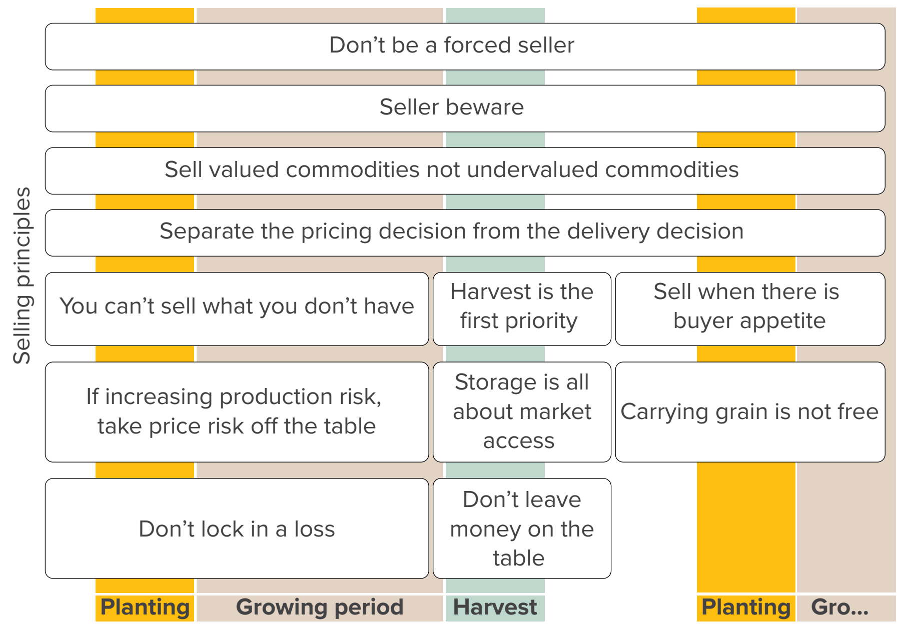


Figure 2: *Grower commodity selling principles timeline* Source: Profarmer Australia

NOTE: The illustration demonstrates the key selling principles throughout the production cycle of a crop.

15.1.2 Establish the business risk profile (when to sell)

Establishing your business risk profile allows the development of target price ranges for each commodity and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify those risks during the production cycle are described below.

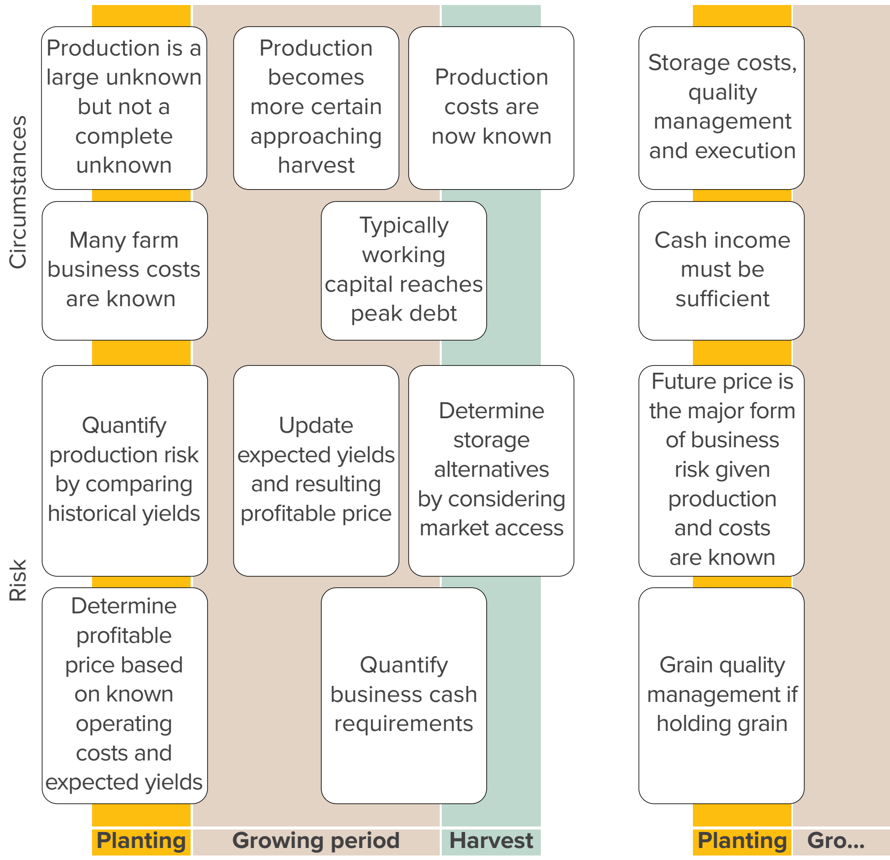


Figure 3: *Typical farm business circumstances and risk.*

Source: Profarmer Australia

NOTE: When does a grower sell their grain? This decision 'making' is dependent on:

- Does production risk allow sales? And what portion of production?
- Is the price profitable?
- Are business cash requirements being met?

Production risk profile of the farm

Production risk is the level of certainty around producing a crop and is influenced by location (climate and soil type), crop type, crop management, and time of the year.

Principle: "You can't sell what you don't have" – don't increase business risk by overcommitting production.

Establish a production risk profile by:

1. Collating historical average yields for each crop type and a below average and above average range.
2. Assessing the likelihood of achieving average yield based on recent seasonal conditions and seasonal outlook.
3. Revising production outlooks as the season progresses.

