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GROWNOTES

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SUNFLOWERS

GRDC
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What's new

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

This version of the GRDC Sunflower GrowNotes (updated December 2016) contains the following updates on original content published in August 2014:

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- New link: Greijdanus A, Kragt M. (2014). The grains industry: An overview of the Australian broad-acre cropping: http://ageconsearch.umn.edu/bitstream/164256/2/WP1400002.pdf

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- New podcast: Growing sunflowers in the south: https://grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2015/09/099-north
- New reference: L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide
- New information: total summer crop area in the northern region: ABS, ABARES 2016

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- New table: Characteristics of sunflower hybrids available in 2014–15: http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

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- New table: Insecticide seed dressings registered for use in sunflowers: http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

Section 4 – Plant growth and physiology

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- New link: Sunflower: what is the cost of losing your leaves? Australian Summer Grains Conference 2016, http://yrd.com.au/ASG16 Program_Presentations V5.pdf

Section 5 – Nutrition and fertiliser

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- New link: Sunflower nutrition: http://www.grdc.com.au/TT-SunflowerNutrition

- New text and reference: Relationship between nitrogen, starting soil water and target yield: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf
- New information, new table: GRDC Tips and Tactics: Sunflower nutrition: https://grdc.com.au/TT-SunflowerNutrition

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- New reference: Sunflower nutrition: http://www.grdc.com.au/TT-SunflowerNutrition

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- New section: Declining soil fertility

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- New information: Plant tissue sampling: http://www.grdc.com.au/TT-SunflowerNutrition
- New table: Plant tissue sampling guidelines: http://www.grdc.com.au/TT-SunflowerNutrition

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- New information: Nitrogen: http://www.grdc.com.au/TT-SunflowerNutrition
- New figure: https://grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Serafin_ManagingNitrogen_edited_paper.pdf

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- New information, new figure: Phosphorus: http://www.grdc.com.au/TT-SunflowerNutrition

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- New information: Sulfur: http://www.grdc.com.au/TT-SunflowerNutrition

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- New information, new figure: Potassium: http://www.grdc.com.au/TT-SunflowerNutrition
- New information: Boron: http://www.grdc.com.au/TT-SunflowerNutrition

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- New information: Zinc: http://www.grdc.com.au/TT-SunflowerNutrition
- New information, new table: Fertiliser application guidelines: http://www.grdc.com.au/TT-SunflowerNutrition

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- New information: Nutritional disorders: http://www.grdc.com.au/TT-SunflowerNutrition

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- New link: SC Peltzer, A Hashem, VA Osten, ML Gupta, AJ Diggle, GP Riethmuller, A Douglas, JM Moore, EA Koetz (2009) Weed management in wide-row cropping systems: a review of current practices and risks for Australian farming systems. Crop & Pasture Science 60, 395–406. http://www.publish.csiro.au/CP/CP08130

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- New link: Collecting and preparing plant specimens for identification: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/304326/Collecting-and-preparing-plant-specimens-for-identification.pdf
- New link: Pest management—Weeds. In Sunflower production, North Dakota State University: https://www.ag.ndsu.edu/extensionentomology/recent-publications-main/publications/A-1331-sunflower-production-field-guide

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- New podcast: Glyphosate resistance survey: https://grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2015/05/80-north
- New link: Weed management in Queensland field crops: https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops

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- New podcast: Harvest weed seed management: https://grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2015/09/095-north

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- New link: Pre-emergent herbicides part of the solution but much still to learn: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Pre-emergent-herbicides-part-of-the-solution-but-much-still-to-learn
- New link: High plains sunflower production handbook, Kansas State University: http://www.agmrc.org/media/cms/Sunflowers_C84E1143C31B9.pdf

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- New link: Weed control in summer crops 2012–13: http://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/management-guides/summer
- New link: Pest Genie: http://www.pestgenie.com.au/DefaultPG.aspx?ReturnUrl=%2f
- New link: JT O'Donovan, EA de St. Remy, PA O'Sullivan, DA Dew, AK Sharma (1985) Influence of the relative time of emergence of wild oat (Avena fatua) on yield loss of barley (Hordeum vulgare) and wheat (Triticum aestivum). Weed Science 33, 498–503: http://www.jstor.org/stable/4044136?seq=1 - page_scan_tab_contents

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- New link: V Osten, H Wu, S Walker, G Wright, A Shields (2006) Weeds and summer crop row spacing studies in Queensland. In Proceedings of the 15th Australian Weeds Conference. Weed Management Society of South Australia: http://caws.org.au/

Section 7 – Insect control

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- New text: Weekly trap catch data for *H. punctigera* and *H. armigera* from locations across all states: https://jamesmaino.shinyapps.io/MothTrapVis/

Section 8 – Nematode control

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- New link: Managing grain crops in nematode infested fields to minimise loss and optimise profit: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Managing-grain-crops-in-nematode-infested-fields-to-minimise-loss-and-optimise-profit

Section 9 – Diseases

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- New link: GRDC Tips and Tactics: Sunflower disease management: https://grdc.com.au/TaT-SunflowerDiseaseManagement

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- New link: Disease control in summer crops and management strategies to minimise financial losses: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Disease-control-in-summer-crops-and-management-strategies-to-minimise-financial-losses

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- New link: Disease control in summer crops and management strategies to minimise financial losses: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Disease-control-in-summer-crops-and-management-strategies-to-minimise-financial-losses
- New text: Stem cankers (*Diaporthe/Phomopsis*): https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Weeds-and-crop-stubble-as-a-pathogen-host-or-reservoir
- New reference: Weeds and crop stubble as a pathogen 'host' or reservoir. What species are involved with what crop impact—implications for management: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Weeds-and-crop-stubble-as-a-pathogen-host-or-reservoir

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- New link: Disease control in summer crops and management strategies to minimise financial losses: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Disease-control-in-summer-crops-and-management-strategies-to-minimise-financial-losses

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- New video: sunflower harvest preparation and pitfalls: https://grdc.com.au/Media-Centre/GroundCover-TV/2014/05/GCTV13/HP9pplFpHgM

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- New video: Stored grain — Sunflower storage: https://grdc.com.au/Media-Centre/GroundCover-TV/2014/05/GCTV13/dNxohVicNqI

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- New link: GRDC Fact Sheet: Safe storage of sunflower seed — aeration drying and cooling: http://www.grdc.com.au/GRDC-FS-SunflowerSeedStorage
- New video: Stored grain — Sunflower cooling: https://grdc.com.au/Media-Centre/GroundCover-TV/2014/05/GCTV13/qT6R6s527BI

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- New video: Stored grain — Sunflower drying: https://grdc.com.au/Media-Centre/GroundCover-TV/2014/05/GCTV13/cdswPScgGZg

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- GRDC Tips and Tactics: Managing frost risk — Northern Southern and Western Regions: https://grdc.com.au/ManagingFrostRisk

Section 15 – Marketing

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- New text, figures and tables: Profarmer Australia

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Introduction

A.1 Agronomy at a glance

- Always plant sunflowers into a full profile of subsoil moisture.
- Sunflowers are dependent on arbuscular mycorrhizal fungi; addition of starter fertiliser is needed in long-fallow situations
- Check past residual herbicide applications; sunflowers are very susceptible to some herbicides.
- A failed crop cannot be grazed or baled.
- Sunflowers leave very little stubble cover for following fallow period.
- Do not mix ordinary (linoleic) seed with high oleic sunflower varieties when planting or harvesting.
- Do not rotate with legumes (as they are susceptible to many of the same diseases).
- Use of insecticidal seed dressings is important.
- Sunflowers can be a useful rotation crop in cereal systems if summer grass weeds are likely to be a problem.
- There are no options for control of broadleaf weeds in-crop.
- Bird damage can be severe, particularly if paddocks are near wooded areas or waterways.
- To protect bees, avoid using insecticides during flowering. [1]

Figure 1: *Sunflowers remain a minor crop and are best suited to deep clay soils with high water-holding capacities.*

Photo. Drew Penberthy, Penagcon

1 QDAF (2011) Sunflower production in Queensland. Department of Agriculture, Fisheries and Forestry Queensland, 13 Sept. 2011, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sunflowers

MORE INFORMATION

Download the Big Yellow Sunflower Pack (BYSP), videos and additional resources at www.bettersunflowers.com.au.

(Information from the BYSP is supported by GRDC and has been incorporated into the GRDC GrowNotes - Sunflowers.)

An extensive library of sunflower information is available at https://bettersunflowers.com.au/documents/library.aspx.

MORE INFORMATION

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

PODCAST

Tony Lockrey from AMPS Agribusiness in Moree discusses growing sunflowers in southern NSW. GRDC Podcast: 099 Growing sunflowers in the south

A.2 Crop overview

Sunflowers are grown for oil production, birdseed and confectionary. Dominant production areas in Queensland are the Central Highlands and Darling Downs, although there are significant crops in many other areas of central, western and southern Queensland. Usually considered a short-season opportunity crop, sunflower, when grown well, is a highly profitable crop that provides some very important rotational benefits. Sunflowers are best suited to mild temperatures, but can be grown in relatively hot areas as long as moisture is not limiting (Figure 1).

For southern Queensland growers, sunflowers are frost-tolerant to the six-leaf stage and can be sown in the spring, earlier than other summer crops. In Central Queensland, sunflower is favoured because it is a reliable producer on shallow soils and provides an option for late summer planting. [2]

In New South Wales (NSW), the main sunflower production region is in the north between Quirindi and Moree. Smaller areas are grown under full irrigation in the south-west around Griffith and Hillston, mainly for seed production. Opportunity-planting of sunflowers occurs in northwest NSW between Walgett and Coonamble, and in the central west. [3]

Sunflower remains a minor summer crop. On average, it represents about 5.5% of the total summer crop area of 1,161,000 ha grown annually in the northern region (5-year average 2013–17), compared with grain sorghum at 50% (578,000 ha) and cotton at 31% (365,000 ha). [4] Interestingly, the split between spring (3%) and summer (2.5%) plantings of sunflower is quite evenly balanced. However, yields of late-planted sunflowers (1.40 t/ha) have been marginally higher than early-planted sunflower (1.36 t/ha) across northern NSW.

Sunflowers have a strong taproot capable of extracting water from a depth of 2–3 m in ideal situations. They are best suited to deep clay soils with high water-holding capacities. They do not tolerate lengthy periods of waterlogging without suffering yield penalties.

Sunflowers are a good rotation crop, highly suited to no-till sowing into stubble-retention situations. Sunflowers are most often sown after a long fallow following a winter cereal but the crop leaves minimal stubble cover following harvest.

Sunflowers are suitable for use in a short fallow following sorghum, or as a double-crop option provided the soil moisture profile is near full. Sunflowers are grown for monounsaturated and polyunsaturated oils, and for the confectionary and birdseed markets. [5]

A.3 Key management issues

- Determine the amount of stored water in the soil profile prior to sowing by soil coring or using a push probe. If there is <80 cm of wet soil (<135 mm plant-available water), consider not sowing sunflowers. [6] Plant into 80–100 cm of wet soil to minimise the risk of crop failure. [7]
- Use no-till for dryland crops because no-till fallows store more soil water than conventional fallows, increasing the probability of higher yields.

2 QDAF (2011) Sunflower production in Queensland. Department of Agriculture, Fisheries and Forestry Queensland, 13 Sept. 2011, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sunflowers

3 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

4 ABS, ABARES 2016

5 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

6 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

7 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

- Opportunity cropping is an option in dryland areas if there is a positive seasonal outlook and good starting soil water.
- Apply nitrogen (N) fertiliser based on an N budget; use your target yield, soil test results and plant-available water at sowing. Previous crop yield and protein content can be used if soil test results are not available. [8] The relationship between N nutrition, starting soil water and target yield is crucial. Excess N causes a reduction in seed oil content, and insufficient N will limit crop yields. [9]
- A uniform crop stand and early canopy closure are essential to maximise crop competition with weeds.
- Use effective weed control options, especially for grasses. Weed control during the first 7 weeks after emergence is critical.
- Be aware of herbicide residues in the soil. Sunflowers are particularly sensitive to sulfonylurea herbicides.
- Select high-yielding hybrids that have the desired traits for your growing conditions.
- Monitor and, if necessary, control insects, especially wireworm at establishment and Rutherglen bug and *Helicoverpa* from budding through flowering. Assess the potential for mice and bird damage.
- Become familiar with the disease pathogens of sunflower and their other hosts to assist with rotation planning and to limit the impact of diseases.
- Do not sow too late; the risk of diseases, particularly *Sclerotinia*, is higher in the cooler areas, e.g. south of Gunnedah.
- Crops sown in late January are more likely to be slow drying down. Be prepared to harvest at higher moisture contents and use aeration where necessary. [10]
- Sunflower can be desiccated to improve and speed up harvest.
- Sow monounsaturated sunflowers in spring preferably, and polyunsaturated sunflowers in summer (late plant).
- Sunflowers are highly suited to no-tillage.
- Weed control is critical in the first 7 weeks after emergence.
- Aim to harvest and deliver grain at 9% moisture. [11]

A.4 End uses

The main end use for sunflower is oil, for which the receival standard is 40%. Oil production utilises two types of sunflower: monounsaturated and polyunsaturated.

In recent years, there has been a growing demand for monounsaturated sunflower oil, although an intrinsic demand remains for polyunsaturated oil.

Monounsaturated oil needs to contain >85% oleic acid. Monounsaturated oil is used for frying and margarines because of its long shelf life and high-temperature cooking stability.

Polyunsaturated sunflower receival standards require linoleic acid contents of >62%. This oil is used for margarines, mayonnaise and cooking oils.

Difficulty in meeting domestic demand in recent years has led to attractive, but variable prices. Fixed tonnage and hectare contracts help to reduce the risk of price fluctuations for growers.

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8 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

9 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

10 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

11 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

Several alternative market options exist, including the confectionary and birdseed markets and the stockfeed trade. Oil content is not a requirement for these markets. Several buyers for these markets are located in regional centres, which reduces freight costs.

Confectionery sunflowers are dehulled and the kernels used in a variety of products including breakfast foods, biscuits, snack bars and bread. Large seed is required with a minimum of 80% of seed passing over an 8/64 slotted screen. This end-use has specific hybrid preferences, so advice should be sought prior to planting, as contracts vary seasonally.

Human consumption in the form of whole seeds is an emerging overseas niche market and involves specialty large-seeded hybrids. [12]

12 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

Planning/Paddock preparation

1.1 Paddock selection

Sunflower paddocks should be selected to maximise crop performance. This includes selecting paddocks with low populations of broadleaf weeds (Figure 1) which compete for water, light and nutrients. In-crop control options for broadleaf weeds are limited.

Paddock selection also plays a role in minimising the risk of disease, primarily from *Sclerotinia*, which is hosted by many other broadleaf crops such as chickpea and canola. Under favourable conditions, *Sclerotinia* can build up and cause lodging and head rot in sunflower. [1]

Sunflowers are a good rotation crop, highly suited to no-till sowing into stubble-retention. Sunflowers are most often sown after a long fallow following a winter cereal; wheat or barley. Sunflowers leaves minimal stubble cover following harvest so are best sown into standing cereal stubble to maintain erosion control. Sunflowers are suitable for use in a short fallow following sorghum, or as a double-crop option provided the soil moisture profile is near full. Select paddocks that were previously sown to a rotation crop.

A rotation from a cereal is preferred, as broadleaf weed control will usually have been carried out in the previous crop and fallow, thus reducing the weed seedbank for the sunflower crop. Consider previously applied residual herbicides. Sunflowers can be affected by herbicides such as the sulfonylureas and atrazine.

Crops of monounsaturated hybrids should be isolated from other sunflower crops to reduce the risk of cross-pollination, which lowers the oleic acid content. Never sow adjoining crops of monounsaturated and polyunsaturated sunflowers where flowering may coincide.

Sunflowers have a strong taproot capable of extracting water from a depth of 1.5–2 m in ideal situations. They are best suited to deep clay soils, with high water-holding capacities. They do not tolerate lengthy periods of waterlogging without suffering yield penalties. [2]

Sunflowers play a small but important role in crop rotation in the northern grains region, where they are typically placed into a long-fallow situation following a winter crop or a short fallow following a summer crop. A survey of 134 paddocks across the northern grains region during 2003–06 found that 41% of sunflower crops were sown into a long fallow following a winter cereal (wheat or barley), 25% of crops were sown into a short fallow following sorghum, and just 13% were double-cropped into wheat or barley stubble (L Serafin and S Belfield, unpublished data). [3]

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1 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

2 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

3 L Serafin, S Belfield, D Herridge (2011) Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region? GRDC Update Papers, 13 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Sunflower-yield-performance-and-agronomy-Where-and-when-do-they-fit-best-in-the-northern-grains-region

Figure 1: *Identify paddocks with low populations of broadleaf weeds.*

Photo: Drew Penberthy, Penagcon

Soil management

Sunflowers are best suited to deep soils in a no-till system. No-till relies on effective weed control in the previous crop and fallow. Combined with stubble cover, it improves moisture retention, leading to consistently higher yielding sunflower crops. No-till also provides a wider sowing window and stores more soil water by reducing runoff. This enables a shorter fallow with more efficient water use, less runoff and less erosion. However, no-till can encourage the build-up of mice compared with conventional land preparation and limits some broadleaf weed control options because of the inability to incorporate pre-emergent herbicides. [4]

Sunflowers can use up to 7.5 mm/day during peak water use at flowering and can extract water from soil with chloride levels of 1200 mg/kg and sodicity (exchangeable sodium percentage, ESP) of 17% (B & W Rural Pty Ltd). [5]

Sowing into standing stubble is important as sunflowers do not leave high levels of stubble and this can expose paddocks to the risk of soil erosion.

1.2 Paddock rotation and history

In northern NSW, sunflowers typically follow a cereal crop. There are few instances where sunflowers are planted after a pulse or oilseed. There are two main reasons for this. First, sunflowers do not provide good stubble cover, an important feature in limiting erosion. As such, it makes sense to plant them after a cereal, which does provide good stubble cover. Second, planting sunflowers after a cereal gives the best rotation break. Sunflowers do not host the same diseases as cereal crops such as crown rot. They also allow the use of alternative herbicide groups to those used in the cereal crop. They are a good option where glyphosate-resistant summer grass paddocks are present and alternative herbicide options are required.

4 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

5 R Long. Water Use Efficiency in sunflowers—an on farm perspective. How do sunflowers compare with other summer crops. B & W Rural Pty Ltd. Australian Oilseed Federation, http://www.australianoilseeds.com/__data/assets/pdf_file/0016/907/Long_Read-Only.pdf

Sunflowers also have a role where nematode populations are limiting crop production, because the crop is resistant to both types of root-lesion nematode, *Pratylenchus thornei* and *P. neglectus*. [6]

Crop history in a paddock can determine the likelihood of disease having a major impact on the current sunflower crop. For example, many broadleaf crops host *Sclerotinia* and can increase inoculum levels for the following sunflower crop. [7]

Stubble can aid survival of pathogens. Growers should be familiar with the pathogens of sunflower as well as those of the other crops in the rotational sequences. [8]

1.3 Benefits of sunflower as a rotation crop

The optimum place for sunflower in the rotation is following a cereal, to maximise the benefit from an integrated weed and disease management perspective.

Sunflowers are most commonly sown following a long fallow from either wheat or barley. This allows broadleaf weed control in the preceding crop and provides adequate stubble cover to minimise erosion. In the 2005–06 season, 51% of paddocks in the above survey were sown into this situation. An alternative is to plant following a short fallow from sorghum, as was the case for 22% of paddocks in the 2005–06 season. (L Serafin and S Belfield, unpublished data)

Sunflowers make the soil softer and more friable than sorghum and also aid in restoring soil structure by breaking up compacted layers with their deep roots. Yield responses from applied nitrogen (N) are variable in sunflowers because of their ability to forage deeper in the soil profiles and tap into N ‘bulges’ at depth. [9]

1.4 Disadvantages of sunflower as a rotation crop

Sunflowers leave very little residual groundcover following harvest, and the remaining stalks are often difficult to manage because of their high stalk strength and slow breakdown. This results in the need to knock down and break up stubble manually, many growers choose to either slash or mulch stalks following harvest. Stubble breakdown also aids in the release of nutrients, such as potassium (K) and N, which are present at high levels in the stover. [10]

Stubble cover is an important means of limiting erosion. As such it is recommended to plant sunflower after a cereal, which does provide good stubble cover. [11]

1.5 Fallow weed control

The increasing use of herbicides during the fallow period provides the same benefits to sunflower that it does to other crops. However, sunflower is sensitive to some commonly used residual herbicides such as atrazine, chlorsulfuron, picloram, imazethapyr, metsulfuron methyl and imazapic. These products should be avoided in areas that might be planted to sunflower or careful consideration given to plant-back periods and conditions.

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6 L Serafin, S Belfield, D Herridge (2011) Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region? GRDC Update Papers, 13 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Sunflower-yield-performance-and-agronomy-Where-and-when-do-they-fit-best-in-the-northern-grains-region

7 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

8 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

9 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

10 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

11 L Serafin, S Belfield, D Herridge (2011) Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region? GRDC Update Papers, 13 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Sunflower-yield-performance-and-agronomy-Where-and-when-do-they-fit-best-in-the-northern-grains-region

Some other chemicals used in fallow weed control have the potential to affect crop emergence if the crop is sown too soon after the chemical application. To reduce this risk, a plant-back period is recommended. Table 1 provides a guide to some commonly used chemicals. [12]

Sunflowers are sensitive to several common residual herbicides, including sulfonylureas (SU). Often there can be residues in the soil from a previous application, which may damage the next crop. The plant-back period will be affected by the time since application, soil type, herbicide rate and rainfall. [13]

Rainfall or irrigation after herbicide application has major implications for most plant-back periods. Consult the label, or a local agronomist, for an accurate assessment of your situation which may include these constraints:

- Glean® and Siege® are not recommended for use on soils of pH ≥6.5.
- Longer intervals are needed in soils of pH >7.8 with Harmony® M.
- No less than 400 mm of rainfall should occur between application of Harmony® M and sowing of rotation crop.
- Do not use Spinnaker® 400 mL/ha in dryland situations unless you intend to recrop with a leguminous crop.
- On shallow soils <30 cm depth, do not plant until 2 years after application. [14]
- Flame® can be used in summer fallow with a 24-month plant-back interval.

Sunflower plant-back intervals can be checked individually on labels or for more information see Weed Management section of the Big Yellow Sunflower Pack at https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

1.6 Seedbed requirements

Poor crop establishment of sunflower can cause major yield losses. High soil-surface temperatures may kill germinating seeds or inhibit elongation of the hypocotyl of young seedlings. High temperature also causes rapid drying of soils, reducing the window of opportunity for planting, and leading to high water demand during the summer growing period.

Tillage is the conventional method of seedbed preparation but makes the soil prone to slaking and dispersion of aggregates. Infiltration of rainwater into the soil is often limited by surface sealing of cracking clay soils.

Heavy rain soon after planting leads to dispersion of clay aggregates, crusting of the soil surface and increased soil strength, preventing proper emergence of seedlings. This process is exacerbated by high evaporation.

Disturbance of the soil can be minimised by using conservation or no tillage techniques. Suitable seedbed conditions are needed only in the planting furrow where the seed is actually placed. No tillage is the most common method of planting sunflowers, as no tillage stores addition moisture in the fallow and retains seedbed moisture longer, widening the potential planting window than conventional tillage.

The use of press-wheels is recommended to improve contact between soil and seed and to improve the transfer of moisture to the seed. Press-wheel pressure and shape can be varied to suit the soil type and seasonal conditions. Too much press-wheel pressure can damage the seed and create a hard band in some soil types. The addition of a chain to drag loose soil back into the row can aid in reducing drying out of the trench and limit a 'Kinze crack' forming.