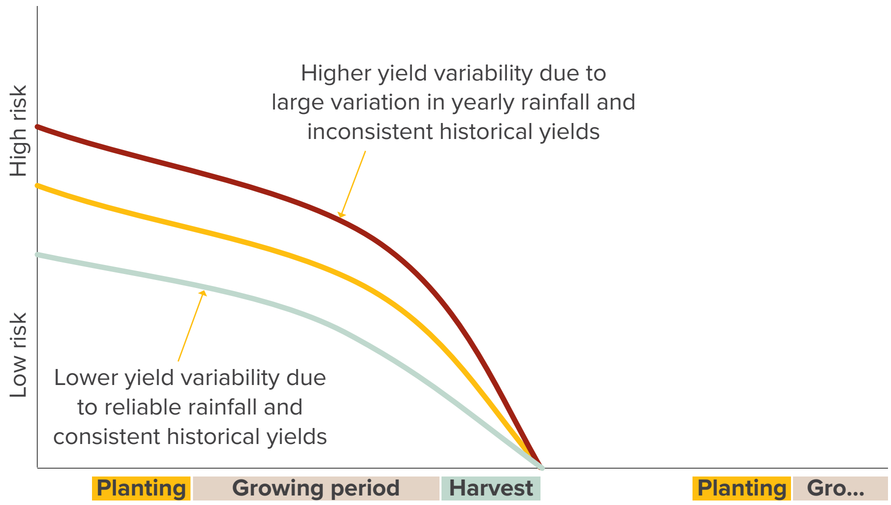


Figure 4: *Typical production risk profile of a farm operation.*

Source: Profarmer Australia

NOTE: The quantity of crop grown is a large unknown early in the year, but not a complete unknown. "You can't sell what you don't have" but it is important to compare historical yields to get a true indication of production risk. This risk reduces as the season progresses and yield becomes more certain. Businesses will face varying production risk level at any given point in time due to rainfall, yield potential, soil type, commodity etc.

Farm costs in their entirety, variable and fixed costs (establishing a target price)

A profitable commodity target price is the cost of production per tonne plus a desired profit margin. It is essential to know the cost of production per tonne for the farm business.

Principle: "Don't lock in a loss" – if committing production ahead of harvest, ensure the price is profitable.

Steps to calculate an estimated profitable price based on total cost of production and a range of yield scenarios is provided in GRDC's *Farming the Business Manual* also provides a cost of production template and tips on grain selling *v.* grain marketing (http://www.grdc.com.au/FarmingTheBusiness).

Income requirements

Understanding farm business cash-flow requirements and peak cash debt enables grain sales to be timed so that cash is available when required. This prevents having to sell grain below the target price to satisfy a need for cash.

Principle: "Don't be a forced seller" – Be ahead of cash requirements to avoid selling in unfavourable markets.

A typical cash-flow to grow a crop is illustrated in Section 11, Figure 5: Lentil during pod-fill and before dry-down on page 6. Costs are incurred upfront and during the growing season with peak working capital debt incurred at or before harvest. This will vary depending on circumstance and enterprise mix. The second figure demonstrates how managing sales can change the farm's cash balance.

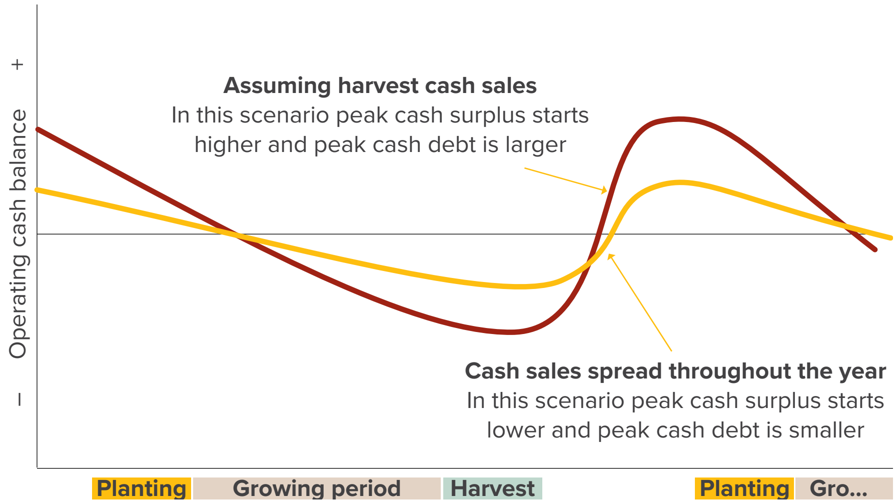


Figure 5: *Typical farm operating cash balance.* Source: Profarmer Australia

NOTE: The chart illustrates the operating cash-flow of a typical farm assuming a heavy reliance on cash sales at harvest *v.* a farm business which spreads sales out throughout the year.

When harvest sales are more heavily relied upon, costs are incurred during the season to grow the crop, resulting in peak operating debt levels at or near harvest. Hence, at harvest there is often a cash injection required for the business. An effective marketing plan will ensure a grower is 'not a forced seller' in order to generate cash-flow.

By spreading sales throughout the year a grower may not be as reliant on executing sales at harvest time in order to generate required cash-flow for the business. This provides a greater ability to capture pricing opportunities in contrast to executing sales in order to fulfil cash requirements.

When to sell revised

The 'when to sell' steps above result in an estimated production tonnage and the risk associated with that tonnage, a target price range for each commodity, and the time of year when cash is most needed.

15.1.3 Ensuring access to markets

Once the selling strategy of when and how to sell is sorted, planning moves to storage and delivery of commodities to ensure timely access to markets and execution of sales. At some point growers need to deliver the commodity to market. Hence, planning on where to store the commodity is important in ensuring access to the market that is likely to yield the highest return.

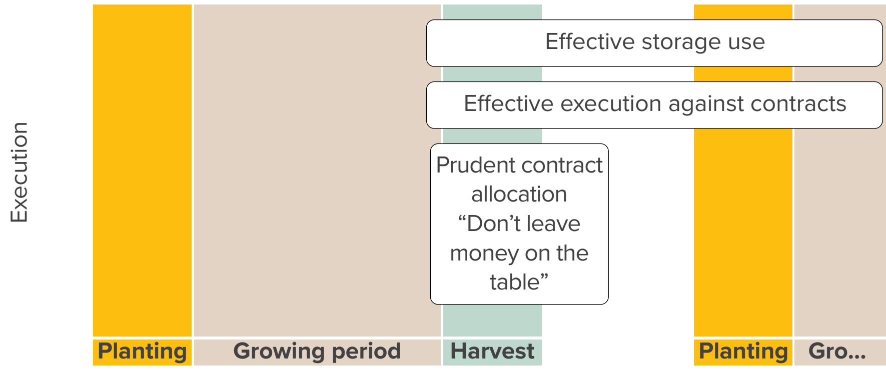


Figure 6: *Effective storage decisions.*

Source: Profarmer Australia

NOTE: Once a grower has made the decision to sell, the question becomes how they achieve this. The decision on how to sell is dependent upon:

- Time of year determines the pricing method.
- Market access determines where to sell.
- Relative value determines what to sell.

Storage and logistics

Return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access to maximise returns as well as harvest logistics.

Storage alternatives include variations around the bulk-handling system, private off-farm storage and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity.

Principle: "Harvest is the first priority" – getting the crop in the bin is most critical to business success during harvest, hence selling should be planned to allow focus on harvest.

Bulk export commodities requiring significant quality management are best suited to the bulk-handling system. Commodities destined for the domestic end-user market (e.g feed lot, processor, or container packer) may be more suited to on-farm or private storage to increase delivery flexibility.

Storing commodities on-farm requires prudent quality management to ensure delivery at agreed specifications and can expose the business to high risk if this aspect is not well planned. Penalties for out-of-specification grain on arrival at a buyer's weighbridge can be expensive. The buyer has no obligation to accept delivery of an out-of-specification load. This means the grower may have to incur the cost of taking the load elsewhere whilst also potentially finding a new buyer. Hence there is potential for a distressed sale which can be costly.

On-farm storage also requires prudent delivery management to ensure commodities are received by the buyer on time with appropriate weighbridge and sampling tickets.

Principle: "Storage is all about market access" – storage decisions depend on quality management and expected markets.

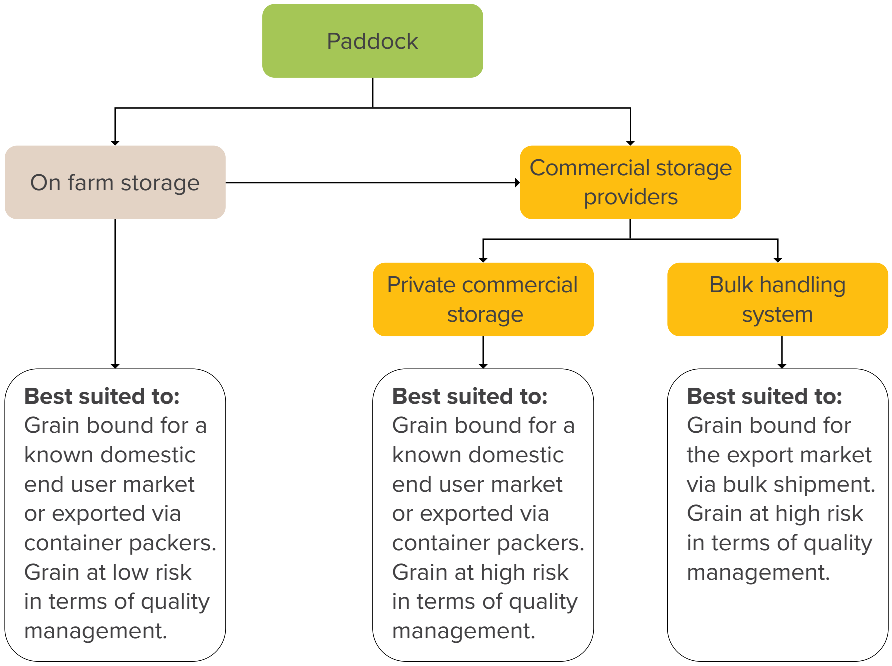


Figure 7: *Grain storage decision making.*

Source: Profarmer Australia

NOTE: Decisions around storage alternatives of harvested commodities depend on market access and quality management requirements.

Cost of carrying grain

Storing grain to access sales opportunities post-harvest invokes a cost to to carry grain. Price targets for carried grain need to account for the cost of carry.

Carry costs consist of:

- monthly storage fee charged by a commercial provider OR capital cost allocation where on-farm storage is utilised; and
- the interest associated with having wealth tied up in grain rather than cash or against debt.

The price of carried grain therefore needs to be higher than what was offered at harvest. The cost of carry applies to storing grain on-farm as there is a cost of capital invested in the farm storage plus the interest component

Principle: "Carrying grain is not free" – the cost of carrying grain needs to be accounted for if holding grain and selling it after harvest is part of the selling strategy.

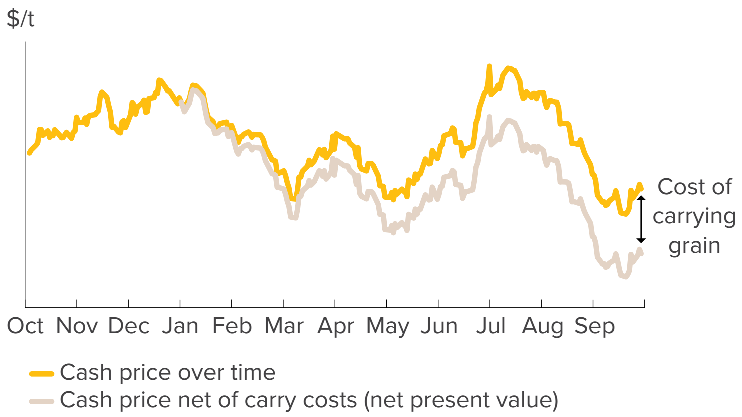


Figure 8: *Cash values v. cash adjusted for the cost of carry.*

Source: Profarmer Australia

NOTE: if selling a cash contract with deferred delivery, a carry charge can be negotiated into the contract. For example in the case of a March sale for March–June delivery on the buyers call at $600/t + $5/t carry per month, if delivered in June this contract would generate revenue of $615/t delivered.

Ensuring market access revised

Optimising farmgate returns involves planning the appropriate storage strategy for each commodity to improve market access and cover carry costs in pricing decisions.

MORE INFORMATION

Stored Grain Information Hub, http://storedgrain.com.au/

15.1.4 Executing tonnes into cash

This section provides guidelines for converting the selling and storage strategy into cash by effective execution of sales.

Set up the tool box

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox includes:

1. Timely information

This is critical for awareness of selling opportunities and includes:

- market information provided by independent parties
- effective price discovery including indicative bids, firm bids, and trade prices
- other market information pertinent to the particular commodity.