12 Australian Sunflower Association (2004) The New Big Black Sunflower Pack.

13 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

14 Australian Sunflower Association (2004) Weed management. The New Big Black Sunflower Pack. Australian Oilseeds Federation

MORE INFORMATION

http://www.australianoilseeds.com/__data/assets/pdf_file/0007/7792/1994_Aust_Grain_Sunflower_Crop_Establishment_and_Yield_Compensation.pdf

MORE INFORMATION

http://www.apsim.info/Portals/0/APSoil/SoilMatters/Mod4/2_04.htm

http://www.grdc.com.au/uploads/documents/GRDC_Water%20Use%20Efficiency%20.North%20version%20231009.pdf

Pre-soaking of seed and injection of water into the planting furrow have been ineffective in improving establishment. [15]

1.7 Soil moisture

Sunflower yields are highly influenced by the amount of water available during the growing season. This can be supplied in three ways:

1. Starting soil water
2. In crop rainfall
3. Irrigation

Sunflowers should not be sown unless the soil profile is wet to a depth of 80 cm (>150 mm plant-available water, PAW) to minimise the risk of crop failure or uneconomic yields. Agronomists suggest an absolute minimum of 150 mm PAW to make the crop commercially successful.

Starting soil water should be assessed by using a push probe or by soil-coring and calculating starting PAW. To calculate PAW, refer to 'Soil Matters' (Dalgliesh and Foale). [16,17] If soil-coring is used, crop lower limits; where available; (the water content of a soil after a crop has extracted all of the water available to it) can be applied to determine the exact amount of PAW. Final sunflower yield will still be a reflection of the starting soil water and the in-crop rainfall received as well as seasonal conditions and crop agronomy. Starting with a full profile of moisture minimises the risk of crop failure. [18]

From the project 'Sunflowers in Northern NSW and Southern Qld—Tools for Success', crop lower limits were established for a selection of soils in northern NSW (see Table 2). [19]

The amount of starting PAW also has an impact on management decisions such as row configuration, with skip-row or wide-row configurations sometimes used when starting soil water is less than ideal. [20]

Sunflowers have a deep taproot, which can extract moisture from up to 2 m depth in ideal soil conditions, and have higher soil water extraction ability than many other crops, including sorghum and maize. This means that more water can be extracted by sunflowers than by other crops from the same soil. [21]

15 B Winter, L Wade, P Blamey, A Douglas (1994) Sunflower crop establishment and yield compensation. Australian Oilseeds Federation. Northern Focus Aug.–Sept. 1994, http://www.australianoilseeds.com/__data/assets/pdf_file/0007/7792/1994_Aust_Grain_Sunflower_Crop_Establishment_and_Yield_Compensation.pdf

16 NP Dalgliesh, MA Foale (1998) Soil matters. Monitoring soil water and nutrients in dryland farming. Agricultural Production Systems Unit, CSIRO, http://www.apsim.info/Portals/0/APSoil/SoilMatters/pdf/front_matter.pdf

17 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

18 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

19 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

20 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

21 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

Table 1: *Soil-water crop lower limits for sunflower in northern NSW.* [22]

Depth of soil	Pine Ridge	Tambar Springs	Breeza	Moree	Biniguy	Ashley
10–30 cm	0.29	0.30	0.26	0.24	0.18	0.24
30–60 cm	0.35	0.35	0.34	0.33	0.20	0.25
60–90 cm	0.38	0.36	0.34	0.31	0.20	0.25
90–120 cm	0.41	0.27	0.30	0.26	0.24	0.30
120–150 cm	0.37	0.34	0.36	0.26	0.25	0.32
150–180 cm	–	–	–	0.26	0.25	0.32
Soil Type	Black Vertosol	Black Vertosol	Black Vertosol	Grey Vertosol	Red Chromosol	Grey Vertosol

Values are proportion volumetric water content of the soil when the crop has extracted as much water as it can.

1.7.1 Irrigation

Sunflowers can be successfully grown under irrigation. Irrigation through pivots or by surface irrigation on raised beds is suitable. Care should be taken when using irrigation systems not to create an environment favourable for diseases such as powdery mildew. [23]

Sunflower yields will be reduced by waterlogging; therefore, quick, even and efficient irrigation is important.

The maximum depth of water extraction is thought to be reached at 50% flowering. Root growth occurs at a rate of 3.2–3.5 cm/day, with the extraction front proceeding at around 3.8 cm/day. Studies by the Department of Employment, Economic Development and Innovation (DEEDI Qld) showed that daily water uptake peaks at ~40 days after sowing, or close to budding.

The amount of irrigation water required varies depending on whether the crop is planted in spring or summer. Spring-planted crops require more water. In northern NSW, the total crop water use is 4.5–7.5 ML/ha. This demand is normally met by a combination of stored soil moisture, rainfall and irrigation. If 250 mm of in-crop rainfall is assumed, then 2.0–5.0 ML/ha may be required as irrigation.

Water stress between flowering and maturity has the biggest impact on grain yield. As a rule of thumb, in self-mulching soils, a water depletion of 75–90 mm can be used to schedule irrigations; however, this depends on soil type. Do not leave the irrigation application too late as water and nutrient access will be limited if roots are broken from deep soil cracking. This can also lead to infection from pathogens such as *Sclerotinia*.

Sunflowers have a relatively low demand for water until about 10 days after bud-visible. The demand for water then increases dramatically until ~26 days after 50% flowering.

The recommended times for surface irrigations are:

1. Prior to sowing—pre-water fields
2. Budding—first irrigation
3. Start of flowering—second irrigation
4. Early seed fill—third irrigation

Caution should be exercised if using overhead irrigation to avoid irrigating during flowering, to ensure that seed-set is not affected. In addition, irrigating too late

22 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

23 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

MORE INFORMATION

L Serafin, S Belfield. Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

GRDC Updates Papers: L Serafin, S Belfield, D Herridge. Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region?

MORE INFORMATION

http://www.climatekelpie.com.au/understand-climate/weather-and-climate-drivers/queensland#ElNino

http://www.climatekelpie.com.au/ask-a-farmer/climate-champion-program

into seed-fill will increase the risk of paddocks remaining wet at harvest, reducing trafficability and potentially causing compaction. [24]

1.8 Yield and targets

Sunflower average yield and oil content varies between seasons; however, the project 'Sunflowers in Northern NSW and Southern Qld—Tools for Success' showed that higher yields are generally achieved in the Gunnedah district than in Moree and southern Queensland (Table 3). As a result nitrogen and gross margin budgeting should be carried out using data for the relevant growing region and incorporate the starting soil water and anticipated in-crop rainfall. [25]

Table 2: *Average dryland yields and oil contents for sunflower crops grown in regions of northern NSW and in southern Queensland.*

Region	Average Yield (t/ha)	Yield Range (t/ha)	Average Oil %	Oil % Range
Moree	1.42	0.50–3.00	39.4	30.7–45.8
Gunnedah	1.78	0.58–2.96	39.0	34.5–45.0
Sthn Qld	1.29	0.30–3.33	41.2*	40.0–43.0

* Only includes data from 8 crops

1.8.1 Seasonal outlook

Queensland Alliance for Agriculture and Food Innovation (QAAFI) produces regular, seasonal outlooks for summer crop producers. These high-value reports are written in an easy-to-read style and are free. For more information, visit https://qaafi.uq.edu.au/article/2016/10/sorghum-crop-outlook-march-2016.

For tips on understanding weather and climate drivers, including the SOI, visit the Climate Kelpie website. Case studies of 37 farmers across Australia who were recruited as Climate Champions as part of the Managing Climate Variability R&D Program can also be accessed at the Climate Kelpie website.

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

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

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

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

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

24 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

25 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

MORE INFORMATION

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

www.australianclimate.net.au

MORE INFORMATION

http://www.australianoilseeds.com/__data/assets/pdf_file/0016/907/Long_Read-Only.pdf

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

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

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. [26]

The Bureau of Meteorology has recently moved from a statistics-based to a physics-based (dynamical) model for its seasonal climate outlooks. The new system has better overall skill, is reliable, allows for incremental improvements in skill over time, and provides a framework for new outlook services including multi-week/monthly outlooks and the forecasting of additional climate variables. [27]

1.8.2 Water Use Efficiency

The yield and quality of summer crops grown in the northern region depends on the amount of plant available water (PAW) and the evaporative demand at flowering and early grainfill.

Water Use Efficiency (WUE) of summer crops is of limited value unless some account is taken of 'rainfall effectiveness'.

A key strategy to reduce production risk is to maximise PAW at planting as sunflowers use soil water relatively early (compared to sorghum or cotton). This is a function of fast early growth and higher leaf area. [28]

Further work should be done to monitor water-use patterns and WUE for sunflowers on wider row configurations. [29]

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

WUE relies on:

- the soil's ability to capture and store water;
- the crop's ability to access water stored in the soil and rainfall during the season;
- the crop's ability to convert water into biomass; and
- the crop's ability to convert biomass into grain (harvest index). [30]

1.8.3 Nutrient efficiency

Nitrogen and sulfur (S) are two of the critical nutrients for sunflower production. Sunflower nutritional requirements are often considered moderate compared with other crops. However, adequate crop nutrition is critical to targeting high yields and oil contents.

Nitrogen is a major nutrient affecting seedling vigour, crop growth and development, and grain yield and quality (seed size and oil content). Many of these factors are influenced by interactions with other nutrients, such as sulfur. Nitrogen is also a major cost to sunflower growers when applied as fertiliser N, in turn affecting crop profitability.

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

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

28 R Long. Water Use Efficiency in sunflowers—an on farm perspective. How do sunflowers compare with other summer crops. B & W Rural Pty Ltd. Australian Oilseed Federation, http://www.australianoilseeds.com/__data/assets/pdf_file/0016/907/Long_Read-Only.pdf

29 R Long. Water Use Efficiency in sunflowers—an on farm perspective. How do sunflowers compare with other summer crops. B & W Rural Pty Ltd. Australian Oilseed Federation, http://www.australianoilseeds.com/__data/assets/pdf_file/0016/907/Long_Read-Only.pdf

30 GRDC (2009) Converting rainfall to grain. Northern Region. GRDC Water Use Efficiency Fact Sheet, http://www.grdc.com.au/uploads/documents/GRDC_Water%20Use%20Efficiency%20North%20version%20231009.pdf

The industry standard for the oil content of sunflower grain is 40%, with a premium and discount system applied to the measured oil content above and below the standard. Commercially, sunflower oil contents are variable and may be largely related to crop nutrition. A benchmarking study by Serafin and Belfield (2008—Sunflower production guidelines for the northern grains region—northern NSW and southern Qld) of 32 commercial paddocks of sunflower in northern NSW and southern Queensland indicated large variations in nitrogen management of the crops, resulting in large variations in N supply. Of concern was the fact that 20% of paddocks had starting soil nitrate-N levels >200 kg/ha.

Four nitrogen rate experiments were conducted in northern NSW in the 2005–06 summer on farms near Tamarang and Pine Ridge on the Liverpool Plains and Gurley and Mallawa in the Moree district.

The major outcome of these replicated trials was the negligible effects of applied fertiliser N on grain yields (until the point of excess) and the negative effect on oil content. This prompted further interrogation of the data, because it appeared that the relationship between N nutrition, starting soil water, target yield and oil content was crucial.

The ratios of soil water to nitrate have been used successfully to target specific grain proteins, in the study of wheat and barley production in southern Queensland (Dalal et al. 2007). Since protein and oil contents of grains are inversely related, it seemed possible to use a similar approach to target oil contents sunflower of >40%.

Starting soil water and N rates were converted to a nitrate: water ratio and the measured oil contents were then subjected to regression analysis.

As N supply increased and the soil nitrate: water ratio increased from 0.35 to 1.80, grain oil contents declined from 45% to ~38%. Grain yields also showed a slight decline through the range of nitrate: water ratios. Matching nitrate to water at ratios of 0.5–1.0 optimised oil contents above the required industry standard of 40% as well as grain yield. Oil contents were, on average, <40% when the nitrate: water ratio was >1.0.

On one hand, there is an important need to supply sufficient N to optimise yield, while on the other not compromising grain quality. In the case of sunflower, high N supply may result in low oil contents and a price penalty.

Data from the four replicated N-rate trials suggest that the concept of targeting oil content through matching of soil nitrate and water at ratios of 0.5–1.0 has merit. Clearly, additional data are required to confirm the relationship. An incomplete data set from a benchmarking study of commercial sunflower crops in northern NSW and southern Queensland (L Serafin and S Belfield, unpublished data) has indicated a similar negative relationship between the nitrate : water ratio and oil content, with 26% of the crops sown into soils with the ratio >1.0. Further investigation to clarify the relationship is planned.

Sulfur is also a major nutrient of sunflowers, but to date little research has been done in the northern grains region to determine potential benefits and specific requirements of S. Sulfur and N interact to determine leaf area, which provides photosynthetic capacity for developing florets and seeds. A deficiency of N and S leads to reduced seed weight and number of seeds, as well as affecting seed quality.

Sunflowers remove 5 kg of S in the seed of a 1-tonne crop; hence, including sunflowers as a regular crop in the rotation has the capacity to remove significant amounts of S over time.

Preliminary trial work has been conducted to investigate the effects of the major nutrients, N, S and K, alone and in combination. Results from a trial conducted in the 2008 season at Pine Ridge showed a yield advantage of applying 5 kg S/ha, broadcast at sowing as gypsum. However, there was no significant difference between applying 10 kg S/ha and the nil treatment. No effects on oil content were recorded.

Further trial work is needed to provide additional data to develop our understanding of the full impacts of S nutrition.

In relation to N management, from the current data set it can be surmised that oil contents were, on average, <40% when the nitrate : water ratio was >1.0. These results suggest that sunflower oil contents may be more specifically targeted and fertiliser N inputs more accurately determined for optimum profitability. The key outcome of this study is that excessive N in relation to starting soil water reduces oil content. However, sufficient N is needed to maintain yield.

Sulfur nutrition and its interaction with N needs further investigation. A positive response to yield was obtained in one preliminary trial. [31]

1.8.4 Double-crop options

Double-cropping is an option in seasons where the soil profile refills quickly; however, it is not recommended where stored moisture is limited. [32] Surprisingly, only 14% of sunflower paddocks are sown into a double-crop situation. [33]

1.9 Nematode status of paddock

MORE INFORMATION

GRDC The current and potential costs from diseases of wheat in Australia

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

In the northern grain region, the predominant root lesion nematode (RLN), *Pratylenchus thornei*, costs the wheat industry AU$38 million annually. Including the secondary species, *P. neglectus*, RLN is found in three-quarters of fields tested. [34]

Resistance and susceptibility of crops can differ for each RLN species, and sunflowers have a role to play where nematode populations are limiting crop production, because the crop is resistant to both *P. thornei* and *P. neglectus*. [35]

As information on nematode incidence and species type becomes available, the use of sunflowers as a management tool for nematodes is likely to increase. RLN are widespread in central and northern NSW, with *P. thornei* generally having a much higher distribution (69% random paddocks) than *P. neglectus* (32% random paddocks). [36]

1.9.1 Nematode testing of soil

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

- whether nematodes are present in your fields and at what density
- which species are present

It is important to know which species are present because some crop-management options are species-specific. If a particular species is present in high numbers, immediate decisions must be made to avoid losses in the next crop to be grown. With low numbers, it is important to take decisions to safeguard future crops. Learning that a paddock is free of these nematodes is valuable information because steps may be taken to avoid future contamination of that field. [37]

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31 L Serafin, S Belfield, D Herridge (2011) Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region? GRDC Update Papers, 13 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Sunflower-yield-performance-and-agronomy-Where-and-when-do-they-fit-best-in-the-northern-grains-region

32 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

33 L Serafin, S Belfield, D Herridge (2011) Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region? GRDC Update Papers 13 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Sunflower-yield-performance-and-agronomy-Where-and-when-do-they-fit-best-in-the-northern-grains-region

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

35 L Serafin, S Belfield, D Herridge (2011) Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region? GRDC Update Papers 13 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Sunflower-yield-performance-and-agronomy-Where-and-when-do-they-fit-best-in-the-northern-grains-region

36 L Serafin, S Belfield, D Herridge (2011) Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region? GRDC Update Papers 13 Sept. 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Sunflower-yield-performance-and-agronomy-Where-and-when-do-they-fit-best-in-the-northern-grains-region

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

MORE INFORMATION

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

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

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

MORE INFORMATION

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

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

1.9.2 Effects of cropping history on nematode status

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

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

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

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

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

For more information, download *Management of root-lesion nematodes in the northern grain region*
http://www.daf.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

Summer crops have an important role in management of RLN. Research shows than when *P. thornei* is present in high populations, two or more resistant crops in sequence are needed to reduce populations to low enough levels to avoid yield loss in the following intolerant, susceptible wheat crops. [38]

For more information on nematode management, see GrowNotes Sunflowers Section 8: Nematodes.

1.10 Insect status of paddock

1.10.1 Insect sampling of soil

Several species of soil-dwelling insects attack seeds and seedlings of sunflowers, causing thinning or complete destruction of plant stands. Sunflowers are more susceptible to seedling damage than are other field crops because damaged sunflower seedlings lack the capacity to regrow or tiller.

Seedlings are most vulnerable to damage:

- before they develop three to four ´true´ leaves
- during periods of moisture stress
- when other factors such as low soil temperature or soil compaction limit plant growth [39]

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

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

39 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers

Soil insects include:

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

Soil insect control measures are normally applied at sowing. Since different insects require different control measures, the species of soil insects must be identified before planting. [40]

Soil sampling by spade

1. Take a number of spade samples from random locations across the field.
2. Check that all spade samples are deep enough to take in the moist soil layer (this is essential).
3. Hand-sort samples to determine type and number of soil insects.
4. Spade sampling is laborious, time-consuming and difficult in heavy clay or wet soils. [41]

Germinating-seed bait technique

Immediately following planting rain:

1. Soak insecticide-free crop seed in water for at least 2 hours? to initiate germination.
2. Bury a dessertspoon of the seed under 1 cm of soil at each corner of a square 5 by 5 m at five widely spaced sites per 100 ha.
3. Mark the position of the seed baits, as large populations of soil insects can destroy the baits.
4. One day after seedling emergence, dig up the plants and count the insects.

Trials have shown no difference in the type of seed used for attracting soil-dwelling insects. However, use of the type of seed to be sown as a crop is likely to indicate the species of pests that could damage that crop.

The major disadvantage of the germinating-grain bait method is the delay between the seed placement and assessment. [42]

Detecting soil-dwelling insects

Soil insects are often difficult to detect because they hide under trash or in the soil. Immature insects such as false wireworm larvae are usually found at the moist–dry soil interface.

For current chemical control options see the websites of Pest Genie Australia or APVMA. [43]

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

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

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

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

Pre-planting

2.1 Varietal performance

Five sunflower hybrids will be marketed in NSW for sowing in 2014–15. It is advisable to grow more than one hybrid to spread risk, as no hybrid excels in all characteristics.

Select hybrids based on end-use requirement, yielding ability (seed and oil), disease tolerance, head inclination, height and good agronomic type. Hybrids and their characteristics are described in Table 1.

Table 1: *Characteristics of sunflower hybrids available in 2016–2017.*

Company	Hybrid	Maturity	End use	Height	Head inclination
Nuseed	Ausigold 4	Medium–slow (early plant) Medium (late plant)	Polyunsaturated Suitable for dehulling	Medium–tall	Pendulous
	Ausistripe 14	Medium	Confectionery/ Birdseed	Medium-tall	Semi-erect
	Ausigold 62	Medium	Monounsaturated	Medium	Semi-erect
Pacific Seeds	Hyoleic 41	Medium–slow	Monounsaturated	Medium–tall	Semi-pendulous
	Sunbird 7	Medium	Confectionery/ Birdseed	Medium–tall	Semi-pendulous

2.1.1 Yielding ability

Select hybrids firstly on yield potential but also on oil content. Use hybrid trial results as a guide (see Table 2) but always try the hybrids on your farm and grow those that produce the best average results for you.

Generally, the medium–slow-maturing hybrids have the highest yield potential. Monounsaturated hybrids yield equal to, or slightly less than, the best polyunsaturated hybrids. However, monounsaturated hybrids usually have a higher oil percentage and attract a price premium. [1]

1 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

Table 2: *Dryland sunflower hybrid performance across seasons and sites 2004–09.*

Hybrid	Yield (t/ha)	Oil content (%)	No. of trials
Hysun 39	1.91	40.96	14
Hyoleic 41	1.87	40.88	16
Hysun 47	1.84	41.61	2
Hysun 38	1.80	39.70	16
Ausigold 7	1.80	41.30	13
SV60066	1.79	–	1
Ausigold 51	1.75	38.76	6
Ausigold 63	1.73	42.46	2
Ausigold 4	1.73	41.08	16
Ausigold 8	1.72	39.37	9
Ausigold 61	1.72	40.88	12
Ausigold 62	1.69	41.30	16
Award	1.67	–	1
Sunbird 7	1.67	37.10	9
Ausigold 5	1.62	39.73	6
Ausigold 50	1.60	36.67	8
SV60050	1.60	–	1
HP002GN	1.58	36.62	5
Ausigold 10	1.53	–	1
Sunoleic 06	1.53	41.30	16
Advantage	1.50	41.11	16
HP004GN	1.50	39.88	5
Jade Emperor	1.48	20.47	3
Ausigold 64	1.47	40.83	2
Ausigold 52	1.32	34.36	4
LSD	0.26 t/ha	2.35%	

2.1.2 Oil, protein or other quality traits

High oil percentages give growers a premium of 1.5% of price for each 1% of oil >40% (use Table 2 as a guide to oil contents). Birdseed and confectionary hybrids such as Sunbird 7 have low relative oil percentages, as oil content is not a requirement for these end uses. [2]

Monounsaturated sunflowers are preferably sown in spring, because higher average night temperatures during seed development will enhance oleic acid content. [3]

Polyunsaturated sunflowers are sown in summer, as they require cool mean daily temperatures to produce high linoleic acid levels. Sowing in the late planting window ensures that seed filling occurs in autumn. Sowing earlier than this, i.e. in spring, usually results in linoleic acid levels in the oil below the required 62%. [4]

2 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

3 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

4 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

2.1.3 Maturity

The growth rate of all hybrids is largely determined by temperature, photoperiod and moisture. In northern NSW, a medium–slow hybrid sown at Moree in early September and at Spring Ridge in mid-October takes about 80–85 days to flower. The same hybrids sown in mid-December to mid-January take about 60 and 65 days, respectively. Medium maturity hybrids are up to 5 days quicker to flower. Quick and medium-quick hybrids are best suited to late sowing times and north-western areas, west of the Newell Highway. [5]

2.1.4 Head inclination and stem curvature

Hybrids with pendulous heads tend to suffer less sunscald at flowering than erect hybrids. However, pendulous hybrids with highly curved stems are more prone to lodging, making harvesting difficult, and water may pool in the back of the heads, increasing susceptibility to disease. [6]

2.2 Planting seed quality

The seed companies provide information on each bag of seed designed to meet government regulations and assist the farmer at planting time.

Information on the bag:

- Variety: name.
- Seed size: 7/8, small; 8/10, medium; 10/14, large.
- Seed count: number of seeds/kg; allow for a 5% tolerance.
- Line or batch no.: the reference number for that seed lot. (Always keep a record for future reference.)

Information on the tag (a tag is attached to most bags; usually, the 'on the bag' information is repeated): [7]

- Purity: minimum purity, other seeds, declared seeds as required by legislation.
- Minimum germination: as required by legislation. The figure quoted is on the safe side (often 85%) and lower than the actual.
- Actual germination: not to be confused with minimum germination. This information is voluntary and can include the following: the actual germination, date of test (if no date, assume seed tested pre-season), number of days to reach the actual germination (usually 7 days). The quicker the seed reaches a value close to the actual the better the quality (e.g. 90% germination in 5 days indicates greater vigour than 90% germination in 10 days).