2. Professional services

Grain selling professional service offerings and cost structures vary considerably. An effective grain-selling professional will put their clients' best interest first by not having conflicts of interest and investing time in the relationship. Return on investment for the farm business through improved farm-gate prices is obtained by accessing timely information, greater market knowledge and greater market access from the professional service.

MORE INFORMATION

The link below provides current financial members of Grain Trade Australia including buyers, independent information providers, brokers, agents, and banks providing over-the-counter grain derivative products (swaps).

http://www.graintrade.org.au/membership

How to sell for cash

Like any market transaction, a cash grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components with each component requiring a level of risk management:

Price

Future price is largely unpredictable, hence devising a selling plan to put current prices into the context of the farm business is critical to manage price risk.

Quantity and quality

When entering a cash contract you are committing to delivery of the nominated amount of grain at the quality specified. Hence production and quality risk must be managed.

Delivery terms

Timing of title transfer from the grower to the buyer is agreed at time of contracting. If this requires delivery direct to end users it relies on prudent execution management to ensure delivery within the contracted period.

Payment terms

In Australia the traditional method of contracting requires title of grain to be transferred ahead of payment; hence counterparty risk must be managed.

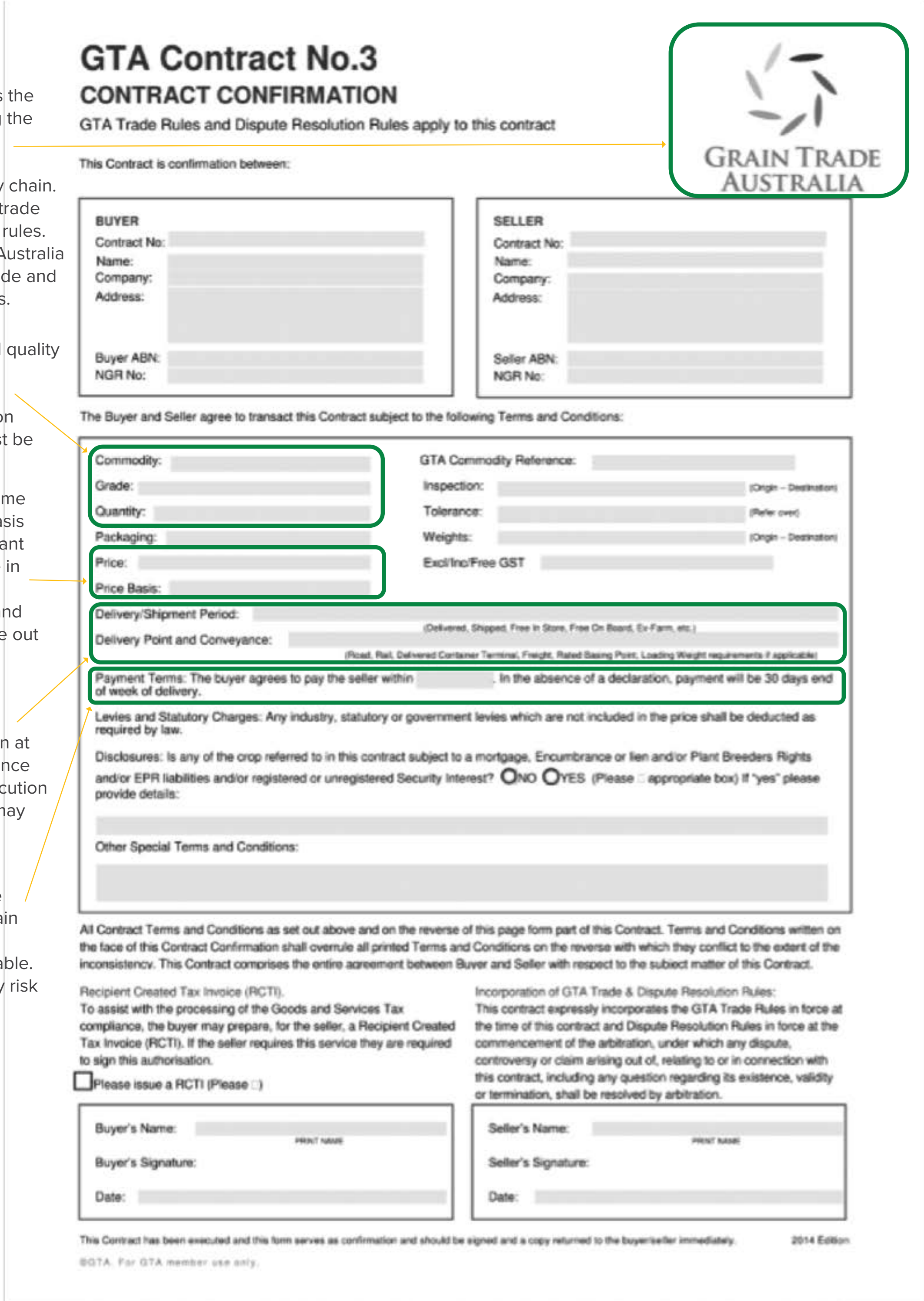
Grain Trade Australia is the industry body ensuring the efficient facilitation of commercial activities across the grain supply chain. This includes contract trade and dispute resolution rules. All wheat contracts in Australia should refer to GTA trade and dispute resolution rules.

Quantity (tonnage) and quality (bin grade) determine the actuals of your commitment. Production and execution risk must be managed.

Price is negotiable at time of contracting. Price basis or price point is important as it determines where in the supply chain the transaction will occur and so what costs will come out of the price before the growers net return.

Timing of delivery (title transfer) is agreed upon at time of contracting. Hence growers negotiate execution and storage risk they may have to manage.

Whilst the majority of transactions are on the premise that title of grain is transferred ahead of payment this is negotiable. Managing counterparty risk is critical.