2.2.1 Seed size

Small (7/8) and medium seed (8/10) is preferred for the spring plant, as smaller seed generally establishes better in cooler conditions. Medium and large seed (10/14) should be used in warmer conditions or when planting deeper into moisture. Larger seed is more suited to precision planters, as smaller, lighter seed may result in doubles in one hole of the planter plate. [8]

5 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

6 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

7 Australian Sunflower Association (2004) The New Big Black Sunflower Pack. Australian Oilseeds Federation

8 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

MORE INFORMATION

http://www.grdc.com.au/Resources/Factsheets/2012/03/Grain-Storage-Fact-Sheet-Storing-Oilseeds

http://www.australianoilseeds.com/__data/assets/pdf_file/0006/4110/Oilseeds_Flyer.pdf

http://www.pacificseeds.com.au/info-and-tools/seed-information/86-seed-storage-information.html

2.2.2 Seed germination and vigour

The minimum germination percentage is usually >90% but check the percentage on the bag or consult seed merchants. [9] Sunflower seed has the germination percentage and the number of seeds per kg marked on each bag. Check the testing date for currency. It is also advisable to plant treated seed to protect against seedling pests and diseases. [10]

2.2.3 Safe rates of fertiliser sown with the seed

The safe rate is affected by the row spacing. Suggested rates of fertiliser which can be safely sown with sunflower seed are shown in Table 3. As row spacing increases the amount of nitrogen and phosphorus which can safely be sown with sunflower seed decreases.

Research conducted by Dowling (1998) showed variations in the response to critical rates of DAP, MAP and triple superphosphate by sunflowers when applied in the seed furrow. Refer to this work before applying fertiliser with the seed. Reductions in establishment may result due to application of certain fertilisers when applied in the seed furrow. Planting equipment and field conditions affect the likelihood of damage. [11] [12]

Table 3: *Safe rates of fertiliser sown with sunflower seed.*

Row spacing cm	N kg/ha	P kg/ha	Fertiliser product kg/ha Urea	DAP	MAP
45	8	22	22	52	80
60	6	17	16	39	60
75	5	13	13	30	50
100	4	10	10	23	45

Source: The New Big Black Sunflower Pack, Australian Sunflower Association, 2004.

9 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

10 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

11 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Agronomy including Irrigation Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=5

12 Australian Sunflower Association (2004) Boron deficiency. The New Big Black Sunflower Pack. p. 29. Australian Oilseeds Federation

Planting

3.1 Seed treatments

Seed used for sowing is often treated with insecticide to provide protection against soil-dwelling insects (Table 1).

Table 1: *Insecticide seed dressings registered for use in sunflowers.* [1]

Example seed treatment trade name and manufacturer #	Active ingredient	Group	Rate to apply to each 100 kg of seed*	Approx cost to treat 100 kg ($) ##	Sorghum	Sunflowers	Maize
Cosmos® – Cropcare	fipronil (500 g/L)	2C	400 mL (canola) 150 mL (sorghum, sunflowers)	336.60 126.30	False wireworm. Protection from black field earwig	False wireworm. Protection from black field earwig	–
Senator® 600 Red – Cropcare Gaucho® 600 – Bayer CropScience	imidacloprid (600 g/L)	4A	400 mL (canola, lucerne) 300 mL (lupin) 120–240 mL (cereals) 1.4 mL/1000 seeds (maize) 430 mL (sorghum, sunflower, sweetcorn)	22.00 16.50 6.60–13.20 0.10/1000 seeds 23.70	True wireworm (*Agrypnus variabilis*), eastern and southern false wireworm, striate false wireworm, black field earwig, wingless cockroach, field cricket, black sunflower scarab	True wireworm (*Agrypnus variabilis*), eastern and southern false wireworm, striate false wireworm, black field earwig, wingless cockroach, field cricket, black sunflower scarab	True wireworm (*Agrypnus variabilis*), eastern and southern false wireworm, striate false wireworm, black field earwig, wingless cockroach, field cricket, black sunflower scarab
Imidacloprid 600 – TitanAg	imidacloprid (600 g/L)	4A	400 mL (canola, lucerne) 300 mL (lupin) 120 or 240 mL (cereals) 1.4 mL/1000seeds (maize) 430 mL (sorghum, sunflower, sweetcorn)	34.50 25.90 13.20–26.35 0.12/1000 seeds 37.10	True wireworm (*Agrypnus variabilis*), eastern and southern false wireworm, striate false wireworm, black field earwig, wingless cockroach, field cricket, black sunflower scarab	True wireworm (*Agrypnus variabilis*), eastern and southern false wireworm, striate false wireworm, black field earwig, wingless cockroach, field cricket, black sunflower scarab	True wireworm (*Agrypnus variabilis*), eastern and southern false wireworm, striate false wireworm, black field earwig, wingless cockroach, field cricket, black sunflower scarab

1 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

Example seed treatment trade name and manufacturer #	Active ingredient	Group	Rate to apply to each 100 kg of seed*	Approx cost to treat 100 kg ($) ##	Sorghum	Sunflowers	Maize
Cruiser 350 FS® – Syngenta	thiamethoxam (350 g/L)	4A	400 mL (sorghum) 260–400 mL (sorghum – corn aphids) 1.4 mL/1000 seeds (maize and sweetcorn) 0.31 mL/1000 seeds (sunflower)		Eastern and southern false wireworm, corn aphids. Protection from black field earwig and true wireworm (*Agrypnus variabilis*)	Eastern and southern false wireworm, true wireworm (*Agrypnus variabilis*)	Eastern, southern and striate false wireworm. Protection from true wireworm (*Agrypnus variabilis*)
Cruiser 600 FS® – Syngenta**	thiamethoxam (600 g/L)	4A	230 mL (sorghum) 0.18 mL/1000 seeds (sunflower) 0.82 mL/1000 seeds (maize and sweetcorn)	NA	Eastern and southern false wireworm. Protection from black field earwig and true wireworm (*Agrypnus variabilis*)	Eastern and southern false wireworm, true wireworm (*Agrypnus variabilis*)	Eastern, southern and striate false wireworm. Protection from true wireworm (*Agrypnus variabilis*)

* Check water rates on the label as they may vary.

** Only available to accredited applicators. Price is included in seed costs.

\# Major products readily available in NSW. Other trade names may also be available.s

\## Prices quoted are GST inclusive at January 2011 and approximate only. Prices will vary depending on product, pack size purchased, seed treatment services i.e. imidaclorprid + fluquinconazole, and special marketing arrangements.

Caution: Observe stock witholding periods on crops produced from treated seed.

3.2 Time of sowing

Sunflower is adapted to a wide range of sowing times. Sowing times are grouped into an early and a late sowing window. Aim to sow at the times shown in Table 2. [2] Sunflowers have distinct advantages, with the opportunity to plant in two sowing windows. The early plant enables sowing of a percentage of the summer crop before the main sowing window opens. Conversely, the late planting window allows double-cropping in favourable seasons and the ability to plant after other summer-crop sowing windows have closed. [3]

The early sowing or spring planting window commences in mid–late August in areas north of Gunnedah, NSW and closes at the end of October. In the southern parts of the northern region, early planting generally commences in October and extends through to November. The late planting window begins at the start of December and finishes at the end of January, except in the Central Highlands, where late planting continues through to the end of February. [4] In southern Queensland the early and late plant windows are often similar to Moree, NSW and Goondiwindi, Queensland. [5]

Sowing time will always be a compromise. The early planting window risks frost and low soil temperatures during establishment and heat during flowering and seed-fill. The late planting window often experiences extreme temperatures during establishment, whereas sowing after the end of January increases the risk of disease.

MORE INFORMATION

NSW DPI Management Guide. Summer crop production guide. Sunflower.

GRDC. Raising the bar with better sunflower agronomy – Sunflower case studies and demonstration site activities.

https://bettersunflowers.com.au/

https://bettersunflowers.com.au/documents/access/docs.ashx?id=110

http://search.informit.com.au/documentSummary;dn=536835516534021;res=IELHSS

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3905943/

http://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Thompson_PhomopsisStemCancer_edited_paper.pdf

2 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

3 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

4 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

5 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Agronomy including Irrigation Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=5

This applies to diseases such as *Sclerotinia* and powdery mildew, which are favoured by rain, cool temperatures and/or high humidity. The risk of frost damage and slow crop dry-down is also exacerbated for late plantings. Sowing time also influences water use, with crops sown later in the spring using more water because of the summer heat. [6]

Sunflowers are tolerant of light frosts in the early and late stages of growth, and of high temperatures, except during the critical stages of flowering and seed-fill.

For early sowings, the soil temperature at 10 cm depth should exceed 10–12°C at 08:00 (8.00 am) Eastern Standard Time and the period of heavy frosts should be finished. While 10°C is the minimum, it is important to plant on rising soil temperatures.

Sunflower establishment will be best when 7–10 days of favourable growing conditions immediately follow planting. Extremes of heat or cold may result in patchy plant stands.

Monounsaturated sunflowers (>85% oleic acid) are preferred for spring sowings, as high temperatures during seed-fill have a relatively small effect on the oleic acid content.

Polyunsaturated sunflowers (>62% linoleic acid) are best suited to the late planting window (December–January) so that crops are filling seed in the cooler autumn months. If sowing is in spring, the oil quality of polyunsaturated hybrids is significantly reduced, as the high temperatures during seed-filling often cause the linoleic acid levels to fall below the 62% minimum required for margarine production.

Sowing after mid–late January in cooler areas such as the southern Liverpool Plains increases the risk of reduced yields from Sclerotinia stem and head rot, which are favoured by autumn rain. Late planting also increases the risk of frost damage and slows grain dry-down. [7]

MORE INFORMATION

https://bettersunflowers.com.au/documents/access/docs.ashx?id=127

Table 2: *Suggested sowing times for sunflowers.*

	Early plant												**Late plant**														
Region	**Aug**				**Sep**				**Oct**				**Nov**				**Dec**				**Jan**				**Feb**	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Goondiwindi, Moree, Narrabri	>	>	●	●	●	●	●	●	<	<							>	>	●	●	●	●	●	●	<	<
Gunnedah, Quirindi					>	>	●	●	●	●	●						>	>	●	●	●	●	●	<	<	
Southern irrigation areas										>	>	●	●	●	●	●	●	●	<	<						

> Earlier than ideal; ● optimum sowing time; < later than ideal

3.3 Targeted plant population

Establishment of a uniform plant stand of adequate density is a critical first step to a successful crop. Precision planters place seed more accurately than air seeders. This usually results in better and more even establishment within the row, resulting in more uniform head size, stalk size and soil water use across a paddock.

Aim for a suitable plant population based on the depth of wet soil at sowing, the likely in-crop rainfall and growing conditions in your area, as shown in Table 3.

6 L Serafin, S Belfield (2008) Sunflower production guidelines for the Northern Grains Region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

7 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

Table 3: *Guide to target plant population (no. of plants/m²).*

	Polyunsaturated/ Monounsaturated	Confectionery/ Birdseed
Dryland		
Marginal	2–2.5	2
Favourable	2.5–3.5	2.5–3.5
Irrigation		
Limited	3.5–5.0	3.0–4.0
Full	5.0–7.0	3.5–4.5

Seed for sowing averages 15,000 seeds/kg but can vary from 10,000 to 22,000 seeds/kg, depending on seed size (Table 4). Always check the seed count on the bag. The minimum germination percentage is usually >90% but check the percentage on the bag or consult seed merchants. [8]

Table 4: *Approximate numbers of seeds per kg.*

ASA seed sizes	Description	Seeds/kg
6/7	Very small seed	18000–25000
7/8	Small seed	15000–22000
8/10	Medium seed	12000–16000
10/14	Large seed	10000–14000
14/18	Very large seed	8000–11000

Small (7/8) and medium seed (8/10) is preferred for the spring planting, as smaller seed generally establishes better in cooler conditions. Medium and large seed (10/14) should be used in warmer conditions or when planting deeper into moisture. Larger seed is more suited to precision planters because smaller, lighter seed may result in doubles in one hole of the planter plate. [9]

Established plant population has a large effect on several factors, including yield. Establishing more plants than suggested in Table 5 risks lower yields, as head sizes are smaller and there is more competition for water.

The 'Sunflowers in Northern NSW and Southern Qld—Tools for Success' benchmarking study showed that excessively low plant populations lead to thick stalks, which damage machinery and limit potential yield. Measured plant populations varied greatly across the three regions as shown in Table 6, and plant populations were often much higher than the recommended or targeted population. [10]

Table 5: *Dryland plant population guide.*

Region	Target plant population ('000/ha)
Moree	25–30
Gunnedah	25–35
Southern Queensland	25–35

8 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

9 L Serafin, D McCaffery, S Thompson DPI (2011) Sunflower. Summer crop production guide. pp. 74–86. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

10 GRDC (2009) Raising the bar with better sunflower agronomy – Sunflower case studies and demonstration site activities, https://grdc.com.au/~/media/8e74986cc5de4f1c868713cdb0d643ec.pdf

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GRDC (2009) Raising the bar with better sunflower agronomy—Sunflower case studies and demonstration site activities.

p. 5. Better Sunflowers Demonstration Site Results—The effect of row spacing and plant population on the yield and quality of dryland sunflowers, Moree, NSW.

p. 7. Better Sunflowers Demonstration Site Results—Plant population and row configuration in dryland sunflowers on the Liverpool Plains, NSW.

Table 6: *Measured plant populations, 2003–06.*

Region	Average plant population (/ha)	Plant population range (/ha)
Moree	32,672	16,000–59,000
Gunnedah	38,867	23,000–60,000
Southern Queensland	34,415	20,000–54,667

Sowing rates should be calculated to target optimal populations for each region. Sunflower seed has the germination percentage and the number of seeds per kg marked on each bag. Check the testing date for currency. It is also advisable to plant with treated seed to protect against seedling pests and diseases. [11] There can be subtle differences in population requirements of some hybrids. Check recommendations with your seed supplier or seed company representative.

3.4 Calculating seed requirements

When calculating seed requirements, allow on average 25% for establishment losses. Depending on planting conditions and machinery, losses can range from 10 to 50%. However, you may be guided by experience when assigning a value for establishment losses.

Seed size can also affect established populations as very small seed may allow doubles or triples to be planted in each hole. [12]

Calculating a planting rate (kg/ha), using seeds/kg from Table 4:
(Target plant population/ha × 10,000) ÷ [(seeds/kg × germination% × (100 – establishment loss%)]

Example calculation:
(35,000 × 10,000) ÷ (15,000 × 93 × (100 – 25) = 3.35 kg/ha

To determine the number of bags of seed required:
[Planting rate (kg/ha) × area (ha)] ÷ bag weight (kg)

3.5 Sowing depth

Sowing depth is dictated largely by available moisture, the planter and the soil type. Sowing depth may range from 2.5 to 7 cm, but most commonly is 3–5 cm. [13]

Sunflowers are highly suited to no-tillage, with 68% of paddocks included in this study sown into no-tillage situations. Smaller proportions had minimum-tillage (17%) and conventional tillage (15%). [14]

Row spacing

Sunflowers may be sown on row spacing ranging from 36 to 100 cm. Row spacings of 75–100 cm allow inter-row cultivation or shielded spraying as additional weed control options. In the Gunnedah and Quirindi areas, the most common row spacing is 75 cm, whereas at Moree, 100 cm row spacings are more typical.

Research at Moree has shown that sowing on 100-cm solid-plant or single-skip row spacings will achieve similar yields to 75-cm single-skip. By contrast, at Gunnedah,

11 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

12 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

13 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

14 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

sowing on 75-cm solid-plant or single-skip, or 100-cm solid-plant, will achieve similar yields.

Double-skip or wide row (150 cm) spacings, although a sound risk-management strategy, carry a yield penalty in the main sunflower-growing regions.

Single-skip row configurations are an option if there is limited stored soil moisture or when planting in marginal dryland environments (e.g. Walgett), although they usually incur a yield penalty. Weed control is more critical and hybrid height should be considered to avoid lodging. [15]

3.6 Sowing equipment

Press-wheels are essential for obtaining good seed–soil contact. Press-wheel selection is also important to ensure that cracking of soil down the seed row does not occur. Where this occurs, seedbeds dry out too quickly, resulting in variable establishment. [16]

The use of precision planters with press-wheels will provide more even and uniform crop establishment, which is why 72% of crops in the 2008 benchmarking study 'Sunflowers in Northern NSW and Southern Qld—Tools for Success' were established by this method. [17]

A press-wheel pressure of 2–4 kg/cm width (of press-wheel) is recommended. Use the greater pressure when sowing moisture is marginal, but be careful about over-pressing the seed and trench, as damage to the seed may result or the trench may become compacted and emergence will be reduced. [18]

Airseeders can be used to sow sunflowers; however, seed placement is highly variable, resulting in uneven plant stands, which are less efficient at utilising moisture, sunlight and nutrients. Stands with gaps allow weeds to establish and create variable maturity within the crop. [19]

Expect an 80% emergence with a row crop planter and 70% for an airseeder equipped with press-wheels, provided planting conditions are favourable and soil insect activity low. [20]

Disc or tyned seeders are suitable for crop establishment but have different applications depending on sowing conditions. Tynes enable moisture seeking (if good quality seed is used) but cause more soil disturbance, leaving a wider seed slot, which results in more rapid moisture loss in the seed furrow than a disc.

Discs cause less disturbance in the seed row and result in the best establishment under ideal conditions; however, their performance will be suboptimal in extremely wet (smearing) or dry (depth-limited) conditions. [21] A seed slot that has cracked open is a real issue, and can be alleviated by using closing harrows or a chain to cover the trench with loose soil, slowing drying out of the trench or row.

MORE INFORMATION

GRDC (2009) Raising the bar with better sunflower agronomy—Sunflower case studies and demonstration site activities.

p. 5. Better Sunflowers Demonstration Site Results—The effect of row spacing and plant population on the yield and quality of dryland sunflowers, Moree, NSW.

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18 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

19 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

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Plant growth and physiology

4.1 Plant growth stages

The time taken for a sunflower plant to develop through the various growth stages is affected by planting time, temperature, photoperiod and soil moisture. Sowing location and hybrid maturity also affect the length of the growing season. Table 1 shows the sunflower growth and development definitions. [1]

Table 1: *Sunflower growth and development definitions.* [2]

Stage		Description
VE	Vegetative Emergence	Seedling has emerged and the first leaf beyond the cotyledons is less than 4 cm long.
V (number) (i.e.) V-1 V-2 V-3 etc.	Vegetative Stages	These are determined by counting the number of true leaves at least 4 cm in length beginning as V-1, V-2, V-3, V-4, etc. If senescence of the lower leaves has occurred, count leaf scars (excluding those where the cotyledons were attached) to determine the proper stage.
R-1	Reproductive Stages	The terminal bud forms a miniature floral head rather than a cluster of leaves. When viewed from directly above, the immature bracts form a many-pointed star-like appearance.
R-2		The immature bud elongates 0.5 to 2.0 cm above the nearest leaf attached to the stem. Disregard leaves attached directly to the back of the bud.
R-3		The immature bud elongates more than 2.0 cm above the nearest leaf.
R-4		The inflorescence begins to open. When viewed from directly above immature ray flowers are visible
R-5 (decimal) (i.e.) R-5.1 R-5.2.,R-5.3 Etc.		This stage is the beginning of flowering. The stage can be divided into sub stages dependent upon the percent of the head area (disk flowers) that has completed or is in flowering Eg. R-5.3 (30%), R-5.8 (80%) etc.
R-6		Flowering is complete and the ray flowers are wilting.
R-7		The back of the head has started to turn a pale yellow colour.
R-8		The back of the head is yellow but the bracts remain green.
R-9		The bracts become yellow and brown. This stage is regarded as physiological maturity.

1 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

2 AA Schneiter, JF Miller (1981) Description of sunflower growth stages. Crop Science 21, 901–903.

4.2 Key development stages of sunflower

The time taken for a sunflower plant to develop through the growth stages from planting to maturity is affected by planting time, temperature, day length, nutrition and moisture. Geographic location and hybrid maturity also have an effect on the length of the growing season. [3]

The following sections outline the various stages of sunflower development.

4.2.1 Germination and emergence

The time taken for germination and emergence of a sunflower seedling is variable, but usually takes between 5 and 10 days, however it may be up to 30 days in certain situations. The speed of germination is dependent on three factors; soil temperature, moisture and oxygen.

The preferred soil temperatures for planting sunflower are 10–12°C. However germination will occur as low as 4°C. Planting into cold soil temperatures means it takes longer for germination and establishment and, as a result, the risk of insect damage or disease is also higher. Planting into warmer soil temperatures results in faster emergence but soil moisture around the seed will decline faster. As long as the establishment has not been affected no yield loss should occur from plants germinating at soil temperatures as low as 7°C.

Sunflowers have epigeal emergence, meaning their cotyledons are pulled rather than pushed through the soil with the seed coat intact and only, once the above ground, does the seed coat then fall off to expose the cotyledons. [4]

4.2.2 Development of the root system

Initially the rate of development of the plant root is greater than the rate of development of the sunflower stem. As an example, when the plant has 8–10 leaves (~25 cm to 30 cm tall) the taproot is about 40 cm to 50 cm deep. The taproot reaches its maximum depth at flowering.

This taproot allows sunflowers to extract more water than wheat or maize and to extract moisture and nutrients from deep in the soil profile. While sunflowers have a primarily tap root system they also develop strong lateral roots in the surface soil area around the top 10–30 cm of the soil which may extend up to 60–150 cm beyond the taproot. (Warmington 1981).

The size of the root system is also an indicator of the crop with a positive relationship between root surface area, leaf surface area and photosynthetic productivity being well documented. [5]

4.2.3 Vegetative growth

Sunflowers can tolerate temperatures ranging from 8°C to 34°C during their growth phase but grow best between 25°C to 28°C, although there is very little difference in growth rates between 18 to 33°C.

Leaves initially develop in pairs (opposite) and then emerge as singular alternate leaves up the stem, until the final number of leaves is reached. The change in leaf arrangement is gradual and the point at which the distinction occurs is not always clear, resulting in a margin for error. The point at which the change occurs may vary from plant to plant, within a given hybrid grown under similar environmental conditions (Schneiter & Miller 1981). Final leaf number may vary from between 20 to 40 leaves in most hybrids.

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3 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

4 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

5 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

Leaf formation and development is initially controlled by sunlight and is influenced by hybrid, day length and crop nutrition. Photosynthesis, which is the driver of plant growth, is the process of converting inorganic material into organic material to create sugars for the plant to grow. Plants take in carbon dioxide (CO_2) through their leaves, water through the roots and use chlorophyll (the green in leaves) and sunlight to produce oxygen and sugars. Chlorophyll traps the solar energy in the leaf and through a series of biochemical pathways, the end result is oxygen, released out through the stomates; and sugars, which are further converted to carbohydrate used as plant food for growth and development (Abbott, 2003).

Sunflowers accumulate significant dry matter through the mass of their leaves, with the greatest accumulation being between budding and flowering (Dusanic, 2008).

Ralph (1982) measured that each individual leaf reaches its peak photosynthesis between 10–14 days after emergence and then goes into a slow decline, so that after 40 days photosynthetic capacity has fallen to only 25% of the maximum potential.

In the vegetative stage of growth, most assimilates produced in the leaves are transported towards the root system, which develops intensively during this stage. However, once bud initiation occurs the plant is triggered to invert the main direction of assimilate transportation and direct it towards the top of the plant (Merrien, 1986).

A sunflower plant can have a very large leaf surface area, documented to reach between 2,000–6,000 cm^2 depending on the growing conditions, namely moisture and nutrition. A plant develops about 50% of its total leaf area by the start of head development and more than 75% by the start of flowering (Warmington, 1981). The retention of leaves is important as a reduction in the photosynthetic area means a reduction in the amount of photosynthate available to the growing seed. Lower photosynthate levels generally mean lower yields.

Younger leaves, which are higher up the plant, have better access to light and there is also an age relationship to photosynthetic capacity. As such, bottom leaves, which senesce earlier are thought to have less impact, when compared to the middle and top leaves.

The middle and top leaves make greater contributions to yield, along with the head. However there is still a direct relationship between total leaf area and yield.

The largest leaves, usually between the 4th and 10th pairs, are said to account for between 60–80% of the total leaf area and play the most important role in seed and oil development (Warmington, 1981). These middle leaves provide nutrients to support the top leaves and the flowering head.

Sunflower leaves are unique in their ability to respond to stress, in particular moisture stress. Plants will commonly wilt in the middle of the day as sunflower leaves do not have the ability to close their stomates to reduce evapo-transpiration losses at night. Many plant species are able to regulate stomatal behaviour at night particularly in response to limited soil nutrient conditions. However is appears sunflower is not able to do this, which is a disadvantage in terms of higher crop water use, but an advantage in relation to nutrient uptake into the plant and continued plant growth (Howard & Donovan, 2006)

A crop simulation model developed in France has suggested that stomatal regulation had the greatest influence on grain yield in sunflower. Late maturation and a high leaf area index also increased grain yield but not to the same extent. In this study, the ability to close the stomates early (as opposed to late) could result in increasing potential yield in drought prone environments (Casadebaig and Debaeke, 2008). In the more reliable production zones, longer maturing, large leaf area with late stomatal closure hybrids may result in the best yield.

Few studies and information is available on the exact contribution of individual leaves to yield. Most studies have instead focused on the impact of defoliation at various growth stages. Johnson (1972) showed that the middle leaves had a greater role in seed yield than leaves in other parts of the plant, mostly thought to be as a result of the greater photosynthetic capacity of these leaves.While leaf area is a major part of the vegetative stage in sunflower growth, the stem of a sunflower plant also plays an important role. The stem is normally straight and comprised of a thick, pith filled centre with rough hairs on the outside.

Defoliation

Knowing which leaves contribute to maximum yield and oil content helps inform decisions around disease, pest and general crop management. Defoliation has been shown to impact:

- yield
- oil content
- number of seeds filled
- hull:kernel ratio

The key questions for industry are: which leaves should be protected; and what is their contribution to final yield and oil content. [6]

NSW DPI researchers conducted three trials over the 2014–15 and 2015–16 seasons. Each treatment involved physically cutting leaves off the sunflower plants, leaving the leaf petiole intact; and measurement of plant structures, final grain yield and oil content. Researchers found that:

- yield was reduced by 76–93% if all leaves were removed
- removing the top one third of leaves had the least impact on yield
- greatest impact on yield was from total leaf removal at R2, R5 and R6
- a reduction in oil content of 5–6% occurred when all leaves were removed at R5 or R6. [7]

Leaf removal at various stages during sunflower growth have been conducted by several overseas researchers and typically conclude that the most sensitive stage is during flowering and seed fill, however, others suggested the stages of R1 through to R6 are most important.

Muro et al. (2001) suggested R3 to be the most critical of all of the stages, as shown in Figure 1. In this series of experiments portions of the total leaf area were removed by cutting with a blade, hence part of each of the leaves of the plant were removed to achieve either 33, 66 or 100% leaf defoliation. Interestingly there was little impact of removing 33% of the total leaf area. However removing 66 and 100% had major impacts on all three measured components.

Muro also utilised his own work and the work of several colleagues to produce a series of graphics showing the effect of stage of growth and % leaf loss (Figure 2). This figure shows clearly the major impact on yield which can be caused by defoliation of greater than 33% leaf area in growth stages R2 through to R7. As expected by growth stage R9 (physiological maturity) there is minimal impact on yield by even total leaf loss. [8]

6 L Serafin, M Hellyar, B Brennan, P Perfrement (2016) Sunflower: what is the cost of losing your leaves? Australian Summer Grains Conference 2016, http://yrd.com.au/ASG16 Program_Presentations V5.pdf

7 L Serafin, M Hellyar, B Brennan, P Perfrement (2016) Sunflower: what is the cost of losing your leaves? Australian Summer Grains Conference 2016, http://yrd.com.au/ASG16 Program_Presentations V5.pdf

8 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

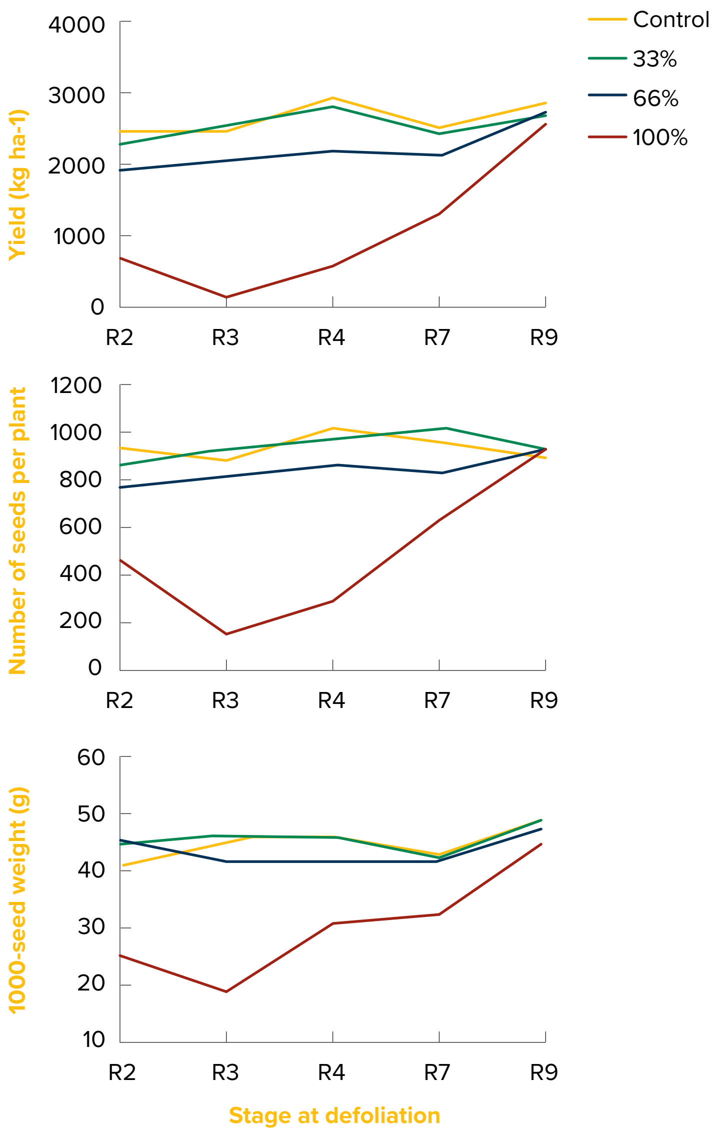

Figure 1: *Effect of defoliation on sunflower yield, number of seeds per plant and 1000 seed weight.*

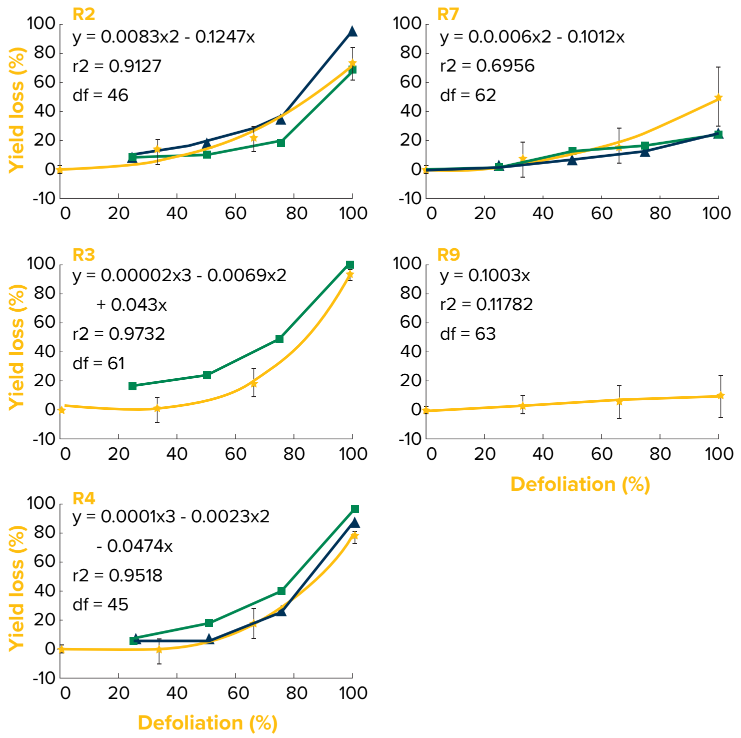

Figure 2: *Regression functions between yield loss (%) and defoliation level for each phenological stage. Measured mean yield losses (star) with standard deviations, and results published by Schneiter et al. (1987, square) and De Beer (1983, triangle) are shown.*

The sunflower stem may grow as tall as 220 cm but, when under drought stress, stems may be as short as 50–60 cm. There should only be one stem on a sunflower plant. Sunflowers have been selected to have only one stem as there is a negative correlation between the number of stems and yield.

Both the stem and the leaves combine to have an impact on final yield, taller plants with higher total leaf areas being positively correlated with seed yield. In contrast, the total number of leaves per plant has a negative impact on seed yield. (Hladni et al. 2004). Research by Habib et al. (2006) demonstrated that stem diameter is positively genetically correlated with 100 seed weight, seeds per plant and seed yield. However stem diameter:stem length ratio were not correlated. Further trials in Pakistan found that sunflowers with increased stem diameter, produced plants that were less prone to lodging due to stouter, shorter plants and produced larger heads with larger seeds, culminating in higher grain yields (Khokhar et al. 2006). [9]

9 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

4.2.4 Bud initiation

Once bud initiation starts, no more leaves will develop, but the leaves will continue to unfold.

The plant will begin developing the bud, during this time each of the disc florets in the bud will be fully differentiated. This process will be completed by around 2 weeks prior to the start of flowering. During this time of bud formation any stress can cause floret abortion, which is often visible in large numbers in the centre of the head as missing seeds.

The total potential number of seeds is determined by the number of florets which are initiated between 20 to 40 days after sowing (Steer and Hocking, 1984). The final number of florets is dependent on the number of florets in each ring which forms in the head and the number of rings.

The bud will continue to grow in diameter until the ray petals become evident. At this stage the bud is usually at least 10 cm in diameter. The ray petals, which are the bright yellow petals which surround the head, will then begin to unfold prior to the commencement of flowering.

Sunflowers turn to follow the sun during the day, referred to as heliotropism, which increases photosynthesis by 9%. This will cease at flowering, when, at this point most of the heads will remain facing north-east. The movement is caused by a bending of the stem and a lifting and lowering of the leaves on the opposite sides of the plant. [10]

4.2.5 Flowering

Sunflowers have a compound head which consists of two types of flowers; the ray flowers and the disc flowers. Once these are evident, flowering has commenced (Figure 3).

The yellow ray petals have a minimal role but are highly attractive to bees and other insects. Ray flowers usually occur in two rows and are sterile. Usually there are between 30 to 70 ray flowers per head, also known as petals.

Figure 3: *Ray petals opening; once the sunflower ray petals are fully open, flowering will commence.*

Photo: Drew Penberthy

The disc flowers which form the centre of the head are the start of developing seeds. The disc flowers progressively open in concentric rings, beginning from the outside

10 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

and working towards the centre. Individual disc flowers complete flowering in 3 days. Commencing early in the morning, typically from 6–8 am the disc flowers open and the anthers are exerted and the pollen is released. Between 1 and 4 rings of flowers open each day, usually over a period of 5 to 10 days. There are between 800 and 3,000 disc flowers per head and between 30 to 50 concentric rows of disc flowers. Each disc flower is capable of producing a seed.

If the disc floret is fertilised, then a seed which will comprise the hull and the kernel, starts to develop If the floret is not fertilised, then a hull may begin to form but the kernel will be absent, resulting in empty hulls at harvest.

Sunflower pollen is fairly large, yellow and oval in shape, with a prickly appearance which allows it to be transported by insects. Sunflower pollen is generally not moved about by wind.

Currently most hybrids are generally largely self-pollinating, however numerous bees usually forage in the crop during flowering. In commercial hybrids all plants produce pollen.

In a hybrid seed production field, two lines are used. A female or A line which does not produce pollen and a male or R (restorer) line which does produce pollen. In this process the synchronisation of flowering between the two lines, favourable environmental conditions and importantly insects to transfer the pollen are all critically important to ensure seed fertilisation and production.

The introduction of hybrid sunflowers was made possible by the discovery in 1968 of cytoplasmic male sterility by a french scientist, Le Clerq. In 1972 using this technology Pacific Seeds released the first hybrid sunflower in Australia, Hysun 30. Hybrids brought significant advances in yield, oil content, disease resistance and plant uniformity to the industry.

At the completion of flowering, the ray petals wilt and fall off, which is referred to as petal drop. The disc flowers will fall off just prior to physiological maturity.

Head type becomes more important at this stage as those which remain upright after the end of flowering are more prone to sunburn. Many commercial varieties have semi-pendulous heads to avoid this.

There are several factors which can impact on pollination and subsequent fertilisation. These can include rain which may wash the pollen off the head, cool weather to the point of near freezing, particularly when the plants are not conditioned to these colder temperatures, drought stress and high temperatures.

Typically drought or moistures stress is most commonly seen as the centre seeds in the head not filling. Whereas the effects of wet or cold weather will often appear as empty hulls in various rings of the head depending on the location of the flowering disc flowers in relation to the impacting event.

Sunflowers will adequately compensate for small reductions in seed set but increasing seed size of neighbouring seeds.

The combination of high temperatures and moisture stress can drastically reduce yields and oil contents during flowering and seed fill. Conversely, frost at flowering will also damage the flowers and reduce seed set. Heads will commonly turn a purple black colour and die if severely affected.

It is important to note that hulls may continue to form and grow to full size even when fertilisation has not occurred, but upon closer inspection these will be found to be empty, i.e. no kernel will be present.

Anecdotal observations have suggested that it is normal for up to 20% of seeds to not be fertilised under normal conditions in a sunflower head, but these are typically not noticed as surrounding seeds fill to compensate for this area in the head. [11]

11 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

4.2.6 Seed filling

The seed is borne in the capitulum or head. Each disc flower has the potential to produce one seed, if fertilised. Each sunflower seed is comprised of a hull (pericarp), true seed coat and a kernel (mainly embryo). Usually the hull averages between 20–26% of the total seed mass.

Figure 4 outlines the development of the sunflower seed (or achene) as determined in work conducted by Mantese et al. (2006). The growth patterns of achene components (pericarp, embryo, oil) were broadly similar across three cultivars of sunflower, with the pericarp growing first and rapid increases of embryo and oil mass taking place later. The pericarp stops growing before the embryo and oil components reached their maximum values. As such, seed development can be split into two stages:

1. Hull (pericarp) development – which typically stops developing 14 days after anthesis.
2. Kernel development – which starts around 8 days after anthesis and is approximately 1/3 of its final weight when the hull development ceases.

The formation of oil in the embryo begins several days after the start of the embryo development. As a result very little oil is deposited during the first third of the seed filling period.

The final oil content also has an interesting relationship with the ability to dehull seed. Seeds with higher oil content are usually more difficult to dehull. Hectolitre weight is also often an indication of ease of dehulling. Seeds with a hectolitre weight above 40 kg/hl are more difficult to dehull.

Head diameter is also often a useful indicator of the likely grain yield. White (1980) described that an ideal head diameter was considered to be in the range of 16–22 cm, as smaller head sizes are usually indicative of a lower seed number per head or poor centre seed fill which cannot be fully compensated by higher plant populations. In contrast, large heads were usually found on plants with excessive leaf areas, fleshy backs of the head and often associated with slow drydown, large seeds with thick hulls and a reduced concentration of seeds per unit area of the head.

Hladni et al. (2008) found that seed yield was most positively correlated with thousand seed weight, total seed number, head diameter and leaf area. The number of seeds present in a head is also usually positively correlated with oil content (White 1980). However, White also demonstrated that oil content is usually negatively correlated with seed yield, 1000 grain weight and head diameter. [12]

12 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

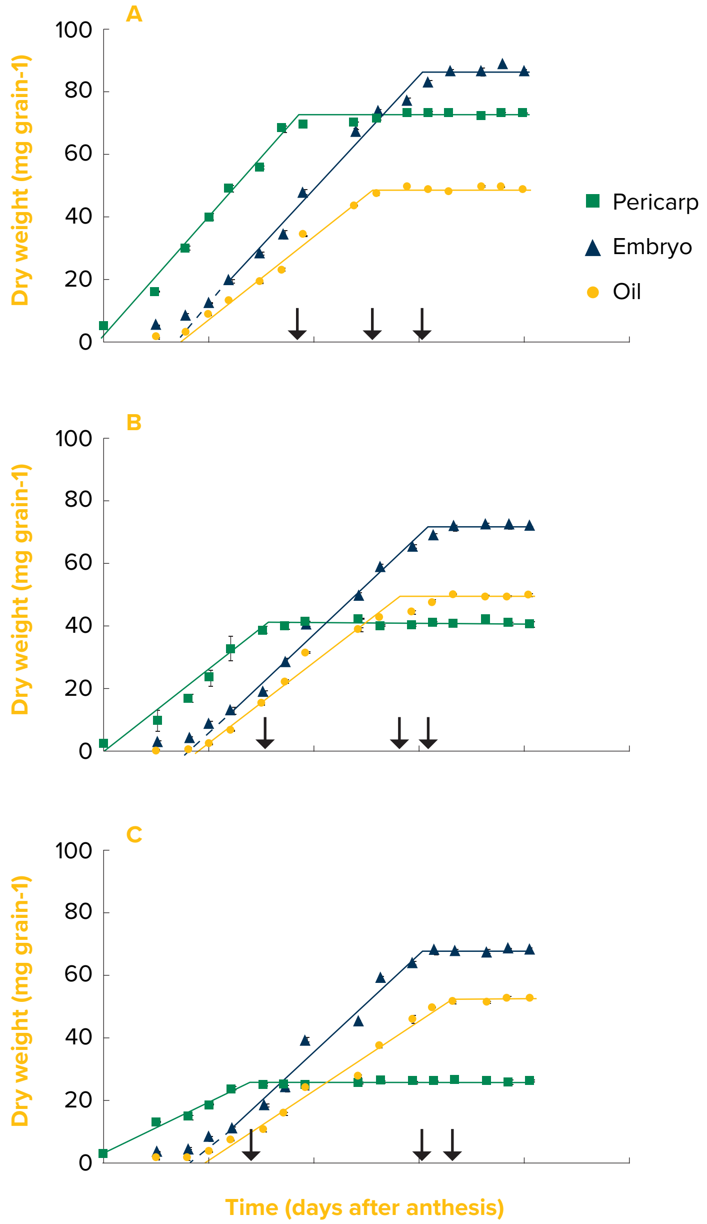

Figure 4: *Dynamics of pericarp, embryo and oil weights per achene for three sunflower cultivars 'Dakar' (A), '11051' (B) and 'Prosol 35' (C). Each point represents the mean of three replicates, vertical bars are ± 1 s.e. The continuous lines show the adjusted bi- linear functions (r2 range 0·89–0·99) and the dashed lines show the extrapolations used to estimate the start of the effective filling. The arrows indicate the end of the oil growth periods for the three achene components. (Mantese, Medan and Hall, 2006).*

4.2.7 Physiological maturity

Physiological maturity signifies when the maximum seed weight has been reached. The crop can then be harvested at any time. However, sufficient dry down needs to occur to reach a moisture content suitable for storage or delivery.

Heads reach physiological maturity approximately 30 days after anthesis, hence seeds on the inner part of the head have a shorter length of time for seed filling and also a lower rate of filling than the outside seeds. As a result, seed size decreases progressively from the outside of the head moving in towards the centre.

In early developmental stages, the receptacle and capitulum are a strong green colour, which is strongly related to the high concentration of chlorophyll in their tissues. As the plant matures, chlorophyll degradation, and the predominance of xanthophylls and other carotenoid pigments are the reason for the colour changing from green to yellow and eventually to brown (Hernandez, 2008). Sunflowers reach physiological maturity when the bracts (termed phyllaries) around the outside of the sunflower head turn brown and brittle and the receptacle base becomes a buttery yellow (Hernandez et al. 2008). This is usually 4 to 6 weeks after flowering.

At this point the sunflower seeds have completed filling and their moisture content is approximately 38% (Rondanini, 2007). It is at this time (30 days after flowering) that maximum dry matter content is usually observed (Dusanic, 2008). From physiological maturity to harvest, the sunflower plant and seeds lose moisture (dry down). Physiological maturity is the appropriate time to apply a desiccant if using one to aid in crop dry down. [13]

4.2.8 Crop desiccation

Crop desiccation is not a common practice in sunflowers. However, it has been used in some seasons to speed up or even out maturity of a crop. Desiccation of a sunflower crop should only commence once the crop has reached physiological maturity. A sunflower plant has reached physiological maturity when the bracts surrounding the head have turned brown. At this point the seed should be mature and the moisture content around 35%. Research in Serbia has shown that the accumulation of protein in sunflower hybrid varies between genotypes, however maximum protein content is reached approximately 21 days after flowering when moisture content is about 45% (Canak et al. 2011). Desiccation after this stage would not affect protein levels in the grain which are important for germination and early seedling growth. [14]

Refer to the weed control section for additional information on crop desiccation.

4.3 Sunflower phenology

Days to critical growth stages, such as flowering, for several commercial sunflower hybrids have been recorded in northern NSW. This information assists in matching hybrid maturity to sowing time.

The exact number of days required to reach specific growth stages can vary depending on temperature, day length, moisture and hybrid, so Tables 2 and 3 should only be used as a guide. The accumulation of growing degree days (GDD), also known as day degrees (DD), can also be used to predict phenological changes in crops and help plan in crop operations. See Table 4 for more information. Day degrees are calculated by taking the mean daily temperature and subtracting the base temperature of 6.7°C for sunflower. Each growing season day is added together cumulatively to give DD at particular growth stages of the crop, as each plant growth stage has defined heat units it must reach to proceed to the next stage.

The critical time for heat stress is 12–15 days after flowering on a spring plant. It is recommended to try and choose hybrid maturity so that it can be matched to avoid these high risk periods. [15]

13 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

14 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

15 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

Table 2: *Development times for a sunflower hybrid at Gunnedah when planted in early October and late December.*

Crop stage	Time for each stage (days) when planting in:	
	Early October	Late December
Planting to emergence	8	4
Emergence to head visible	45	37
Head visible to start of flowering	27	24
Flowering to physiological maturity (PM)	40	42
Stage length		
Planting to start of flowering	80	65
Planting to PM; – slow maturity hybrid – medium maturity hybrid	 120 110	 100 107
PM to harvest	20–30	30–40

Source: NSW DPI, Sunflower Agfact

Table 3: *Days to critical growth stages of various sunflower hybrids.*

Hybrid	Region	Days to 4 cm bud	Days to mid flower	Days to petal drop
Hyoleic 41	Moree	74	86	101
	Gunnedah – Early	78	n.d.	n.d.
Ausigold 61	Moree	71	84	109
	Gunnedah – Early	75	90	n.d.
	Gunnedah – Late	n.d.	74	82
Ausigold 62	Moree	71	83	95
	Gunnedah – Early	73	90	n.d.
	Gunnedah – Late	n.d.	70	78
Sunoleic 06	Moree	71	84	97
	Gunnedah – Early	75	92	n.d.
	Gunnedah – Late	n.d.	67	78
Sunbird 7	Moree	65	83	109
	Gunnedah – Early	72	n.d.	n.d.
Hysun 39	Moree	70	82	100
	Gunnedah – Early	76	90	n.d.
	Gunnedah – Late	n.d.	70	n.d.
Advantage	Moree	72	87	97
	Gunnedah– Early	76	n.d.	n.d.
	Gunnedah – Late	n.d.	69	n.d.
Ausigold 4	Moree	72	84	109
	Gunnedah– Early	74	90	n.d.
	Gunnedah – Late	n.d.	67	n.d.

Source: Belfield and Serafin, pers. comm.

Table 4: *Cumulative day degrees for sunflower.*

Growth Stage	Description	GDD °C
Emergence	Cotyledons completely unfolded	138–191
Leaf stages	2 leaves unfolded	249–313
	4 leaves unfolded	359–435
	6 leaves unfolded	470–558
Flowering	Flowering begins. At least one open disc floret on 50% or more plants	935–1077
	Flowering 50% complete	1081–1232
Seed fill	Seed fill begins. 10% of seeds have reached final size	1255–1417
Maturity	Seeds begin to mature. 10% of seed has changed colour	1547–1725
Maturity complete	90% seed has changed colour. Await completion of dry down for direct heading.	1780–1972

Source: Miller, Lanier and Brandt, 2001

4.4 Drivers of growth and development

4.4.1 Genetic

Genotype has a major impact on the yield and oil content of hybrids. It is the foremost factor in influencing fatty acid composition of sunflower oil (Knowles 1988). However, oil content is ultimately highly varied by environmental factors during seed filling, as is the composition of unsaturated fatty acids (linoleic/oleic acid) (Petcu et al. 2001). Over time, Australian sunflower breeders have worked towards releasing hybrids with higher oil contents through using conventional breeding. Certainly one of the major advances in yield were achieved when hybrid sunflowers became commercially available in the early 1970s as opposed to the traditional open pollinated types.