GTA Contract No.3
CONTRACT CONFIRMATION
GTA Trade Rules and Dispute Resolution Rules apply to this contract
GRAIN TRADE AUSTRALIA

This Contract is confirmation between:

BUYER
Contract No:
Name:
Company:
Address:
Buyer ABN:
NGR No:

SELLER
Contract No:
Name:
Company:
Address:
Seller ABN:
NGR No:

The Buyer and Seller agree to transact this Contract subject to the following Terms and Conditions:

Commodity:
Grade:
Quantity:
Packaging:
Price:
Price Basis:
GTA Commodity Reference:
Inspection: (Origin – Destination)
Tolerance: (Refer over)
Weights: (Origin – Destination)
Excl/Inc/Free GST
Delivery/Shipment Period: (Delivered, Shipped, Free In Store, Free On Board, Ex-Farm, etc.)
Delivery Point and Conveyance: (Road, Rail, Delivered Container Terminal, Freight, Rated Basing Port, 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
©GTA. For GTA member use only.

Figure 9: *Typical cash contracting as per Grain Trade Australia standards.*

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. Figure 10 depicts the terminology used to describe pricing points along the grain supply chain and the associated costs to come out of each price before growers receive their net farm-gate return.

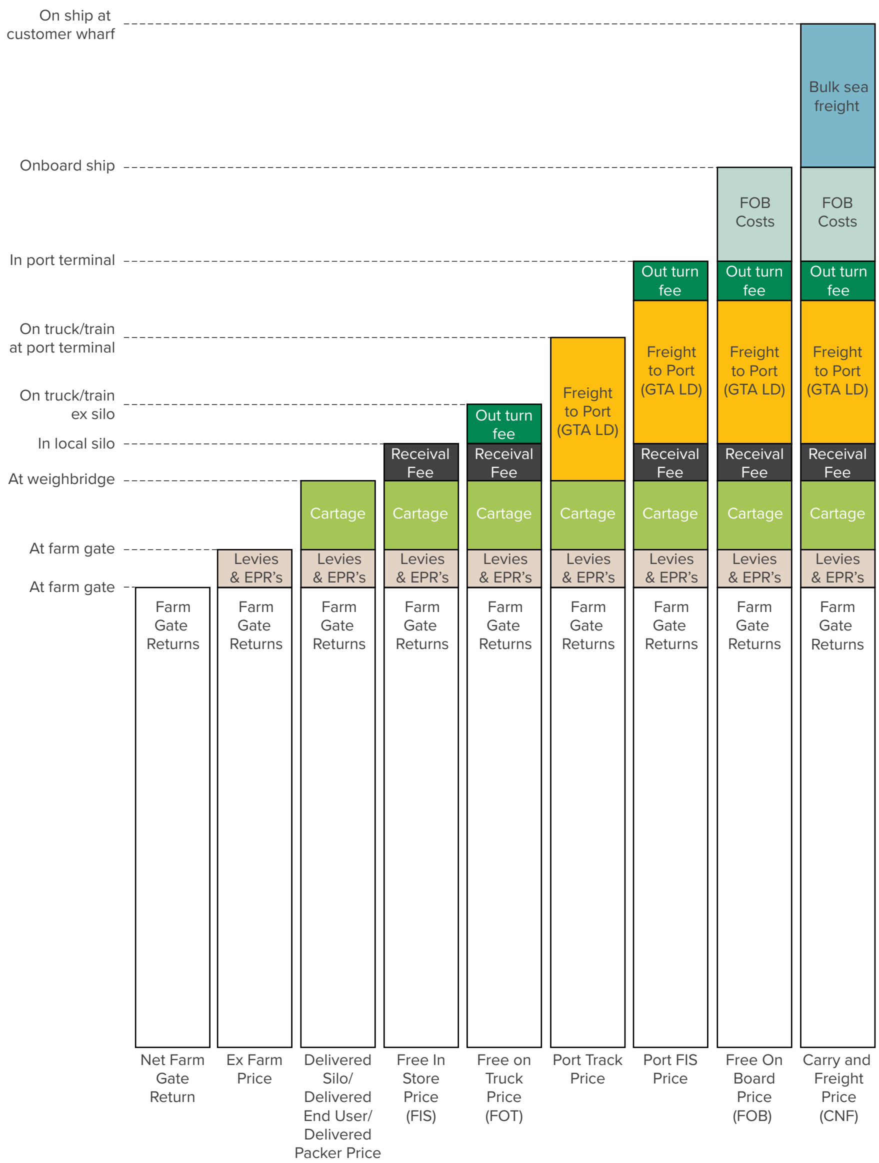


Figure 10: *Costs and pricing points throughout the supply chain.*

Source: Profarmer Australia

Cash sales generally occur through three methods:

Negotiation via personal contact

Traditionally prices are posted as a 'public indicative bid'. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and available for all commodities.

Accepting a 'public firm bid'

Cash prices in the form of public firm bids are posted during harvest and for warehoused grain by merchants on a site basis. Growers can sell their parcel of grain immediately by accepting the price on offer via an online facility and then transfer the grain online to the buyer. The availability of this depends on location and commodity.

Placing a firm offer

Growers can place a firm offer price on a parcel of grain by approaching buyers with a set tonnage and quality at a predetermined price. The buyers do not have to accept the offer and may simply say no or disregard the offer.

There are increasingly more channels via which to place a firm offer.

One way this can be achieved anonymously is using the Clear Grain Exchange (www.cleargrain.com.au), which, is an independent online exchange. If the firm offer and firm bid matches, the parcel transacts via a secure settlement facility where title of grain does not transfer from the grower until funds are received from the buyer. The availability of this depends on location and commodity.

Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

Some bulk handler platforms are also providing facilities for sellers to place firm offers to the market. Including GrainCorp via their CropConnect product.

Finally a grower can place a firm offer directly with an individual buyer.

Counterparty risk

Most sales involve transferring title of grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

Principle: “Seller beware” – there is not much point selling for an extra $5/t if you don’t get paid.

Counterparty risk management includes:

1. Dealing only with known and trusted counterparties.
2. Conducting a credit check (banks will do this) before dealing with a buyer they are unsure of.
3. Only sell a small amount of grain to unknown counterparties.
4. Considering credit insurance or letter of credit from the buyer.
5. Never delivering a second load of grain if payment has not been received for the first.
6. Not parting with title of grain before payment or request a cash deposit of part of the value ahead of delivery. Payment terms are negotiable at time of contracting, alternatively the Clear Grain Exchange provides secure settlement where-by the grower maintains title of grain until payment is received by the buyer, and then title and payment is settled simultaneously.