Radford (1977) commented that sunflowers with large achenes exhibit a slightly higher germination percentage and greater mean hypocotyl length than small achenes, which resulted in higher field emergence percentages when sown below 6 cm. However, the size of achenes had no effect on final yield. [16]

4.4.2 Environment

The environment can have a major impact on sunflower growth and development. Flowering time, for example can be increased by up to 15 days due to day length. Shading can also have an impact by reducing leaf area and crop height. More importantly shading from bud initiation onwards can reduce seed and oil production by as much as 60% (Warmington, 1981). Several of the major environmental factors influencing sunflower growth and development are discussed below.

Day length

Sunflower development is affected by day length with the plants moving through growth stages quicker when days are longer. Sunflower development can be affected by day length in the emergence to bud visible stages, but hybrids vary in their response. See the phenology section for information on hybrid variation in response to day length.

Sunflowers have the ability to orientate their leaves towards the sun so carbon dioxide fixation is fairly constant (0.5 mg per sq cm per hour) during daylight hours. Hence longer days result in greater photosynthesis.

16 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

Photoperiod can affect the length of time between the start of floral initiation to the bud visible stage as well as the start and finish of floral initiation. However, some hybrids show a reverse response to photoperiod, depending on whether they have been sown in spring or summer. (Hall 2004, p 29)

Temperature

Sunflower growth is driven largely by temperature. Temperature may vary the time taken to reach physiological maturity by as much as 25–30 days.

Spring sown crops are generally growing during milder temperatures, which prolong vegetative growth, favouring production of a larger plant and thus higher yield potential. Generally spring sown sunflowers are also taller as a result.

Higher temperatures during vegetative growth will cause plant development to proceed at a faster rate. The optimum temperatures for sunflower growth are between 25–28°C. While hot temperatures (>35°C) have adverse effects, as discussed in the heat stress section of this chapter.

High oleic sunflowers are recommended to be sown in the spring as warm temperatures during grain fill are needed to produce oleic acid. Studies in controlled temperatures have shown oleic acid percentages are decreased by low night temperatures.

Conversely polyunsaturated sunflowers need to fill seed during lower temperatures to achieve linoleic acid contents above 62%. Filling during high temperatures will reduce the linoleic acid content to below these receival standards. Hence, there is an inverse relationship between temperature and linoleic acid content.

Temperature influences the length of flowering, with the duration of flowering shorter under higher temperatures. However, the range is usually 5–10 days. Temperature during flowering is critical. Excessive temperatures during flowering and seed fill affect oil quality and quantity, as well as reducing seed yield.

Maximum seed dry weight is reached approximately 650 day degrees after pollination. At pollination the moisture content of the developing seed is about 78% which declines to around 38% at physiological maturity. Oil production starts soon after pollination (detectable 3 days after). However, there is a lag of around 150 day degrees before significant oil production occurs.

Linoleic acid levels increase at a regular rate during seed development, meaning there is not one critical phase during seed fill when linoleic acid contents can be affected, but the whole period is important. Oleic acid content declines throughthe period of seed filling. [17]

17 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

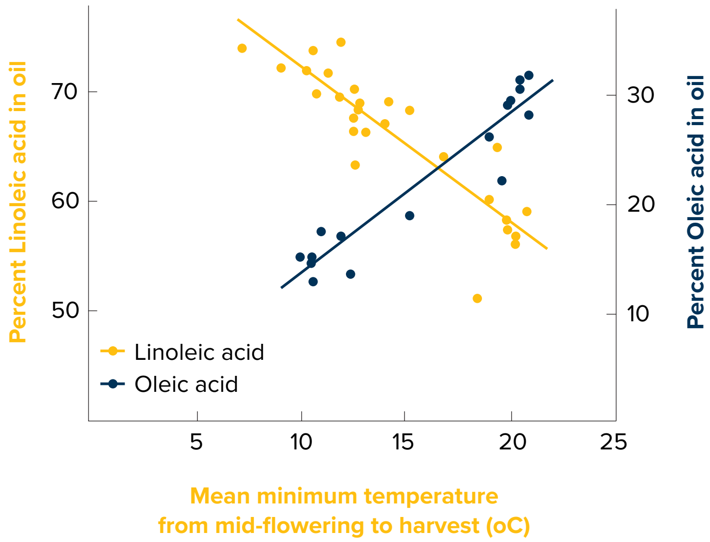

Figure 5: *Relationship between mean minimum temperature from mid flowering to harvest and the linoleic and oleic acid content of sunflower oil.*

Source: Harris, McWilliam, English and Mason, 1977.

As illustrated in Figure 5, oleic acid percentage is higher with higher night temperatures and is not related to daily minimum temperature. Night time temperatures have the greatest effect on oil quality.

Temperature can regulate the rate and duration of grain fill.

Moisture

Moisture stress can reduce yields from the late bud through to seed fill stage. Additional information on moisture and water use is contained in the water use section in the agronomy module.

Sunflowers have several mechanisms which help them respond to moisture stress. The major mechanism is that, in response to less water, the plants produce smaller leaves to conserve water. Leaves produced under water stress are often 25–35% smaller in size.

Transpiration is the process of water vapour loss from plant leaves with 90% of losses occurring from the stomata and 10% from plant cuticles. It is thought that only 1% of water taken up by plants is utilised for biochemical processe within the plant (Evans online). Each square centimetre of leaf transpires about 12 mg of water per hour, so a smaller leaf results in less water loss. In the heat of the day, 85 mg of water can be lost for the same carbon dioxide gain.

Moisture stress is important at two main growth stages, head formation to the start of flowering (which affects seed yield) and post flowering when oil content will be reduced. A study in Romania found that in 5 hybrids evaluated, under moisture stress conditions oleic acid content decreased by up to 14% and linoleic acid contents increased equivalently. However the saturated fatty acids (palmitic and stearic acid) which are a minor component of sunflower oil, were not significantly altered by water stress (Petcu et al. 2001). This decrease in oleic acid levels could be detrimental to Australian monounsaturated hybrids if moisture stress reduced content below the threshold receival standard. [18]

18 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

4.4.3 Nutrition

Crop nutrition is a key driver of sunflower growth and development. Nitrogen is the principal nutrient required as it influences leaf number and size, which relates to yield. Nitrogen has the greatest influence from 4 leaf stage onwards. However several other nutrients have important roles in crop growth and development. Information on specific nutrients is contained in the crop nutrition section in the agronomy module. [19]

4.5 Adverse effects on growth and development

There are many factors which can have an adverse effect on sunflower growth and development. These factors can influence yield by reducing the number of seeds set, the weight of each seed, the ratio of kernel to hull, as well as influencing oil content and quality. Several of these factors are discussed below.

4.5.1 Frost

Sunflowers are reasonably tolerant of frost at certain stages. Newly emerged seedlings are frost tolerant (down to –5°C) until the 6 to 8 leaf stage but are frost sensitive from the 6 leaf stage until the seed ripening stage. Sunflower buds are susceptible to frost damage and also a significant drop in air temperature can be detrimental at this stage.

Frosting during the bud development stage can result in distortion of the bud, failure to set seed and even a complete lack of flower production. This may also be seen as blackening or purpling around the edges of the head. Frosts of 2°C prevent flowers opening and subsequently reduce the seed set. Frosts of –2 to 0°C during grain fill can significantly reduce yield. [20]

4.5.2 Hail

Hail may damage sunflowers in several ways, including plant death, physical injury to the stem, head and leaf defoliation. All of these may reduce yield.

The growth stage when hail damage occurs has a major impact on the effect on yield. Hail in the early vegetative stages can greatly reduce yield if the terminal bud is damaged, generally plants with damaged terminals will tiller and these tillers produce small heads. Defoliation from the stages of R1–R6 appear to be most sensitive, since much of the photosynthate produced at this time is directed to head development.

Plant death is a common occurrence when plants are small. If the plant population is reduced significantly, the remaining plants will compensate if the damage occurs early in the growth stages (e.g 2–8 leaf stage). However beyond this stage the plants cannot compensate enough and yields may be reduced.

Injured plants may also suffer terminal bud damage or stem breakage or bruising. If plants are injured but unable to contribute to yield, they will still use water and nutrients, an unfavourable situation. [21]

Table 5 gives indications of the likely yield reduction should hail damage occur in a sunflower crop.

19 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

20 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

21 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

Table 5: *Approximate percent yield reduction due to hail damage at various growth stages.*

Growth Stage	Percent leaf area destroyed					Percent stand reduction				
	60	70	80	90	100	40	50	60	70	80
VE – V3	3	4	7	10	15	11	12	14	18	32
V6-V8	5	6	10	16	22	11	12	14	18	33
V12- VN	7	12	18	26	35	12	13	15	21	35
R1	9	16	24	34	47	16	18	21	29	43
R3	32	44	59	78	99	24	29	34	41	53
R5	25	37	49	67	90	31	39	45	54	66
R6	24	35	46	63	80	35	44	52	62	73
R7	13	16	18	20	22	-	-	-	-	-
R8	7	8	9	10	11	-	-	-	-	-

Source: Table information formed by extracting data from Berglund, D.R. 1994. Sunflower Production, North Dakota State University, Fargo, North Dakota, USA.

4.5.3 Drought

Dryland sunflowers have reasonable drought tolerance, particularly if planted into a full profile of moisture. Extreme drought will reduce the plant height, leaf area and head diameters, resulting in reduced yields. Additional information on drought can be found under moisture stress in the water use section in the agronomy module. [22]

4.5.4 Heat stress

High temperatures during flowering and seed set will reduce yields and oil contents. Head and seed temperatures usually are 5 to 10°C higher than the air temperature. Yield is generally reduced due to a reduction in seed number and increase in small grains. In addition, sunscald can affect heads which are erect or semi erect as the angle of head inclination is directed at the sun, receiving high heat intensity under hot conditions. This causes brownish red seed hulls and undeveloped seeds.

The effect of temperature on fatty acid composition is most important during early stages of seed fill. Rondanini et al. (2005), found that high alternating day/night temperatures for 4 days or longer with a mean daily grain temperature greater than 35°C produced significant reductions in grain yield and quality. Yield was reduced due to lower seed weights resulting in an increase in the percentage of half full grains in all sections of the head (outside, inter, middle sections). Reductions were highest during early grain fill (10–12 days after anthesis) with reduced yield of 6%/°C above a mean grain temperature of 29°C. Later heat stress (18–24 days after anthesis) resulted in yield reductions of 4%/°C above 33°C, demonstrating that the timing of heat stress is critical to yield and quality responses.

This experiment also found that heat stress 10–18 days after anthesis resulted in lower final pericarp weight due to thinner cell walls in the schlerenchyma and less cell layers. High temperatures (especially 10–12 days after anthesis) reduce both the rate and duration of oil deposition in the developing seed (Rondanini et al. 2005). Constantly higher temperatures reduce oil content when occurring in the grain fill oil deposition period, when compared to alternating high/low temperatures (Rondanini & Mantese, 2004). Temperatures greater than 35°C also affect other grain properties including fatty acid composition and hull to kernel ratio. Additional information on the effect of temperature is contained in Section 2. [23]

22 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

23 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

4.5.5 Waterlogging

Waterlogging can have an impact on plant growth and development. Waterlogging involved the rapid reduction in the amount of oxygen available in the soil. This has a direct impact water and nutrient uptake and also on physiological processes such as photosynthesis, respiration and leaf senescence.

The effects of waterlogging will vary depending on a number of factors including soil type, e.g. slow draining, length of inundation and crop growth stage. [24]

4.6 Photos of stages of sunflower development

VE

V2

24 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/

V4

V6

R1


R3


R4


R5.5

R5.8

R6

R9

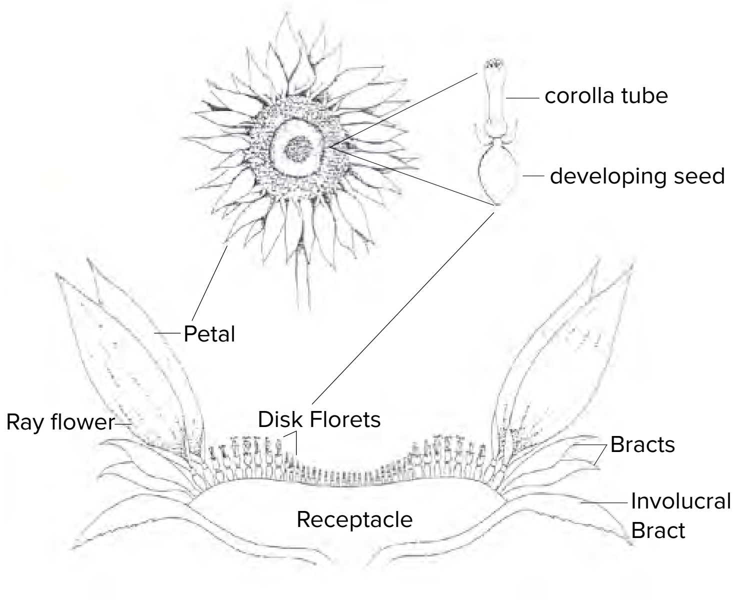

Figure 6: *Parts of the flower – sunflower.*

Photos: Loretta Serafin and Stephanie Belfield, NSW DPI

Source: Sunflower Production and Pest Management Extension Bulletin 25, December 1985, NDSU

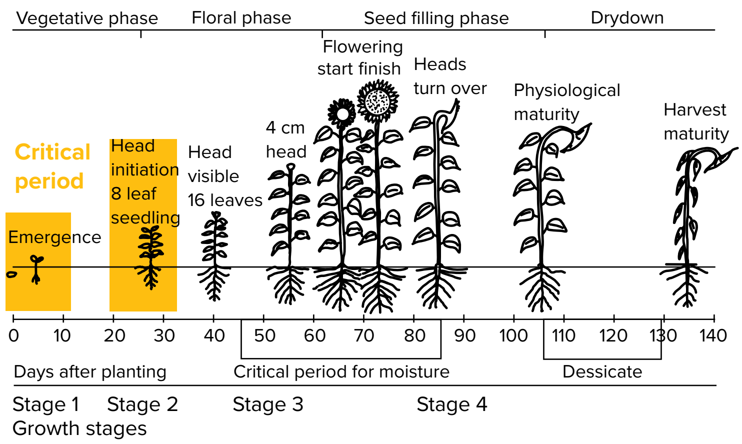

Figure 7: *Sunflower growth stages from a December planting.*

Source: Pacific Seeds Cropping Yearbook 2009/2010 – Sunflower, Pg 7

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MORE INFORMATION

GRDC Tips and Tactics: Sunflower nutrition

Nutrition and fertiliser

Sunflowers require adequate nutrition yet have a significantly lower requirement for several of the major nutrients when compared to other crops. [1] The relationship between nitrogen (N), starting soil water and target yield is crucial in sunflower crops (Figure 1). [2]

Figure 1: *Nitrogen nutrition is important for healthy sunflower crops.*

Key points

- Sunflower are moderately tolerant to a range of soil constraints and prefer a friable soil surface for best crop establishment.
- Use soil tests to target nutrient management for both optimal oil and maximum grain yields.
- Nitrogen (N) is the nutrient taken up in the greatest quantities by sunflower and is essential for many plant processes.
- Excessive levels of N can reduce oil content while insufficient N will limit crop yields.
- Phosphorus (P) is the second most frequently limiting nutrient for sunflower crops.
- If arbuscular mycorrhizal (AM) fungi levels are low, supplying adequate P and zinc is very important.
- Germinating sunflower seed is very sensitive to fertiliser placed in the seed trench; growers should aim to limit the amount of fertiliser placed in close contact with the seed and use side banding to limit contact. [3]

1 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

2 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

3 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

Table 1 contains the amount of some of the nutrients removed in the largest quantity in seed, stubble and the plant total.

Table 1: *Nutrient uptake and removal at two levels of production.*

Yield		1 t/ha			2.5 t/ha	
Nutrient	Seed	Stover	Total	Seed	Stover	Total
N	26	14	40	60	35	95
P	4	1	5	9	3	12
K	8	22	30	18	55	73
S	1.7	3.0	4.7	4	8	12

Source: Australian Soil Fertility Manual

5.1 Soil requirements

Crop response to fertiliser can be limited by soil chemical factors such as pH, salinity, sodicity and their effect on nutrient availability and soil structure. The first step to developing a fertiliser plan is to understand soil background limitations. Establish a realistic yield target by allowing for their negative impacts on fertiliser performance. [4]

5.1.1 pH

Sunflowers grow best in neutral soils but a pH range from slightly acid to alkaline is suitable.

They are generally not tolerant of acidic soils with a pHCa of 5.0 or below. Sunflower are very sensitive to aluminium (Al) toxicity. In the field, sunflower commonly respond to liming on soils with surface Al saturation >5%. However, if the Al levels are high in the subsoil, limited options for amelioration are available. Aluminium toxicity is most evident in plant roots displaying distinct shortening and thickening, and a reduction in root hair density.

Despite sensitivity to Al, sunflowers tolerate high concentrations of manganese (Mn) in the root environment. Manganese availability can also increase with soil acidity.

5.1.2 Salinity

Sunflowers are moderately tolerant to salinity; they are less tolerant than cotton, wheat or sorghum but more tolerant than soybean or maize. The threshold soil salinity level for sunflowers is 4–5 dS/m (conductivity measure) and the rate of yield decline about 5% per dS/m above threshold.

Sunflowers affected by salinity display symptoms of stunting, thin stems, dull yellow-green leaves and look moisture stressed and wilted. Symptoms appear first on older leaves which appear dull and develop leaf tip margin necrosis, which spreads over the whole leaf surface. Under high levels of salinity, young leaves are also affected, causing browning off which may eventually lead to plant death.

Paddocks with salinity as a subsoil constraint should be identified and the depth to the subsoil constraint noted in order to calculate the reduction in plant available water and mineral N. Subsoil constraints effectively reduce the amount of soil water available and mineral N to the crop as the root exploration will be limited.

5.1.3 Soil cations and structural stability

In soils with high clay contents (i.e. greater than 15%), an excess of sodium, potassium or magnesium on cation exchange sites can result in surface soil dispersion and crusting. This structural instability commonly reduces crop establishment and can also

4 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

occur at depth, limiting root growth, which in turn inhibits the plants' access to water and nutrients.

In the absence of sodicity-driven soil structural effects, sunflower is categorised as having moderate tolerance to sodium (ESP 30–40%). High sodicity does not appear to affect oil content but may delay germination and flowering. [5]

MORE INFORMATION

RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 265–279.

5.2 Declining soil fertility

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

Pasture leys, legume rotations and fertilisers all play an important role in maintaining and improving the chemical, biological and physical fertility of soils, fertilisers remain the major source of nutrients to replace those removed by grain production. Fertiliser programs must supply a balance of the required nutrients in amounts needed to achieve a crop's yield potential. The higher yielding the crop, the greater the amount of nutrient removed. Increasing fertiliser costs means growers are increasing pulses within their crop rotation and even the use of ley pastures to complement their fertiliser programs and possibly boost soil organic matter. [6]

5.2.1 Soil organic matter

Soil organic matter (SOM) is a critical component of healthy soils and sustainable agricultural production. Growers understand that crops grown in healthy soils perform better and are easier to manage. Soil organic matter is '*all of the organic materials found in soils irrespective of its origin or state of decomposition*' [7] that is anything in or on the soil of biological origin, alive or dead. It is composed mainly of carbon (approximately 60%) as well as a variety of nutrients (including nitrogen, phosphorus and sulfur). It is difficult to actually measure the SOM content of soil directly so we measure the soil organic carbon (SOC) content and estimate SOM through a conversion factor:

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

It is important to understand the role of plants in the SOM cycle. Photosynthesis is the process by which plants take in carbon dioxide (CO_2) from the atmosphere, combine with water taken up from the soil, and utilising the energy from the sun, form carbohydrate (organic matter) and release oxygen (O_2). This is the start of the SOM cycle. When the leaves and roots (carbohydrate) die they enter the soil and become SOM. These residues are decomposed by soil organisms which provides them with the energy to grow and reproduce. The SOM cycle is a continuum of different forms (or fractions) with different time frames under which decomposition takes place. Over time SOM moves through these fractions; particulate, humic and resistant fractions. As SOM decomposes carbon is released from the system along with any nutrients that are not utilised by the microorganisms. These nutrients are then available for plants to utilise. Eventually a component of these residues will become resistant to further decomposition (resistant fraction Figure 2).

5 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

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

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

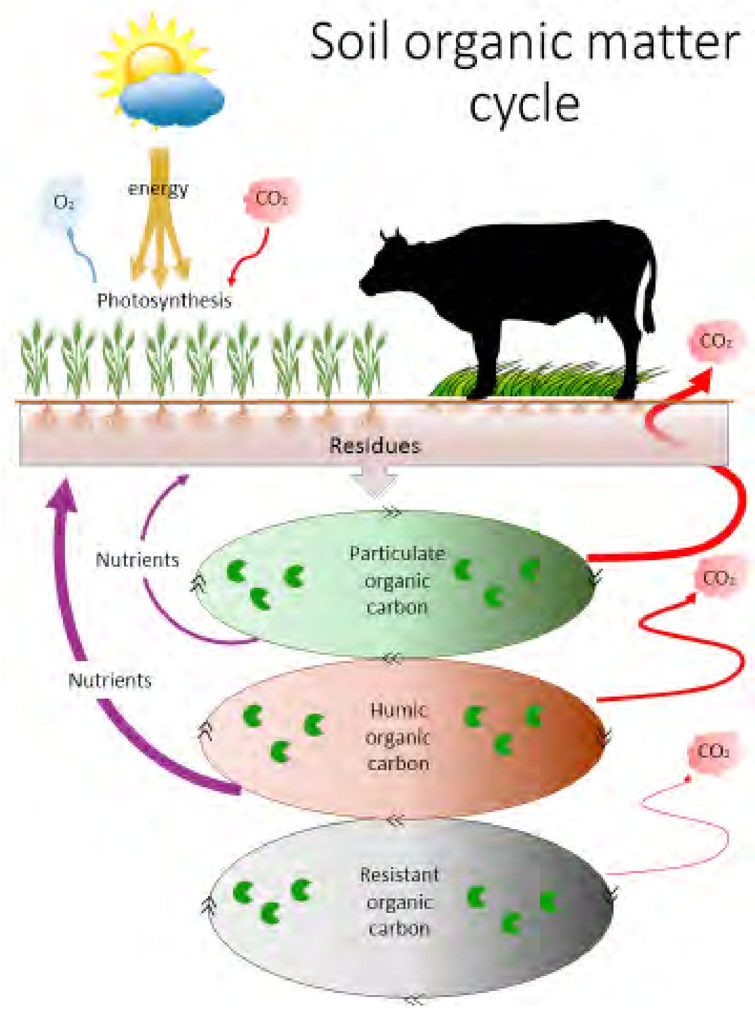

Figure 2: *Organic matter cycle.*

Source: J Gentry, QDAF

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

Australian soils are generally low in SOM. Initial SOM levels are limited by dry matter production (and so climate) for each land type/location. SOM levels have declined under traditional cropping practices. On-farm measures (sampled 2012–15) from over 500 sites in Queensland and northern NSW confirm that soil organic matter, measured as soil organic carbon, declines dramatically when land is cleared and continuously cropped. This decline affects all soils and land types but is most dramatic for the brigalow–belah soils because their starting organic carbon levels are so high (Figure 3). [8]

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

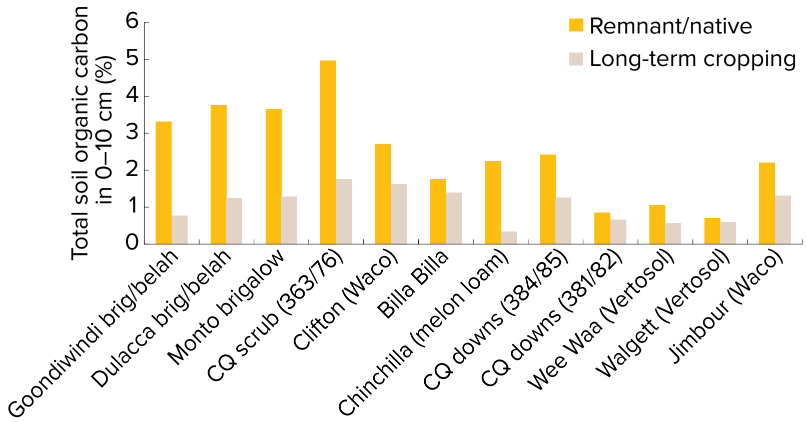

Figure 3: *The decline of soil organic carbon in long-term cropping systems.* [9]

Declining levels of SOM have implications for soil structure, soil moisture retention, nutrient delivery and microbial activity. However, probably the single most important effect is the decline in the soil's capacity to mineralise organic nitrogen (N) to plant-available N. Past research (1983) has shown that N mineralisation capacity was reduced by 39–57%, with an overall average decline of 52% (Figure 4). [10] This translated into reduced wheat yields when crops were grown without fertiliser N.

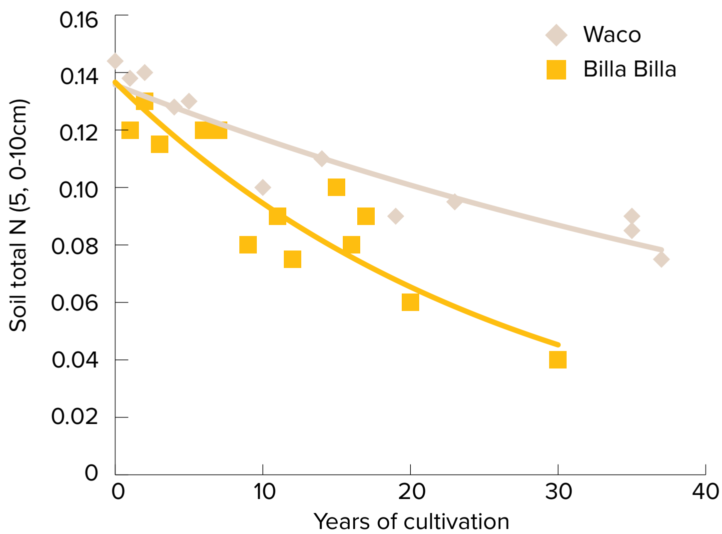

Figure 4: *Graph of decline in soil total N with years of cropping. The decline was greater for the Billa Billa soil (clay content 34%) than the Waco soil (clay content 74%).*

Source: based on Dalal & Mayer (1986a,b) [11]

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

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

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

5.2.2 Current situation

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

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

Total soil organic carbon levels vary within a paddock, from paddock to paddock and from region to region. Comprehensive sampling was under taken throughout the northern region, with over 900 sites sampled and analysed for total organic carbon at 0–10 cm depth. These results varied enormously across sites. The average was 1.46% however it varied from under 0.5% to over 5% (Figure 5). [12] A selection of these data from representative soil types throughout the northern grains region clearly indicates how soil carbon levels can be significantly different due to soil type (Figure 6). [13]

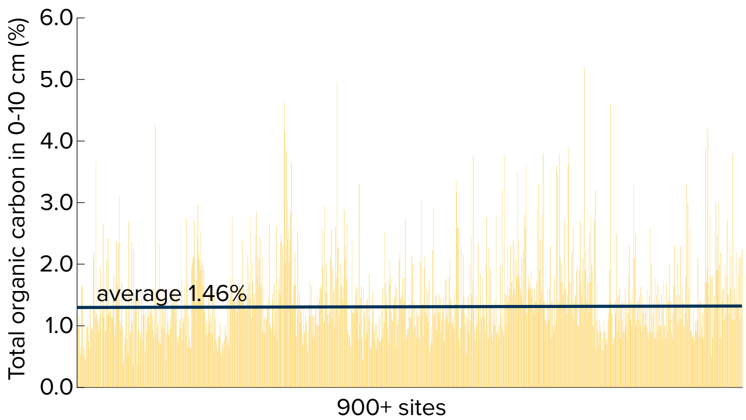

Figure 5: *Soil organic carbon levels on mixed farms within the GRDC Northern Region.* [14]

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

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

14 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112_117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

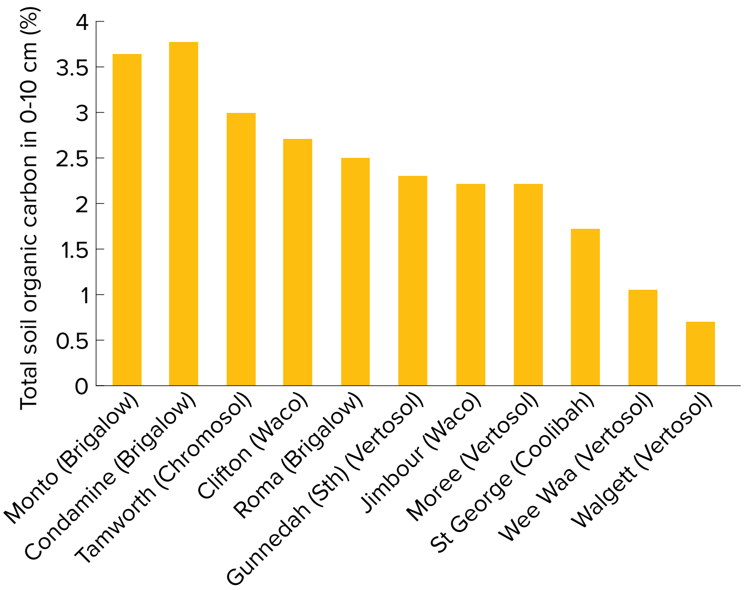

Figure 6: *Impact of land-type on total soil carbon levels (0–10 cm) across the northern region.* [15]

5.2.3 Options for reversing the decline in soil organic matter

Soil organic matter is an under-valued capital resource that needs informed management. Levels of SOC are the result of the balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition, harvested material) in each soil and farming. [16] So maximising total dry matter production will encourage higher SOC levels, and clearing native vegetation for grain cropping will typically reduce SOC and SOM levels. [17]

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

Research in the past has shown the most direct, effective means of increasing SOM levels is through the use of pastures, however these pasture have to be productive. A grass only pasture will run out of N especially in older paddocks, which is normally the reason why these paddocks are retired from cropping. As a result, a source of nitrogen is required to maximise dry matter production, this can be supplied via a legume or N fertiliser. The rotation experiments of I. Holford and colleagues at Tamworth, NSW and R. Dalal and colleagues in southeast Queensland provide good evidence of this (Table 2).

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

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

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

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

MORE INFORMATION

SA Hossain, RC Dalal, SA Waring, WM Strong, EJ Weston (1996) Comparison of legume-based cropping systems at Warra, Queensland. 1. Soil nitrogen and organic carbon accretion and potentially mineralisable nitrogen. Australian Journal of Soil Research 34, 273–287.

MORE INFORMATION

SA Hossain, WM Strong, SA Waring, RC Dalal, EJ Weston (1996) Comparison of legume-based cropping systems at Warra, Queensland. 2. Mineral nitrogen accumulation and availability to the subsequent wheat crop. Australian Journal of Soil Research 34, 289–297.

Clearly, time and good sources of both carbon and nitrogen are required to build up SOM, which is exactly what the 4-year grass–legume ley provided. Nitrogen was supplied via N_2 fixation by the lucerne and annual medic in the pasture, with most of the carbon supplied by the grasses, purple pigeon grass and Rhodes grass. There were no inputs of fertiliser nitrogen in any of the treatments in Table 2. [18]

Table 2: *Effects of different rotations on soil total N and organic C (t/ha) to 30 cm and as gain relative to continuous wheat.*

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

Source: Hossain et al. 1996a

Further research was initiated in 2012 to identify cropping practices that have the potential to increase or maintain soil organic carbon and soil organic matter levels at the highest levels possible in a productive cropping system. Paired sampling has shown that returning cropping country to pasture will increase soil carbon levels (Figure 7). However, there were large variations in carbon level increases detected, indicating not all soil types or pastures preform the same. Soil type influences the speed by which carbon levels change, i.e. a sandy soil will lose and store carbon faster than a soil high in clay. As too does the quality and productivity of the pasture, maximising dry matter production by ensuring adequate nutrition (especially in terms of nitrogen and phosphorus) will maximise increases in soil carbon over time. Current research in Queensland being undertaken by the Department of Agriculture, Fisheries and Forestry (QDAF) is indicating that the most promising practice to date to rebuild soil carbon stocks, in the shortest time frame, is the establishment of a highly productive pasture rotation with annual applications of nitrogen fertiliser, however, adding an adapted legume is also effective. [19]

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

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

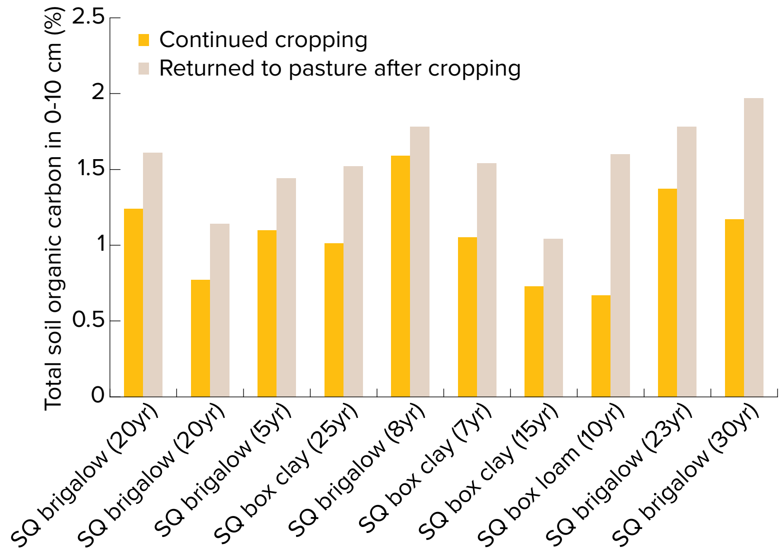

Figure 7: *Total organic carbon comparisons for croplands resown to pasture.* [20]

Impact of fertiliser N inputs on soil

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

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

If, on the other hand, the soil is deficient in mineral N, then more of the C is respired by the soil microbes and less is locked into the stable organic matter. [21]

5.3 Soil testing

Soil testing and professional interpretation of results should be an integral part of all management strategies. Soil tests estimate the amount of each nutrient available to the plant rather than the total amount in the soil. Valuable information obtainable from a soil test includes current nutrient status, acidity or alkalinity (pH), soil salinity (electrical conductivity, EC), and sodicity (exchangeable sodium percentage, ESP), which can affect soil structure.

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

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

MORE INFORMATION

http://www.fertiliser.org.au/Fertcare

http://agronomycommunity.incitecpivotfertilisers.com.au/~/media/Files/IPL pdfs/Crop Soil Sampling Procedure1.ashx

http://www.backpaddock.com.au

http://www.afsa.net.au/index.php?action=content&page=11

http://www.aspac-australasia.com

Soil test information should not be used alone to determine nutrient requirements. It should be used in conjunction with test strip results and previous crop performance to determine nutrients removed by that crop, as well as previous soil test records, to obtain as much information as possible about the nutrient status of a particular paddock.

Figure 8: *Soil sampling: soils must be sampled to the correct depth.*

Soils must sampled to the correct depth (Figure 8). Sampling depths of 0–10 and 10–30 cm should be used for all nutrients. An additional sample at 30–60 cm is required for sulfur (S), and samples at 30–60, 60–90 and 90–120 cm (or to the bottom of the soil's effective rooting depth) are needed for N, pH, EC and chloride.

Care must be taken when interpreting soil test results; nutrients can become stranded in the dry surface layer of the soil after many years of no-till or reduced tillage, and deep nutrient reserves may be unavailable because of other soil factors, such as EC levels, sodicity or acidity. [22]

5.3.1 Test strips

Test strips allow you to fine-tune the fertiliser program. To gain the maximum benefit:

- Run them over a number of years, as results from any single year can be misleading.
- Obtain accurate strip weights.
- Oil-test a sample of grain from each strip.
- Harvest strips before your main harvest. Use yield monitoring if available.

When setting up a test strip area:

- Ensure that you can accurately locate the strips—a GPS reading is valuable.
- Repeat each fertiliser treatment two or three times (if comparing fewer than four treatments, more replication is needed).
- Change only one product rate at a time.
- Separate each strip of fertiliser by a control or nil-fertiliser strip.
- Ensure the tests are done over a part of the paddock with a uniform soil type.
- Keep clear of shade lines, trees, fences, headlands and any known anomalies in the field.
- Ensure that the test strip area is ~100 m long, with each strip 1–2 header widths.

A number of local Grower Solutions Groups, such as the Northern Grower Alliance (NGA) and Grain Orana Alliance (GOA), as well as NSW Department of Primary Industries (DPI) and Department of Agriculture, Fisheries and Forestry Queensland (QDAF) conduct nutrition trials in most years.

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

MORE INFORMATION

www.nga.org.au

www.grainorana.com.au

MORE INFORMATION

http://www.aspac-australasia.com/index.php/component/labproficiency

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-108-Jan-Feb-2014/Sunflowers-balancing-act

MORE INFORMATION

GRDC Update Paper
http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/03/Nitrogen-uptake-pathways-and-implications-for-foliar-and-solid-fertiliser

http://www.dpi.nsw.gov.au/agriculture/resources/soils/improvement/n-acidify

Colour photographs of nutrient deficiencies can be found in: 'Hungry crops: a guide to nutrient deficiencies in field crops' by NJ Grundon (1987) (Department of Primary Industries, Queensland Government, Information Series Q187002). [23]

5.3.2 Rules of thumb

1. Choose the same soil test package each year (including methods); otherwise, comparisons between years will be useless. For example, for phosphorus (P), do not use Colwell-P one year, then DGT-P the next; the two tests measure different forms of available P in the soil.
2. If you do not use a standard approach to sampling, a comparison of the data between different tests will not be reliable. Aim for data that have the best chance of representing the whole paddock, and mix the sample thoroughly.

For monitoring, sampling needs to cover roughly the same area each time to ensure meaningful comparisons between years. Permanent markers on fence posts to mark a sampling transect, or a handheld GPS or your smartphone, will serve this purpose.

Soil-testing laboratories should be able to provide information on appropriate soil sampling and sample-handling protocols for specific industries and crop types. Refer to the 'Australian Soil Fertility Manual' (see www.publish.csiro.au/pid/5338.htm) or download the GRDC Fact Sheet 'Better fertiliser decisions for crop nutrition' at http://www.grdc.com.au/GRDC-FS-BFDCN. [24]

Use an ASPAC- and NATA-accredited testing service. The results are more likely to be statistically valid and have reduced variation between tests.

5.3.3 Soil testing for N

The approximate amount of N available in the soil can be determined by soil testing. Soil tests should be taken at various places in each paddock to a depth of at least 90–120 cm. Primary roots grow to a depth of 2 m [25] and can extract N from this level. Test results are an indication only, so historical grain yield and protein levels from the paddock should also be used to determine N requirements. [26] Environmental conditions, including temperature, time and rainfall events, can affect starting levels of soil N; therefore, it is important to test later in the summer fallow or make adjustments to factor in mineralisation amounts as well as denitrification and leaching events.

Forms of N fertiliser

Nitrogen is available in four main forms:

1. Nitrate, e.g. ammonium nitrate, sodium nitrate, potassium nitrate
2. Ammonium, e.g. anhydrous ammonia, sulfate of ammonia, ammonium nitrate
3. Amide, e.g. urea
4. Organic, e.g. blood and bone, meat meal

It is important to choose the right product, as different compositions are more suited to certain conditions.

Calculating N fertiliser application

If N fertiliser is required, the calculation below can be used to obtain the quantity of fertiliser required. For example, if 40 kg N/ha is required, this rate of N can be supplied by applying 87 kg/ha of urea (46% N) (Table 3).

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

24 GRDC (2013) Better fertiliser decisions for crop nutrition. Northern, Southern and Western Regions. GRDC Crop Nutrition Fact Sheet Nov. 2013, http://www.grdc.com.au/GRDC-FS-BFDCN

25 NSW DPI Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

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

Fertiliser product required (kg/ha) = rate of N required kg N/ha × 100/(% N in fertiliser product) [27]

Table 3: *Nitrogen fertilisers commonly used in broad-scale farming.*

Fertiliser	% N	% P	% S
Urea	46		
Ammonium sulfate	21		24
Calcium ammonium nitrate	27		
Di-ammonium phosphate	17.5–18.0	20	
CSBP Agras No. 1®	17.5	7.6	17
CSBP Agyield®	17.5	17.5	4.5
CSBP Agrich®	12.0	11.4	12
CSBP Agstar®	15.5	12.8	11
Summit Easycrop 2®	31	9	4
Summit Canola 2®	33		12
Summit Topyield 3®	27.3	11.5	5
Summit Cereal®	18.5	11.0	14.4
Summit Canola 1 ®	18.5	11.0	14.4
Summit Croprich ®	18	14	11.5
Summit Sustain®	10.8	12	1
Summit Cropyield®	17.1	19.6	3.5
Summit DAPSZC®	17.1	18.3	8

Source: DAFWA.

'NBudget' calculator

'NBudget' is an Excel-based calculator for estimating the fertiliser N requirements of cereal and oilseed crops and N_2 fixation by legumes. It contains rule-of-thumb values for soil nitrate based on paddock fertility status and recent paddock history, with linked equations for calculating soil nitrate following crop growth and post-crop fallow.

Other key calculations in NBudget determine: soil water at sowing based on fallow rainfall or depth of wet soil; biomass and grain yields of the different crops based on water-use efficiencies; N_2 fixation of legumes based on crop biomass and soil nitrate effects; and production of crop residues and the net release or immobilisation of nitrate-N from those residues as they decompose in the soil.

Input data to develop NBudget were sourced from published and unpublished experiments conducted principally by the farming systems and plant (N) nutrition programs of the NSW and Queensland agricultural agencies during the past 30 years. The data required to run NBudget include: location and description of the paddock as very low, low–medium, medium or high fertility; tillage practice; yield and protein level (for cereals) of the previous crop; fertiliser N applied to previous crop; simple assessment of risk of crown rot for the winter cereals; and fallow rainfall or depth of wet soil.

For a detailed guide to use of NBudget and N management, download Dr David Herridge's publication, 'Managing legume and fertiliser N for northern grains

27 QDAF (2012) Wheat—nutrition. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/nutrition

cropping': https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf. [28]

5.3.4 Soil testing for P

Colwell-P

The Colwell-P test uses a bicarbonate (alkaline) extraction process to assess the level of readily available soil P. It was the original test for P response in wheat in northern NSW. It is used with the P buffering index (PBI) to indicate the sufficiency and accessibility of P in the soil.

BSES-P

The BSES-P test was developed for the sugar industry and is now an important tool in the grains industry. BSES-P uses a dilute acid extraction to assess the size of slow-release soil P reserves. These reserves do not provide enough P within a season to meet yield requirements, but they partially replenish plant-available P.

Because the P measured by BSES-P releases only slowly, changes in the test value of subsoil layers may take years. Therefore, this test needs to be done only every 4–6 years, and is most important in the subsoil layers.

P buffering index

The 'buffering capacity' of a soil refers to its ability to maintain P concentration in solution as the plant roots absorb the P. The PBI indicates the availability of soil P. The higher the value, the more difficult it is for a plant to access P from the soil solution. Generally, a PBI value <300 (a range that would include most northern Vertosols) indicates that soil P, as assessed by Colwell-P, is readily available.

Colwell-P and PBI values are needed in both 0–10 and 10–30 cm soil tests.

BSES-P is optional in the 0–10 cm layer but essential in the 10–30 cm layer. [29]

Traditionally when testing to determine a crop's P requirement, a soil sample from 0–10 or 0–15 cm was taken and analysed for Colwell-P and PBI. According to recent work into depletion and stratification of P, as well as the existence (or otherwise) of additional slow-release P reserves that can be detected using the BSES-P test, Colwell-P alone is unlikely to provide all of the information to make an informed decision. Of particular note is the lack of correlation between the two soil P tests, with this most obvious in samples from below 10 cm.

Although data are still being collected on the rates at which these BSES-P reserves can become available to plants (i.e. over days, weeks or long fallows), current observations suggest that subsoils with quite low BSES-P levels (i.e. <25–30 mg/kg) are still able to meet the demands of a well-developed root system (i.e. a trickle of P from many roots accessing a large soil volume).

However, there are many subsoils across the region where soil P (both Colwell and BSES) is low. For example, grain P data from wheat, barley and sorghum collected across the region in the GRDC-funded project '*Toward a better P nutrition package: diagnosing P status and application strategies to improve fertiliser*' (DAQ00084) suggest that 20–25% of all crops were marginal–low in P, whereas the proportion of marginal–low-P chickpea crops was much higher. Early results suggest that some significant yield gains may be possible on these soils. [30]

MORE INFORMATION

GRDC Update Papers
http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/NEW-WAYS-TO-ESTIMATE-CROP-NEEDS-AND-DELIVER-P-TO-IMPROVE-THE-RETURN-ON-FERTILISER-INVESTMENT

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/05/Toward-a-Better-P-Nutrition-Package-Diagnosing-P-Status-and-Application-Strategies-to-Improve-Fertiliser-Response

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Nutritional-interactions-of-N-P-K-and-S-on-the-Darling-Downs

GRDC Podcast
http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2013/11/21-north

28 D Herridge (2013) Managing legume and fertiliser N for northern grains cropping. Revised version. GRDC, http://www.grdc.com.au/~/media/6E5659619C7C4063AB3C8E58A4DE39E7.pdf

29 GRDC (2012) Northern region—phosphorus management. GRDC Crop nutrition Fact Sheet Nov. 2012, http://www.grdc.com.au/~/media/578CC7FEE649428D9C4C90B7461537D0.pdf

30 M Bell, D Lester, P Moody, C Guppy (2010) New ways to estimate crop needs and deliver P to improve the return on fertiliser investment. GRDC Update Papers 17 Sept. 2010, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/NEW-WAYS-TO-ESTIMATE-CROP-NEEDS-AND-DELIVER-P-TO-IMPROVE-THE-RETURN-ON-FERTILISER-INVESTMENT

5.4 Plant tissue sampling

Plant tissue testing is an underused crop nutrition management tool. It is more reliable than soil testing for nutrients where local soil test calibrations are not available, or when checking on the effectiveness of a change to a fertiliser program (Figure 9).

For these reasons, critical tissue concentrations should be associated specifically with defined stages of plant growth or plant part rather than growth periods (i.e. days from sowing). Growers are advised to follow laboratory guides or instructions for sample collection.

Plant nutrient status varies according to plant age, variety and weather conditions. The difference between deficient and adequate (or toxic) levels of some micronutrients can be very small. Agronomists consider one test alone not enough; several tissue tests need to be done over time throughout the growing period to establish whether the crop is tracking according to the season at hand.