Above all, act commercially to ensure the time invested in a selling strategy is not wasted by poor counterparty risk management. Achieving $5/t more and not getting paid is a disastrous outcome.

MORE INFORMATION

http://www.australiangrainexport.com.au/docs/Grain%20Contracts%20Guide.pdf

http://www.graintrade.org.au/contracts

http://www.pulseaus.com.au/marketing/receival-trading-standards

http://www.graintrade.org.au/commodity_standards

http://www.profarmergrain.com.au

http://www.graintransact.com.au

http://www.grainflow.com.au

http://emeraldgrain.com/grower-logins/

https://www.cleargrain.com.au/get-started

https://www.dailygrain.com.au/

Relative values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well and hold commodities that are not well priced at any given time. That is, give preference to the commodities of the highest relative value. This achieves price protection for the overall farm business revenue and enables more flexibility to a grower's selling program whilst achieving the business goals of reducing overall risk.

Principle: "Sell valued commodities; not undervalued commodities" – if one commodity is priced strongly relative to another, focus sales there. Don't sell the cheaper commodity for a discount.

Contract allocation

Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (price, premiums-discounts, oil bonuses etc) and optimising your allocation reflects immediately on your bottom line.

Consideration needs to be made based on the quality or grades you have available to deliver, the contracts you already have in place and how revenues will be calculated on each contract. Key considerations include; does the contract calculate revenues based on a sliding scale or on predetermined quality 'buckets'. Whenever you have more grain to allocate than pre-committed to contracts, don't forget to consider the premiums and discounts available in the current cash market as part of your contract allocation decision.

Principle: "Don't leave money on the table" – contract allocation decisions don't take long, and can be worth thousands of dollars to your bottom line.

Read market signals

The appetite of buyers to buy a particular commodity will differ over time depending on market circumstances. Ideally growers should aim to sell their commodity when buyer appetite is strong and stand aside from the market when buyers are not that interested in buying the commodity.

Appetite in pulse markets can be fickle, erratic and the buy-side can be illiquid. Hence monitoring market signals is critical to achieving the best possible returns.

Principle: "Sell when there is buyer appetite" – when buyers are chasing grain, growers have more market power to demand a price when selling.

Buyer appetite can be monitored by:

- The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate buyer appetite is strong. However, if there is one buyer $5/t above the next best bid, it may mean cash prices are susceptible to falling $5/t if that buyer satisfies their buying appetite. In pulse markets the spread between the highest and the second highest bidder can be more than $100/t at times.
- Monitoring actual trades against public indicative bids. When trades are occurring above indicative public bids it may indicate strong appetite from merchants and the ability for growers to offer their grain at price premiums to public bids.

Sales execution revised

The selling strategy is converted to maximum business revenue by:

1. *Ensuring timely access to information, advice and trading facilities.*
2. *Using different cash market mechanisms when appropriate.*
3. *Minimising counterparty risk by effective due diligence.*
4. *Understanding relative value and selling commodities when they are priced well.*
5. *Thoughtful contract allocation.*
6. *Reading market signals to extract value from the market or prevent selling at a discount.*

15.2 Southern lentils – market dynamics and execution

15.2.1 Price determinants for southern lentils

Australia is a relatively small player in terms of world pulse production, producing 1.5–2.5 million tonnes of pulses in any given year, compared with global production of approximately 60 million tonnes. Lentil is one of the three largest produced pulses across the globe, with 5 million tonnes produced annually. Australia continues to become a growing participant in this market with 200,000– 450,000 tonnes produced in recent seasons, accounting for 5–10% of the global crop. Australia, along with the US and Canada are the main exporters of lentil on the global market.

There are two key types of lentil grown across the globe – red and green. Australia primarily grows red lentil varieties which are suited to the lower rainfall climate evident across Australian growing regions. Green lentil varieties continue to be produced in Australia, however volumes remain small due largely to the limited marketing options available. South Australia and Victoria account for 95% of Australian lentil production, which is primarily exported through the container and 'delivered' markets. NSW and Western Autralian lentil production has grown in recent seasons in response to strong pricing, however volumes remain small. Key production regions for lentils within Victoria are both the Mallee and the Wimmera, while in South Australia production is focused on the through the Yorke Peninsula, Lower Eyre Peninsula, Mid North, and South East South Australia.

The Indian subcontinent is the key importer of pulses globally with the major export markets for Australian lentils including Sri Lanka, Bangladesh, India and Pakistan. Each export market has its own specification requirements and varietal preferences. Hence, it is important to understand the end market of each lentil variety being grown.

The Australian domestic market absorbs only a small proportion of Australian lentil production, with the majority exported primarily to the Indian subcontinent. Given this dynamic Australian farm-gate prices are heavily influenced by global production volatility and international trade values into each of the major destinations.

For example, when Canada, another key global producer suffers below average yields, Australian lentil values tend to find support as global availability of supply is reduced. However, in years when Canadian production is high there is increased competition to secure export business and Australian product can become discounted in order to compete.

Similarly, production issues impacting pulses grown in the Indian subcontinent result in an increase in demand for imported product, providing flow on support to the Australian market. However, in years when production within countries of the Indian subcontinent is in surplus, import requirements are considerably lower, with some becoming net exporters. This reduction in global appetite from key importers due to an oversupply can result in Australian lentil becoming discounted.

Some of the global influences on Australian lentil pricing are listed below:

- The domestic lentil production of both the US and Canada. Any negative influences on production will reduce the global supply and increase the demand for Australian exports.
- Production of lentils within the Indian sub continent. This region is the largest importer of lentils globally, a negative influence on their domestic production places a greater requirement for imports.