The key to successful plant tissue testing is ensuring the crop is sampled when actively growing, and the sample is collected from the appropriate plant part, at the correct growth stage and time. For example, time of day and soil moisture availability are important for some nutrients for consistency of results when doing consecutive tissue tests. Some plant tissue diagnostic values are presented in Table 4. [31]

Table 4: *Plant tissue sampling guidelines for top 1 to 3 mature leaves of sunflower at bud stage.*

Nutrient	Sufficient range
Nitrogen (%)	2.0–3.4
Phosphorus (%)	0.25–0.49
Potassium (%)	1.5–2.9
Sulfur (%)	0.2–0.39
Calcium (%)	0.3–1.9
Magnesium (%)	0.2–1.4
Zinc mg/kg	15–69
Copper mg/kg	6.24
Iron mg/kg	20–249
Manganese mg/kg	15–99
Boron mg/kg	35–150

Source: Reuter and Robinson, 1996

When applying fertiliser to treat a suspected deficiency, leave a strip untreated. Use a visual response (where a 20% yield difference is not evident) or plot harvesting of the strips can allow you to confirm limiting micronutrients. [32]

31 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

32 GRDC (2013) Micronutrients. Northern, Southern and Western Regions. GRDC Crop Nutrition Fact Sheet Nov. 2013, http://www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

PODCAST

http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2010/06/Plant-Tissue-Testing-uncovering-hidden-hunger

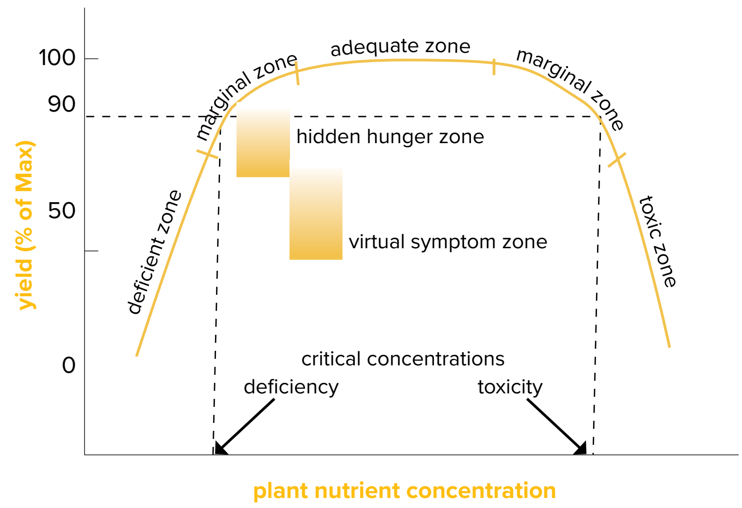

Figure 9: *Generalised grain yield response curve.*

5.5 Hierarchy of crop fertility needs

Current research by QDAF on the Darling Downs confirms a hierarchy of crop fertility needs. There must be sufficient plant-available N to get a response to P, and there must be sufficient P for S and/or potassium (K) responses to occur. [33]

Additive effects of N and P appear to account for most of the aboveground growth and yield response. [34]

Liebig's law of the minimum, often called Liebig's law or the law of the minimum, is a principle developed in agricultural science by Carl Sprengel (1828) and later popularised by Justus von Liebig. It states that growth is controlled not by the total amount of resources available, but by the scarcest resource (i.e. limiting factor) (Figure 10). [35]

Figure 10: *Leibig's law, or law of the minimum.*

33 D Lester, M Bell (2013) Nutritional interactions of N, P, K and S on the Darling Downs. GRDC Update Papers 7 March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Nutritional-interactions-of-N-P-K-and-S-on-the-Darling-Downs

34 D Lester, M Bell (2013) Nutritional interactions of N, P, K and S on the Darling Downs. GRDC Update Papers 7 March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Nutritional-interactions-of-N-P-K-and-S-on-the-Darling-Downs

35 Anon. Liebig's law of the minimum, http://en.wikipedia.org/wiki/Liebig's_law_of_the_minimum

MORE INFORMATION

GRDC Update Paper
http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Observations-on-a-general-decline-in-fertility-of-multiple-nutrients

5.6 Nitrogen

Nitrogen (N) is the major nutrient required by sunflowers and has the greatest impact on characteristics such as the size and number of leaves, seed size and weight, yield and oil content. There is an interaction between S and N for many of these factors as well. Excess N causes a reduction in oil contents, whilst insufficient N will limit crop yield. The challenge is targeting the optimum level. An N budget helps target optimal yield and oil contents. [36]

Sunflower has a lower requirement for N than sorghum and winter cereals. However, N is the nutrient required in the greatest quantity by a sunflower crop. Cropping history, years of cropping, fallow conditions and yield potential determine the quantity of N fertiliser needed. [37]

As a guide, for high-yielding crops on the Liverpool Plains, use 60–100 kg N/ha. In the Moree and Narrabri districts, little N is usually used, but on responsive paddocks up to 50 kg N/ha should be applied. Irrigated crops need 100–140 kg N/ha depending on target yields. [38]

Nitrogen budgeting can be used to help determine the N requirements of a crop by using the following calculations. The quantity of N removed in 1 tonne of grain is ~40 kg, of which 26 kg is in the seed and 14 kg in the stover. The quantity of N required to grow the crop is ~1.7 times the amount removed in the seed. [39]

N removed in seed (kg/ha):
Target yield (t/ha) × N removed (kg/t)

N required for crop (kg/ha):
N removed in seed × 1.7

Example calculation:
2 t/ha (target yield) × 26 (kg N removed/t seed) × 1.7 = 88 kg N/ha

Fertiliser required = N required for crop (88 kg/ha) – soil N reserve – expected soil N mineralisation
= 88 kg/ha – 50 kg/ha – 10 kg/ha (1% organic carbon × 5% × 200 mm of rainfall)

Total fertiliser requirement = 28 kg/ha (in some regions, some loss figures may need to be accounted for)

Nitrogen taken up by a crop comes from the available soil nitrate-N and from fertiliser-N. Soil nitrate-N is estimated by soil testing (preferably to 120 cm depth) or by reviewing the previous crop history, in particular the grain yield and protein content of the previous crop. [40] It is reasonable to expect sunflowers to extract N to at least this depth unless there are subsoil constraints. [41]

Pre-plant application of N fertiliser or banding of fertiliser 5 cm below and to the side of the seed is recommended. Germinating seed is very susceptible to N fertiliser burn if sown in close contact. [42]

Sunflower roots are able to extract water and N from depths of 1.5 m or greater in the soil profile so can be a useful crop in tapping deep N bulges.

36 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

37 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

38 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

39 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

40 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

41 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region–northern NSW and southern Qld. Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

42 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

For monounsaturated sunflower markets, a bonus/discount system applies for oil content above or below 40%. Protein and oil content of grains are inversely related, therefore too much N can reduce oil content.

The relationship between soil nitrate-N and soil water (0–120 cm) has been found useful in managing oil content. Limited studies in NSW suggested that matching nitrate:water at ratios 0.5–1.0 optimised oil content above the required industry standard of 40%, as well as grain yield. Oil contents were, on average, less than 40% when the nitrate: water ratio was more than 1.0 (Figure 11). [43]

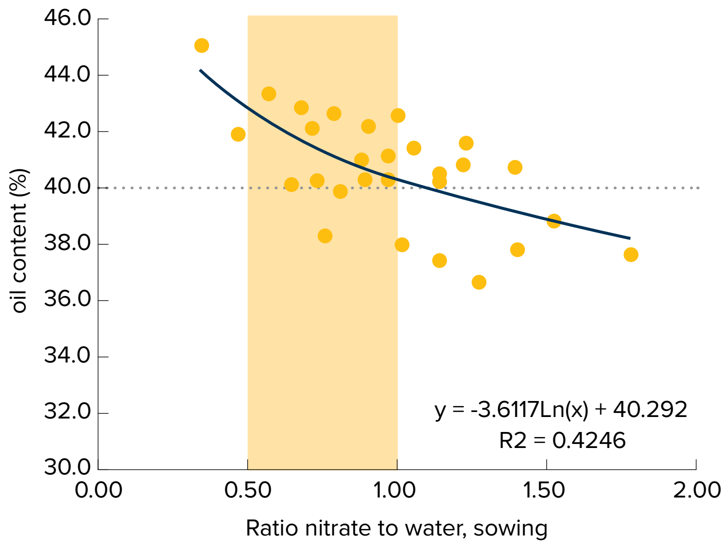

Figure 11: *The relationship between the starting soil nitrate:water ratio and oil content of sunflower.* [44]

Source: Serafin, Belfield & Herridge, 2010

Benchmarking project

In the 'Sunflowers in Northern NSW and Southern Qld—Tools for Success' benchmarking project, N fertiliser rates were consistently low in the Moree district, averaging 23 kg N/ha over the 3-year project. These rates fell well short of those required to meet the district average of 1.4 t/ha. By contrast, N rates in the Gunnedah district were consistently high. Southern Queensland crops received, on average, enough N for yields of 1.1 t/ha, close to the average yield.

The supply of adequate nutrition to a sunflower crop is of great importance; however, in the northern grains region, the type and amount of nutrition supplied is highly variable (Table 5).

43 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

44 L Serafin, S Belfield, D Herridge D (2010) Managing Nitrogen to optimise sunflower yield and oil content. Proceedings of the 1st Australian Summer Grains Conference, Gold Coast, Australia, https://grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Serafin_ManagingNitrogen_edited_paper.pdf

Table 5: *Sunflower nutrition and average fertiliser application in the northern grains region.*

Benchmarking year	Average yield (t/ha)	N (kg/ha)	P (kg/ha)	S (kg/ha)	Zn (kg/ha)	% of paddocks not fertilised
Moree						
2003–04	1.18	7.0	3.2	0.4	0.40	50
2004–05	1.57	15.2	3.6	0.6	0.42	15
2005–06	1.41	31.6	2.2	0.3	0.35	17
Gunnedah						
2003–04	1.66	68.1	2.7	2.7	0.30	10
2004–05	2.22	69.3	7.4	2.8	0.68	5
2005–06	1.47	71.0	4.6	15.3	0.51	6
Southern Queensland						
2003–04	1.58	60.0	6.5	0.7	0.83	0
2004–05	1.01	36.9	2.8	0.8	0.25	10
2005–06	1.25	43.6	3.2	0.9	0.43	20

Replicated trials

The effect of N on yield and oil content was evaluated over two seasons at sites in northern NSW. Trials conducted at Pine Ridge on a site with high starting levels of soil N demonstrated the effects of excessive N (Figure 12).

The starting soil N level at this site was 143 kg N/ha, sufficient to achieve 3.3 t/ha. Most of this N had accumulated as a bulge at 60–120 cm soil depth.

This amount of N was in excess of that required for dryland yields. Hence, a decline in yield and oil content resulted from additional N applied.

The relationship between N, starting soil water and target yield is crucial to yield and oil content.

The relationship between optimum yield and oil content was also demonstrated at the Gurley trial site (Figure 13). Starting soil N levels were measured as 52 kg N/ha, sufficient to achieve a yield of 1.2 t/ha.

The maximum yield achieved at this site was with the addition of 125 kg N/ha (1.7 t/ha), whereas the maximum oil content was achieved with no additional N. Nitrogen application needs to be balanced; at this site, 60 kg/ha of additional N would have optimised yield and oil content.

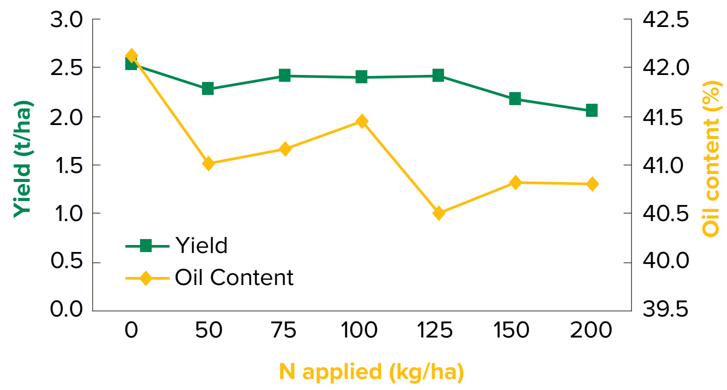

Figure 12: *Relationship between nitrogen, oil content and yield of sunflowers, Pine Ridge–Gunnedah, 2005–06.*

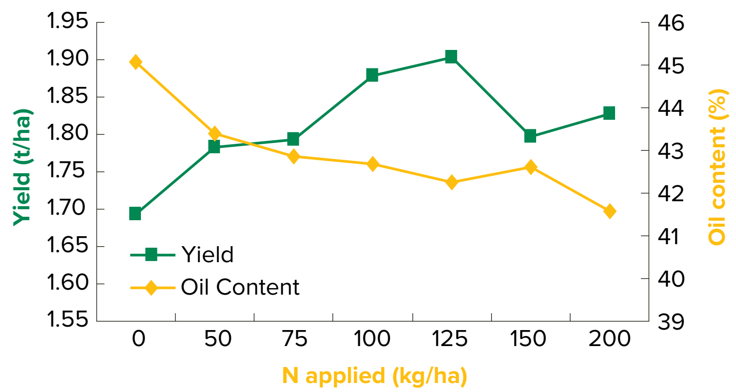

Figure 13: *Relationship between nitrogen, oil content and yield of sunflowers, Gurley–Moree, 2005–06.*

Benchmarking paddocks

Thirty-two paddocks were sampled to determine starting soil nitrate levels in 2004–05 and 2005–06. One-fifth of paddocks sampled had starting nitrate levels >200 kg/ha, enough N to produce 4.6 t/ha, an unattainable yield under dryland conditions.

As N costs rise, awareness of N quantity and distribution through the soil profile and crop requirements become increasingly important. Not only does too much N negatively affect oil contents and yields, the gross margin declines. [45]

5.7 Phosphorus

Phosphorus (P) is the second most frequently limiting nutrient for sunflower production. Sunflowers respond to P deficiency by flowering and maturing faster.

The quantity of P removed in 1 tonne of grain is approximately 5 kg, of which 70–80% is in the seed and 20–30% in crop residues. Phosphorus fertiliser needs are best

45 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

determined by soil tests, soil type, test strips, consideration of likely arbuscular mycorrhizal (AM) fungi levels, paddock history and local experience. In paddocks where P is needed, apply at least 10 kg P/ha or at a rate to match P removal. In southern NSW at least 20 kg P/ha is usually required, increasing to 40–50 kg P/ha if sunflowers follow a rice crop. At high rates, alternative application methods to sowing with the seed may need to be considered to prevent fertiliser burn.

The value of deep application of P and potassium (K) has been demonstrated on a range of cereal crops in Vertosol soils. To date there is little research data to demonstrate responsiveness in sunflower as measured in other tap-rooted crops such as chickpea and mungbean. If AM fungi levels are low—such as after a long fallow canola or rice—supplying adequate phosphorus and zinc fertiliser is very important (Figure 14). [46]

Figure 14: *Dark green healthy leaf (right) compared with P-deficient leaf showing dull yellow chlorosis and dark grey necrotic lesions (left).*

Photo: NJ Grundon

5.8 Sulfur

Sulfur (S) forms important partnerships with N during sunflower production. Together, they determine leaf area, which provides photosynthates to developing florets and seeds, following through to yield and seed size. Deficiency when combined with N reduces yield as seed weight and the number of seeds per plant declines.

The amount of S removed in the seed of a 1-t crop is 5 kg/ha, with uptake highest between budding and anthesis; a large proportion is also taken up post-anthesis (Table 6). [47]

Table 6: *Sulfur uptake by sunflower.*

Growth stage	% Uptake
Emergence – budding	20
Budding – anthesis	45
Post-anthesis	35

Sulfur has not been identified as a problem to date on the cracking clay soils of northern NSW and Queensland, which usually contain ample amounts of S as gypsum in the subsoil. Responses are most likely on shallow soils, deep sands and where sunflowers are double cropped.

If N is adequate but S is deficient:

- sulfur stress at budding will decrease oil yields by 30% due to lower single seed weight and less seeds per plant
- sulfur stress at anthesis will produce a 17% decrease in oil yield due to reduced seeds per plant due to floret abortion.

46 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

47 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

Sulfur deficiency can be corrected before anthesis, which will increase seed weight, providing N is adequate. [48]

5.9 Potassium

Potassium (K) is required for stalk and tissue strength. Sunflowers have a high requirement for K, with every 1 t/ha of yield removing 30 kg K/ha. [49] This is removed as 8 kg K/ha in the seed, and the remaining 22 kg K/ha in the stover. Responses to K are unlikely if soil test levels are >0.25 meq/100 g. [50] It becomes more critical when soil sodium levels rise; the plant requires more K in the soil than Na, otherwise the crop will take up too much Na and reduce yields (Figure 15).

There are anecdotal reports that sunflower stalks release K slowly during breakdown, having a beneficial effect on following crops such as cotton. [51]

While low K has been associated with increased crop lodging in other countries, K responses are generally not seen in sunflowers in Australia. [52]

Figure 15: *Potassium-deficient leaf showing marginal and interveinal chlorosis and necrosis.*

Photo: NJ Grundon

5.10 Boron

Sunflower is a crop that has a high boron (B) requirement and is very sensitive to boron deficiency. Despite the majority of sunflowers being grown on alkaline calcium rich soils which lower B availability, B deficiency is rare. Transitory B deficiency may occur as a result of climatic conditions that limit uptake and translocation of B from soil to plant structures undergoing rapid growth.

Boron content of many soils increases with depth, making deep soil sampling and plant tissue analysis necessary after root extension has reached at least 60 cm. Sunflower is tolerant of high soil B. [53]

Classical boron (B) deficiency symptoms and some others suspected to be caused by B deficiency have become more common over the past 5–7 years. Symptoms generally show up at or near flowering and include malformed upper leaves, which may show purplish or bronze-coloured patches.

The growing point may become necrotic, plants are stunted, internodes shortened and root development poor. Older leaves may have necrotic patches and

48 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

49 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

50 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

51 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and souther Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

52 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

53 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

discoloration and be thick and leathery. Flowers may be deformed and seed-set poor. Boron deficiency can also cause weakening of the stalk, resulting in lodging or head loss as the weight of the developing flower puts stress on the weakened stem. Black lesions are sometimes seen on the stem and deterioration of the pith is common.

Boron deficiency is commonly associated with moisture stress and need not be due to low levels of B in the soil. Instead, the ability to uptake and translocate B may be affected by stress. For example, B deficiency has been reported when good growing conditions are abruptly followed by hot dry conditions. Boron-deficient plants often show up in patches, particularly in shallow soils on ridgelines. [54]

5.11 Zinc

Fertiliser responses to zinc (Zn) often occur on heavy alkaline soils. However, they are more easily detected in crops such as maize and sorghum. Plant tissue analysis is a more reliable indicator of sunflower responsiveness than soil testing. Using starter fertilisers containing Zn or using foliar Zn applications can assist in addressing deficiencies. [55] Zinc can be broadcast at 10–20 kg Zn/ha and worked into the soil well before sowing. Banding Zn-compound fertilisers (rather than zinc-blended fertilisers) with the seed at planting is an effective way of applying zinc. Alternatively, when crops have 8–10 leaves, apply two foliar sprays of zinc sulfate heptahydrate solution (1 kg/100 L water) at 150–200 L/ha, 7–10 days apart. [56]

5.12 Fertiliser application guidelines

Germinating sunflower seed is very sensitive to fertiliser placed in the seed trench, and fertiliser should therefore be placed away from the seed, or consideration given to the amount and type of fertiliser placed in close contact with the seed (Table 7).

If sunflowers are planted using row crop equipment, the majority of the P and K should be side-banded 5 cm beside and 5 cm below the seed during planting. Some or all of the N can also be applied pre-plant or side-banded, provided that the total amount of fertiliser material (NPKS) side-banded does not exceed 330 kg/ha of product. Nitrogen can also be side-dressed before the plants are 30 cm tall (6–8 leaf stage).

If applying some starter fertiliser in the seed trench, the rates in Table 7 provide guidelines (kg/ha) for two common seedbed utilisation (SBU) factors for a light clay soil with good soil moisture in the seed zone. SBU is the opener width divided by row spacing times 100. For example, 2.5% SBU is 2.5 cm opener with 100 cm row spacing. [57]

Table 7: *Starter fertiliser rates based on common sunflower seedbed utilisation factors for a light clay soil with good soil moisture.*

Product (kg/ha)	Seedbed utilisation (%)	
	2.5%	3.3%
MAP	11.5	15
DAP	14	18

Source: Seed-Placed Fertilizer Decision Aid, International Plant Nutrition Institute

54 Australian Sunflower Association (2004) Boron deficiency. The New Big Black Sunflower Pack. p. 29. Australian Oilseeds Federation

55 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

56 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

57 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

5.13 Nutritional disorders

Diagnosing sunflower nutrient deficiencies or toxicities can be confusing as symptoms may appear similar to other environmental or disease conditions. Use soil and plant tissue testing as a guide as well as consulting with reference literature and industry resources to assist in correct identification. Table 8 contains a guide to some nutrient deficiencies and toxicities. [58]

Table 8: *Symptoms of nutrient deficiency and toxicity in sunflowers.* [59]

Deficiencies	Symptoms	Occurrence	May be confused with...	Management
Nitrogen	Pale older leaves, stunting, less leaves, thin stems	Sandy soils, low organic matter, long history of cropping, incorrect N budgeting, waterlogging.	S deficiency (first displays on new growth) which is opposite to N deficiency.	N budget before sowing to ensure adequate N applied at or before sowing for target yield. Foliar in crop if deficient before bud initiation
Phosphorus	Lack vigour, smaller plants and heads; slow maturity, thin stems, older leaves - grey necrosis initially on leaf tip margins. Water soaked necrotic concentric circles	Low organic matter, highly acidic or alkaline soils where P is more strongly adsorbed, long cropping history, low VAM, eroded topsoil	Reduced plant growth is very difficult to diagnose; leaf necrotic symptoms may be confused with Alternaria or Septoria	Preferably apply P at sowing banded below the seed as starter fertiliser also containing zinc
Potassium	Stunted plants, poor vigour, delayed maturity, oldest leaves interveinal chlorosis that develops necrosis. Leaves point down and may be cupped up or down.	Low organic matter, long history of cropping or haymaking, sandy low K soils - leached soils.	Mg deficiency	K fertiliser at or before sowing, not in contact with seed. Foliar spray possible but not usually requ1ired
Sulfur	Chlorosis of young leaves	Low organic matter, acid sandy soils, long cropping history	N deficiency; Mb deficiency	No field reports known but suspected. Apply gypsum or sulfate of ammonia pre sowing.
Calcium	Stunted plants, short thick stems; emerging leaves crinkled. Top leaves and head bracts may have interveinal necrosis or die if severe. Lower leaves may have mottled chlorosis and necrosis.	Acid sandy soils where Ca leached. Strongly alkaline or sodic soils; high Al and low exchangeable Ca levels	Cu deficiency {leaf crinkling). B deficiency (also affects growing point). However B deficiency causes thickening, cupping, bronzing.	Unlikely to occur. If it does apply lime or dolomite in acid soils or gypsum in alkaline soils.
Magnesium	Stunted plants, shortened internode length, thin stems. First notice mottled, interveinal chlorosis of lower leaves. Severe deficiency may cause leaf downward cupping and bronzing.	Acid sandy soils. Soils over fertilised with Ca or K.	K deficiency	No field reports known. If concerned could apply dolomite in the fallow prior to sowing or Magnesium sulfate at or before sowing.
Zinc	Stunted plants, young leaves narrow, wavy leaf margin, leaf wilting , brown spot necrosis on leaves	Highly alkaline soils, leached sandy soils, loss of topsoil, low arbuscular mycorrhiza soils	Moisture stressed - wilting	Starter fertiliser with P and Zn banded at sowing; foliar Zn chelate in crop
Boron	Youngest leaves and bud leaves pale yellow. Bud ceases to expand, develops grey necrotic area near leaf base, yellow mid leaf, green leaf tip	Leached sandy soils;alkaline soils with free lime; low organic matter	Ca or Cu deficiency in vegetative state	Chelated B sprays in crop

58 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

59 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Agronomy https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=5

Deficiencies	Symptoms	Occurrence	May be confused with...	Management
Iron	Younger leaves have pale yellow interveinal chlorosis, plant stunting, spindly stems. Severe cases develop brown necrosis	Alkaline soils as iron is less available at high pH. Waterlogged soils, acid soils with excess Mn, Zn, Cu, Ni	Zinc toxicity	Foliar spray of iron chelate
Molybdenum	Older leaves are pale yellow; leaves may become cupped with necrotic leaf margins. Reduced establishment, seedling death.	Acid soils especially under irrigation	N and S but they usually occur later than Mb symptoms and Mb more distinct	Apply sodium molybdate before sowing, or as an in crop foliar spray. Alternatively use a Mb seed dressing.
Toxicities	**Symptoms**	**Occurrence**	**May be confused with...**	**Management**
Aluminium	Roots discoloured, multiple short, thick lateralroots. Poor seedling emergence, stunted plants, low vigour and yield	Highly acidic soils (pH<5)	P and Mg deficiency on leaves	Lime acid soils to raise pH.
Manganese	Brown/black spots on lower stem, petioles, leaf blade hairs; severe symptoms are interveinal chlorosis upper leaves , white necrotic patches, leaf crinkling.	Highly acid soils or poorly drained soils high in Mn	Distinctly individual except petiole necrosis may look like Ca deficiency or disease	Lime acid soils, improve drainage. Don't grow sunflower in poorly drained soils

Source: Big Yellow Sunflower Pack 2015

MORE INFORMATION

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Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

Weed management studies in sunflower. V Osten, G Wright, M McCosker.