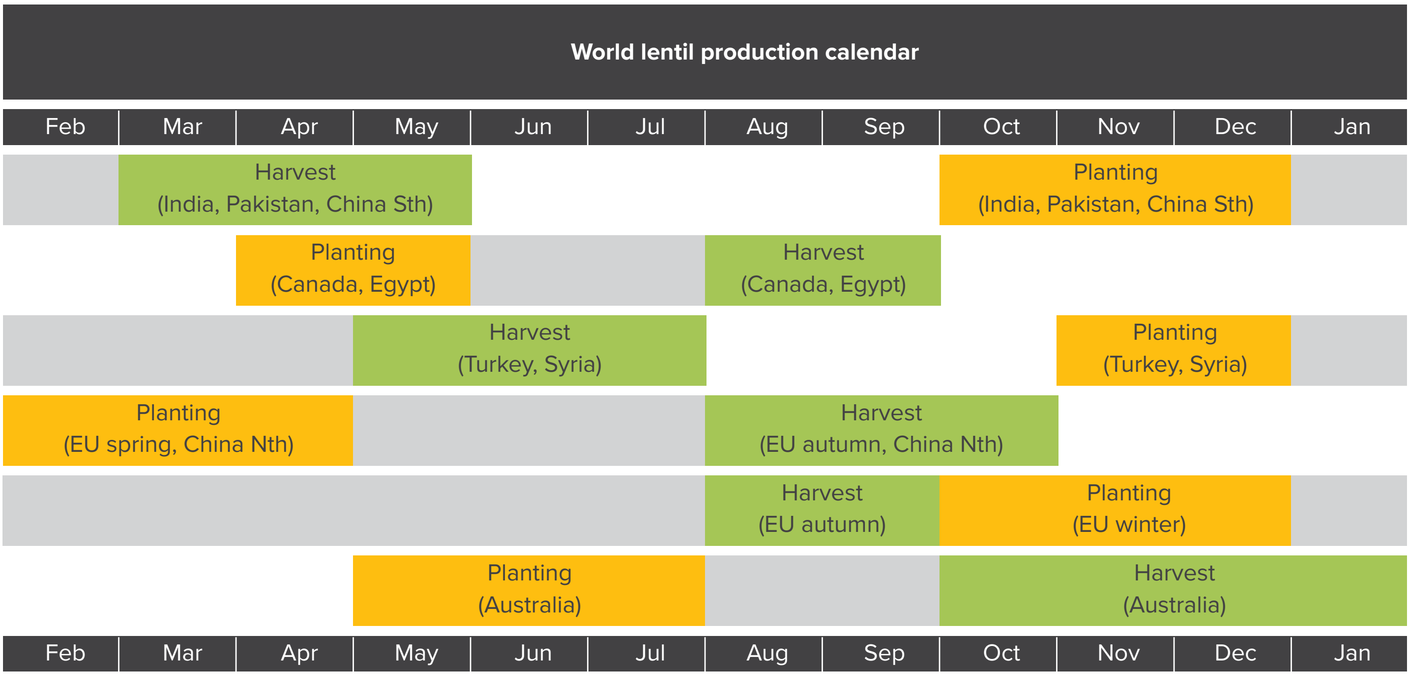


Figure 11: *Global lentil production calendar.* Source: Profarmer Australia

Some of the local influences on Australian lentil pricing are listed below:

- Australian domestic production of lentil.
- Seasonal conditions and the subsequent ramifications on the quality of the Australian lentil crop. With lentil required to meet strict specifications to be exported, adverse weather that impacts the quality over a broad area of the Australian crop has the potential to provide support.

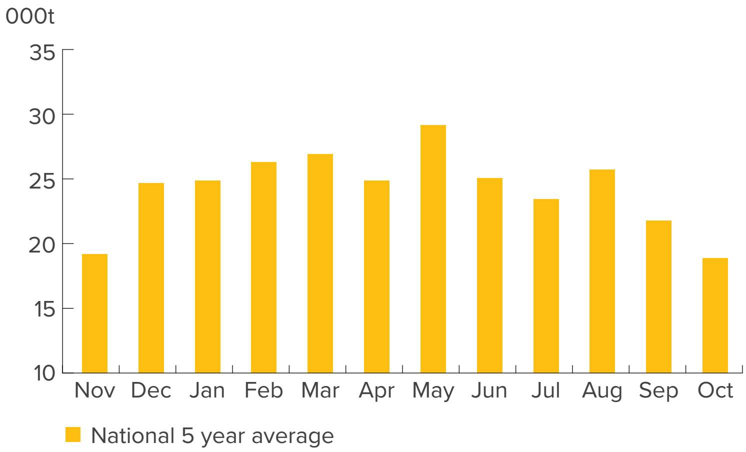


Figure 12: *Five year average monthly export pace ('000t).* Source: Australian Crop Forecasters

NOTE: Australian lentil export pace is typically strongest shortly after our harvest as buyers seek to move crop ahead of the Indian sub-continent harvest.

MORE INFORMATION

See Global Pulse Overview – who's who in the zoo?

https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/viable-growth-in-the-pulse-industry

15.2.2 Ensuring market access for southern lentils

The primary market for the southern lentil crop is exports for human consumption. Production in the southern growing region is focused in north-west Victoria and throughout South Australia, where it is primarily executed through the container or 'delivered' market. The southern region is the largest production region in Australia. However given the high value nature of lentils, as well as the counterparty risk of trading into key export regions, the crop continues to be exported primarily in containers.

To ensure access to this market, grain is required to be stored on-farm or delivered directly to the 'packer' at the time of harvest. Premiums may be available for lentil stored on-farm, allowing the buyer greater flexibility. However the cost of storage must always be considered.

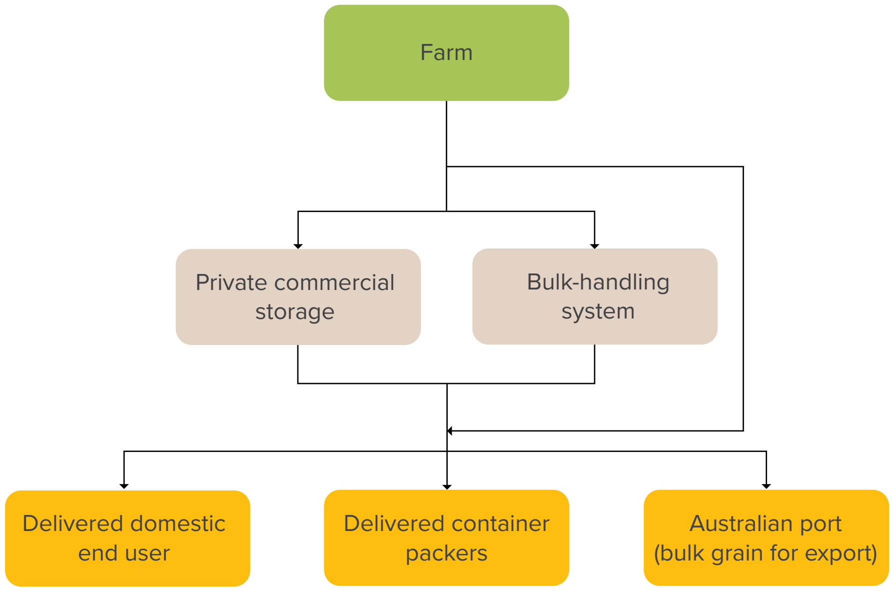


Figure 13: *Australian Supply-chain flow.*

There is virtually no"fall-back" safety net of a feed price if quality does not meet export food market criteria (and if there is a feed price,it is a much less than for other pulses). lentils with green kernels are difficult to sell even as feed (bitter taste).

NOTE: Storage decisions should be determined by assessing market access. The large majority of Australian lentil is exported in containers. Hence, private commercial storage and on farm storage can both provide efficiencies to market.

15.2.3 Executing tonnes into cash for southern lentils

Given the volatile nature of lentil pricing, setting a target price using the principles outlined in section 15.2.2 minimises the risk of taking a non-profitable price or holding out for an unrealistically high price that may not occur. Pricing deciles for lentil are provided as a guide.

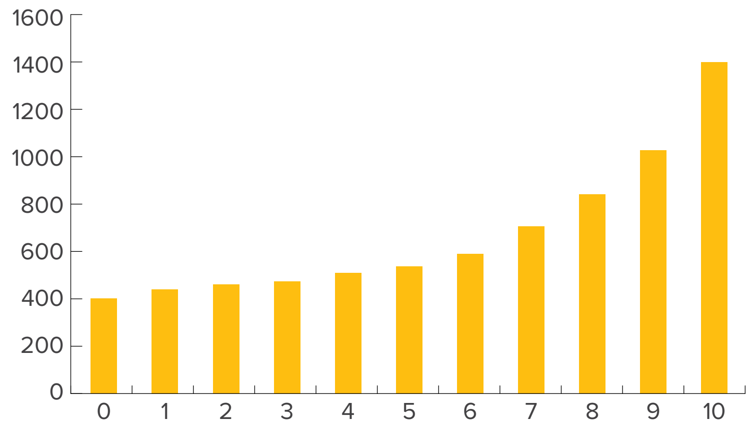


Figure 14: *Port Adelaide Lentil Deciles.*

Source: Profarmer Australia

Selling options for lentil include:

1. Store on-farm then sell–Most common occurrence. Lentil is relatively safe to store and requires less maintenance than cereal grains. It does however remain important to monitor and maintain quality, with lentil required to meet strict quality specifications for export in order to avoid being discounted at the time of delivery. Must consider cost of storage in target pricing.
2. Cash sale at harvest–least preferred option as buyer demand does not always coincide with harvest. Values can come under pressure at harvest time if an influx of grower selling occurs in a small window, subsequently providing buyers with confidence they can meet their short or medium term commitments.
3. Warehouse then sell–this provides flexibility for sales if on-farm storage is not available. Must consider warehousing costs in cost of production and target prices. In South Australia this is an alternative option offered through the major bulk handlers. Availability of this option from 'packers' within the 'delivered' market in both South Australia and Victoria will vary depending on each individual buyer.

There are some forward price mechanisms available for lentil including area contracts, as well as a traditional fixed volume forward contracts. Whilst area based contracts tend to price at a discount to fixed volume contracts, this discount needs to be weighed up against the level of production risk inherent in each contract.

As with all sales, counterparty risk and understanding contract of sale is essential. Counterparty risk considerations is especially important for pulse marketing as there is often a higher risk of contract default in international pulse markets than for canola or cereals due to the markets they are traded into and lack of appropriate price risk tools (such as futures). This can place extra risk on Australian-based traders endeavouring to find homes for your product.

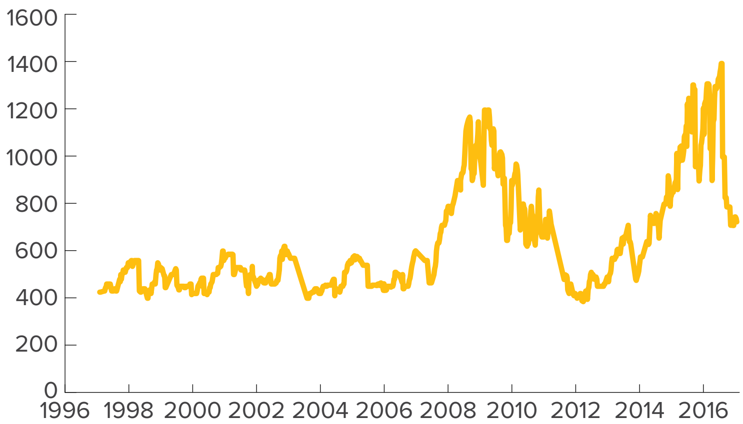


Figure 15: *Long-term Port Adelaide lentil price history.*

Source: Profarmer Australia

Current research

Project Summaries https://grdc.com.au/research/projects

As part of a continuous investment cycle each year the Grains Research and Development Corporation (GRDC) invests in several hundred research, development and extension, and capacity building projects. To raise awareness of these investments the GRDC has made available summaries of these projects.

These project summaries have been compiled by the 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 https://grdc.com.au/research/projects

Final Report Summaries https://grdc.com.au/research/reports

In the interests of raising awareness of the 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 https://grdc.com.au/research/reports

Online Farm Trials www.farmtrials.com.au

The Online Farm Trials project brings national grains research data and information directly to the grower, agronomist, researcher and grain industry community through innovative online technology. Online Farm Trials is designed to provide growers with the information they need to improve the productivity and sustainability of their farming enterprises.

Using specifically developed research applications, users are able to search the Online Farm Trials database to find a wide range of individual trial reports, project summary reports and other relevant trial research documents produced and supplied by Online Farm Trials contributors.

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

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