SC Peltzer, A Hashem, VA Osten, ML Gupta, AJ Diggle, GP Riethmuller, A Douglas, JM Moore, EA Koetz (2009) Weed management in wide-row cropping systems: a review of current practices and risks for Australian farming systems. Crop & Pasture Science 60, 395–406.

Weed control

Good weed control is essential for the production of high-yielding and profitable crops. Yield losses caused by weeds can vary greatly, from almost negligible to the complete loss of a crop. Weeds also cause harvest problems, reduce grain quality, contaminate grain, and re-infest paddocks. [1]

Weeds lower crop yields by competing for soil water, nutrients, space and light. In dryland crops where water is often limited, competition for water is the most important factor in reducing yields. For irrigated crops, competition for light and nutrients are more important. Cropping options can also be restricted by difficulty or inability to control weeds in some crops, for example burrs and thornapples in sunflowers.

The first 7 weeks after emergence is the most critical period for weed competition in sunflowers. Early sunflower growth can be reduced by as much as 39% without effective weed control. Additionally, weeds can harbour pests and diseases of the crop. [2]

It is important to rotate herbicide groups to reduce the risk of resistance to Group A herbicides.

The most common broadleaf weeds in sunflowers are bladder ketmia, fleabane (Figure 1), bindweed and milk thistle. The most common grass weeds in sunflowers are barnyard grass and volunteer sorghum.

Figure 1: *Fleabane is one of the most common broadleaf weeds in sunflower crops.*

1 J Fleming, T McNee, T Cook, B Manning (2013) Weed control in summer crops 2012–13. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/248471/Weed-control-in-summer-crops-2012–13.pdf

2 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

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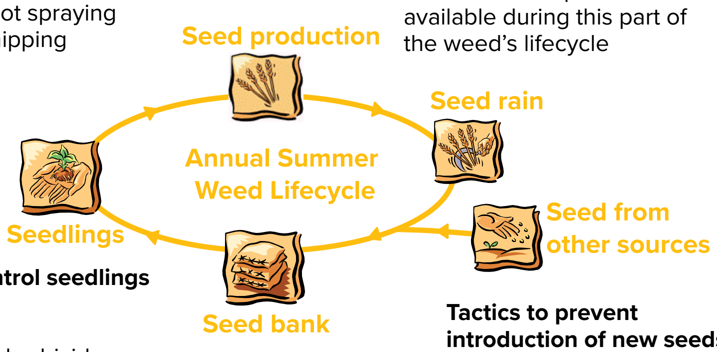
[A Storrie (2009) Collecting and preparing plant specimens for identification. NSW Industry & Investment, Primefact 919]

[DR Berglund (Ed.) (2007) Pest management—Weeds. In Sunflower production. Extension Publication A-1331. North Dakota Agricultural Experiment Station and North Dakota State University Extension Service]

Tactics to stop seed production
Fallow
- Spot spraying
- Grazing
- Chipping
At and just prior to planting
- Sow competitive crop
In-crop
- Crop desiccant for late flushes
- Spot spraying
- Chipping

Tactics to stop seed rain
Few effective options available during this part of the weed's lifecycle



Tactics to control seedlings
Fallow
- Cultivation
- Knock-down herbicides
- Double knock
At and just prior to planting
- Sowing with full disturbance
- Knockdown herbicides
- Double knock
- Sow competitive crop
In-crop
- Selective post-emergent herbicides)
- Inter-row cultivation
- Shielded spraying of knockdown herbicides

Tactics to deplete seed-bank
Fallow
- Residual herbicides
At and just prior to planting
- Pre-emergent residual herbicides
- Band application of residual herbicides
- Delayed sowing

Tactics to prevent introduction of new seeds
Fallow
- Manage adjacent non-crop areas
- Machinery hygiene
- Stop movement with stock
At and just prior to planting
- Manage adjacent non-crop areas
- Sowing weed-free seed
- Machinery hygiene
In-crop
- Manage adjacent non-crop areas
- Machinery hygiene

Figure 2: *Integrated weed management for sunflowers. (T McGillion and A Storrie, 2006; V Osten, 2010)* [3]

3 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

MORE INFORMATION

Maurie Street from Grain Orana Alliance discusses glyphosate resistance in ryegrass. GRDC Podcast: 080 Glyphosate resistance survey

Weed management in Queensland field crops

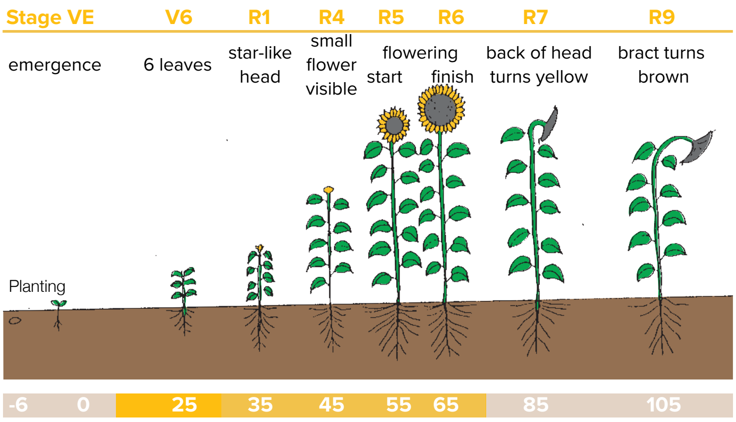


Figure 3: *Sunflower growth stages.* [4]

Table 1: *Herbicide application timing.* [5]

Pre-emergent	PSPE	Post-emergent	Pre-harvest desiccation
Incorporated (PSI)	metolachlor	butroxydim	diquat glyphosate
Incorporated by sowing (IBS)	pendimethalin	fluazifop-p	
metolachlor – PSI, IBS	prometryne	haloxyfop	
pendimethalin - PSI		propaquizafop	
trifluralin- PSI		quizalofop	
		sethoxydim	

In the 'Sunflowers in Northern NSW and Southern Qld—Tools for Success' benchmarking study, only 20% of paddocks in 2004–05 and 13% in 2003–04 and 2005–06 had no weeds detected. This indicates the need for better weed control in sunflowers. [6] The large number of weed species detected by the project and the prominence of broadleaf weeds is a reflection of the lack of herbicides available for post-emergence control of these weeds and limitations with paddock selection.

There are pre-emergence application options for sunflowers, and herbicides are registered and available for post-emergence control of grass weeds. With the increasing incidence of resistance to Group A herbicides, these options should be used as part of an integrated weed management strategy. The identification of glyphosate-resistant barnyard and liverseed grass in northern NSW is a further complication for weed management. Rotation of herbicide groups is difficult with many crops, including sunflower, so an integrated system that combines a number of tactics should be used for weed control. [7] Good herbicide-based weed control can be achieved in sunflowers when glyphosate-resistant barnyard grass and feathertop

4 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

5 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

6 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

7 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

Rhodes grass are present, through use of selective grass-weed control products such as haloxyfop (Verdict®).

Inter-row cultivation is an option to help control broadleaf weeds. Shielded spraying is used on a limited scale, because of the difficulty in application without damaging the sunflowers. [8]

Registered herbicide options for use in-crop are limited, so it is important to select paddocks with low weed populations, particularly broadleaf weeds.

Grass weed control options are available but are all Group A herbicides, and with increasing Group A herbicide resistance, post-emergence options are further reduced. Avoid paddocks that contain bladder ketmia, fleabane, bindweed, milk thistle, barnyard grass and volunteer sorghum, which were noted in the study to be particularly common.

The high incidence of barnyard grass is particularly important, with the recent identification of glyphosate resistance. Volunteer sorghum levels were of concern from a rotational point of view, illustrating the importance of effectively desiccating sorghum crops and fallow grass-weed control. [9]

For sporadic populations of weeds such as thornapples (*Datura* spp.), Noogoora burr and Johnson grass, the time-proven method of chipping or spot spraying is often the most effective and economical control and avoids expensive contaminations at harvest.

Important: You must use a product registered for the required purpose. Always check the label and follow the label instructions. State registration and label instructions should take precedence over all other recommendations. [10]

6.1 Fallow weed control

The increasing use of herbicides during the fallow period for fallow efficiencies and management of resistant weeds provides the same benefits to sunflower as to other summer crops. However, sunflowers are sensitive to some commonly used residual herbicides such as atrazine, chlorsulfuron (Glean®), picloram (Tordon®), imazethapyr (Spinnaker®), imazapic (Flame®), and metsulfuron-methyl (Ally®). These products should be avoided in areas that could be planted to sunflowers.

Some other chemicals used in fallow weed control have the potential to affect crop emergence if the crop is sown too soon after the chemical application. To reduce this risk, a plant-back period is recommended. Please check labels for guidance on plant-backs. Table 1 provides a guide to some commonly used chemicals. [11]

6.2 Pre-emergent herbicides

Paddocks with high broadleaf weed populations should be avoided as in-crop control options are limited and expensive. Pre-emergence application of Stomp® or Stomp Xtra® (pendimethalin) is an option for controlling several grass and broadleaf weeds in sunflower. [12]

Pre-emergent (soil-active/residual) herbicides need to be incorporated by cultivation (pre-emergent or incorporated-by-sowing) or rainfall (post-sowing pre-emergent) to be effective. The efficacy of these herbicides is often compromised by lack of incorporation in no-till systems, crop residues and highly variable rainfall. Even with

8 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

9 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

10 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

11 Australian Sunflower Association (2004) Weed management. The New Big Black Sunflower Pack. Australian Oilseeds Federation

12 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

MORE INFORMATION

http://www.australianoilseeds.com/Technical_Info/apvma_minor_crop_permits#Sunflower

www.apvma.gov.au

PODCAST

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

MORE INFORMATION

http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/summer

Raising the bar with better sunflower agronomy

MORE INFORMATION

http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/summer

MORE INFORMATION

GRDC Update Paper: Pre-emergent herbicides part of the solution but much still to learn

High plains sunflower production handbook MF2384 (1999) Kansas State University Agricultural Research Station and Cooperative Extension Service

incorporation, if no follow-up rain occurs for weeks or months, the herbicides can remain inactive in the topsoil. Weeds can germinate below the chemical band and emerge through the dry soil and establish. These herbicides are only effective on establishing seedlings and have little effect on established plants.

These herbicides are highly effective and reliable in irrigated sunflowers. [13]

Table 3: *Herbicides for grass weeds – pre-emergent application – and weeds controlled or suppressed.*

Active constituent	**metolachlor 720 g/L & s-metolachlor 960 g/L**	**pendimethalin 330, 440 & 455 g/L**	**trifluralin 480 g/L**
Trade names	Various & Dual® Gold	Various & Stomp® Xtra	Various
Incorporation / timing	PSI, IBS, PSPE,	PSI, PSPE	PSI
Grass weeds			
Annual phalaris			✓
Annual ryegrass			✓
Barnyard grass	✓	✓	✓
Button grass			
Crab grass			✓
Crowsfoot grass	✓	✓	
Early spring grass		✓	
Guinea grass			✓
Johnson grass seedlings			✓
Liverseed grass	✓	✓	✓
Mossman river grass		✓	✓
Native millet		✓	
Pale pigeon grass	✓	✓	
Paspalidium		✓	
Pepper grass		✓	
Qld bluegrass		✓	
Red flinders grass		✓	
Spiny burr grass			
Stink grass		✓	
Summer grass	✓		✓
Weeping lovegrass	✓	✓	✓
Wild oats			
Herbicide group	K	D	D

NOTE: PSI = pre-sowing incorporated; IBS = Incorporated by sowing; PSPE = post sowing pre-emergent
Adapted from: Manning et al. 2008; Infopest, Nov 2009

13 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

Table 4: *Herbicides for broadleaf weeds – pre-sowing application – and weeds controlled or suppressed.*

Active constituent	**metolachlor 720 g/L & s-metolachlor 960 g/L**	**pendimethalin 330, 435, 440 & 455 g/L**	**trifluralin 480 g/L**
Trade names	Various & Dual® Gold	Various & Stomp® Xtra	Various
Incorporation / timing	PSI, IBS	PSI	PSI
Broadleaf weeds			
Amaranthus		✓	✓
Blackberry nightshade	✓	✓	✓
Common heliotrope		✓	✓
Fat hen	✓	✓	
Mintweed		✓	
Pigweed	✓	✓	✓
Potato weed	✓		
Redshank			✓
Sowthistle	✓		
Stagger weed		✓	
Wandering jew	✓		
Wireweed		✓	✓
Yellow vine (caltrop)		✓	✓
Herbicide Group	K	D	D

Adapted from: Manning et al. 2008; Infopest, Nov 2009

Table 5: *Herbicides for broadleaf weeds – post sowing pre-emergent application – and weeds controlled or suppressed.*

Active constituent	metolachlor 720 g/L & s-metolachlor 960 g/L	pendimethalin 330, 435, 440 & 455 g/L	prometryne 900 g/kg
Trade names	Various & Dual® Gold	Various & Stomp® Xtra	Nufarm Prometryne 900
Incorporation / timing	PSPE	PSPE	PSPE
Broadleaf weeds			
Amaranthus		✓	✓
Blackberry nightshade	✓		
Bladder ketmia			✓
Common heliotrope		✓	
Fat hen	✓		
Mintweed		✓	
Morning glory			✓
Pigweed	✓	✓	✓
Potato weed	✓		
Sowthistle	✓	✓	
Stagger weed		✓	
Wandering jew	✓		
Wireweed		✓	
Yellow vine (caltrop)		✓	✓
Herbicide Group	K	D	D

Adapted from: Manning et al. 2008; Infopest, Nov 2009

6.3 Post-emergent herbicides

Post-emergent herbicides have the advantage that they are not applied until the weeds have emerged. There are a number of highly effective grass herbicides (Table 5) registered for use in sunflowers. However, there are no selective post-emergent herbicides registered for broadleaf weeds.

The major disadvantages for post-emergent herbicides are poor control due to poor application and unsuitable meteorological conditions during and after application and plant stress.

Herbicide resistance risk for the Group A mode of action selective grass herbicides is high. Therefore, over-use of these products without an integrated weed management plan in operation, will lead to the failure of these herbicides in as few as six applications.

MORE INFORMATION

J Fleming, T McNee, T Cook, B Manning (2012) Weed control in summer crops 2012–13. NSW Department of Primary Industries

Pest Genie

JT O'Donovan, EA de St. Remy, PA O'Sullivan, DA Dew, AK Sharma (1985) Influence of the relative time of emergence of wild oat (Avena fatua) on yield loss of barley (Hordeum vulgare) and wheat (Triticum aestivum). Weed Science 33, 498–503.

Table 6: *Post-emergent selective grass herbicides and weeds controlled or suppressed.*

Active constituent	butroxydim 250 g/kg	fluazifop-p 212 & 128 g/L	haloxyfop-r 520 g/L	propaquizafop 100 g/L	quizalafop-p- ethyl 99.5 g/L	sethoxydim 186 g/L
Trade names	Factor® WG	Various & Fusilade® Forte	Verdict® 520 & various	Correct® & various	Targa® & various	Sertin® 186 EC
Annual ryegrass					✓	✓
Barnyard grass	✓	✓	✓	✓	✓	✓
Crab grass	✓	✓				
Crowsfoot grass	✓	✓	✓	✓	✓	✓
Dinebra	✓				✓	
Early spring grass	✓					
Johnson grass seedlings	✓	✓	✓	✓	✓	✓
Liverseed grass	✓	✓	✓	✓	✓	✓
Millet	✓		✓		✓	
Mossman river grass		✓	✓			
Pale pigeon grass		✓			✓	
Rhodes grass	✓	✓			✓	
Spiny burr grass	✓					
Stink grass	✓				✓	✓
Summer grass	✓	✓	✓		✓	✓
Sweet summer grass						
Volunteer barley	✓		✓	✓	✓	
Volunteer maize	✓					
Volunteer sorghum	✓			✓		✓
Volunteer wheat	✓		✓	✓	✓	✓
Windmill grass	✓					
Wild oats		✓			✓	✓
Herbicide group	A	A	A	A	A	A

Adapted from: Manning et al. 2008; Infopest, Nov 2009

6.4 Inter-row spraying

Effective weed control to ensure maximum yields and a clean grain sample is best achieved by a combination of crop rotation, good fallow weed control, judicious use of the range of registered herbicides, inter-row cultivation and shielded spraying.

Sunflowers are poor competitors compared to many other crops such as winter cereals. Despite this, the best available agronomy should be implemented to optimise crop environment and growth. Parameters that can improve competitiveness, include crop variety choice, row spacing, sowing rate and sowing depth, optimal crop nutrition and control of diseases and pests.

The development and adoption of auto-steer systems has made inter-row control of weeds in crops more feasible due to reduced operator error during the weed control operation.

MORE INFORMATION

V Osten, H Wu, S Walker, G Wright, A Shields (2006) Weeds and summer crop row spacing studies in Queensland. In Proceedings of the 15th Australian Weeds Conference. Weed Management Society of South Australia

http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/summer

Inter-row weed control allows the use of low herbicide resistance risk, non-selective herbicides to control a range of grass and broadleaf weed seedlings. In sunflowers, this can be particularly useful for the management of broadleaf weeds.

Directed (without shields) inter-row spraying can be effective if used when crop plants are small and conditions minimise the risk of herbicide contacting the crop.

Inter-row shielded spraying is an effective method of controlling small seedlings early in the crops growth with lower risks of crop damage compared with directed sprays.

Shielded sprayers must be correctly calibrated and operated. The bottom of the shields must be less than 5 cm from the ground, and coarse spray droplets used. This means keeping application volumes greater than 70 L/ha and ground speeds around 5 kph.

Dust produced by the shield skirts can also reduce the effectiveness of the herbicide, particularly glyphosate, paraquat and diquat.

The herbicides registered for use in sunflowers for inter-row application using a shield sprayer are paraquat, diquat and 2,2-DPA. [14]

For more information consult your agronomist.

6.5 Cultural control: inter-row cultivation

Inter-row cultivation gives the opportunity to control small annual weeds without herbicides, or in combination with over-row banded herbicides and can be used as a ´back up´ if herbicides fail. Moisture stressed or herbicide resistant weeds can also be controlled. Inter-row cultivation is more effective in drier seasons with higher levels of control and less stimulation of weed germination.

Studies in central Queensland have shown that inter-row cultivation can reduce the effects of a competitive weed like sweet summer grass that can reduce sunflower yield by 65%.

Inter-row cultivation in sunflowers is normally conducted when the crop is 5 to 6 leaf.

Like spraying, weed size is critical to high levels of weed control. Research in Canada found that, as weed size increased, level of control decreased. Table 11 shows the effect of timing of rotary hoeing on control of fat hen (*Chenopodium album*). With many weed species the highest levels of control occurs using cultivation after germination but before emergence. Therefore, highest levels of control will be achieved with two cultivations.

Inter-row cultivation is now more feasible with guidance technology like Robocrop® ‘floating’ tool bar systems and auto-steer. Operator fatigue has always been a problem with inter-row cultivation and spraying leading to crop damage and loss of sections of crop row. These systems allow closer cultivation to the crop row and reduce the number of weeds near the row which compete strongly with young sunflowers.

Timing of inter-row cultivation will also be determined by the developmental stage of the crop. Cultivating when the crop is too large can damage roots, reducing yield.

Use of inter-row cultivation will also be restricted if stubble cover is high. Cultivation in high trash cover can cause balling of the stubble with soil, which could bury crop plants and make further inter-row operation difficult. Loss of stubble cover from cultivation also poses significant moisture loss and erosion risks.

Inter-row operations are relatively slow with 40 ha treated per day being typical.

14 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

MORE INFORMATION

Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

6.6 Potential herbicide damage effect

Sunflowers can be unintentionally damaged by herbicides via application of registered products, soil residues and herbicide drift. Sunflowers are particularly sensitive to atrazine (Group C), and sulfonylurea (Group B) herbicides such as metsulfuron, chlorsulfuron and triasulfuron

Research conducted in northern NSW in the 2007–08 season showed that registered products can cause crop yellowing and stunting, although sunflowers may be more tolerant to damage sustained early in the season. Vapour drift is confined to volatile herbicides such as 2,4-D ester. [15]

Vapours may arise directly from the spray or from evaporation of herbicide from sprayed surfaces. Use of 2,4-D ester in summer can lead to vapour drift damage of highly susceptible crops such as tomatoes, sunflowers, soybeans, cotton and grapes. This may occur hours after the herbicide has been applied.

Vapours and minute particles float in the may be carried for many kilometres in thermal updraughts before being deposited.

Sensitive crops may be up to 10,000 times more sensitive than the crop being sprayed. Even small quantities of drifting herbicide can cause severe damage to highly sensitive plants. [16]

6.7 References and further reading

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DC Cloutier, ML Leblanc (2001) Mechanical weed control in agriculture. In Physical control methods in plant protection. (Eds C Vincent, B Panneton, F Fleurat-Lessard) Springer, pp. 191–203

JF Holland, DW McNamara (1982) Weed control and row spacing in dry-land grain sorghum in northern NSW. Australian Journal of Experimental Agriculture & Animal Husbandry 22, 310–316

T McGillion, A Storrie (Eds) (2006) Integrated weed management in Australian cropping systems—a training resource for farm advisors. CRC for Australian Weed Management

15 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Weed Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=4

16 J Fleming, T McNee, T Cook, B Manning (2013) Weed control in summer crops 2012–13. NSW DPI Management Guide. NSW Department of Agriculture, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/248471/Weed-control-in-summer-crops-2012-13.pdf

Insect control

Sunflowers are attacked by a number of insect pests at various stages of crop development. Most pests are not specific to sunflowers and originate from other crops, weed hosts or plant residues in the soil.

7.1 Establishment pests

Several species of soil-dwelling insects attack seeds and seedlings of sunflowers, causing thinning or complete destruction of plant stands. Sunflowers are more susceptible to seedling damage than other field crops because damaged sunflower seedlings lack the capacity to regrow or tiller. Seedlings are most vulnerable to damage:

- before they develop three or four 'true' leaves
- during periods of moisture stress
- when other factors such as low soil temperature or soil compaction limit plant growth [1]

Establishment pests include false wireworm, true wireworm, wingless cockroaches, field crickets, thrips, black field earwigs, black scarab beetles, cutworms and armyworms (Figure 1). These pests are significant only in central Queensland, except false wireworm larvae, which can affect spring plantings in southern Queensland and northern NSW. [2]

Figure 1: *Armyworms are among the significant establishment pests of sunflowers.*

Photo: Drew Penberthy, Penagcon

1 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers#Wireworms

2 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

7.2 Post-establishment pests

Once sunflowers have established, several other pests can attack the crop. Post-establishment pests include Rutherglen bug (*Nysius vinitor and N. clevelandensis*), heliothis (*Helicoverpa* spp.) caterpillars, whiteflies, loopers, and green vegetable bug (*Nezara viridula*). [3] However, the major pests requiring monitoring in the period from budding to maturity are the Rutherglen bug and *Helicoverpa* caterpillars. [4]

Bees

Bees play only a small role in sunflower yields, except in seed production blocks, but are often seen foraging in large numbers in sunflower fields (Figure 2). When it is necessary to apply insecticides during flowering, give preference to insecticides with a low residual toxicity and spray in the late afternoon when bees have stopped foraging. [5]

Figure 2: *Bees are often seen foraging in large numbers in sunflowers but only play a small role in yields.*

Photo: Drew Penberthy, Penagcon

Management

Soil-dwelling insects such as false wireworm beetles, cockroaches and black field crickets have the potential to significantly reduce plant stands. Activity is likely to be greatest in retained stubble, but the benefits of stubble retention far outweigh insect damage. However monitoring for, and control of, these insects is relatively simple and inexpensive. [6]

3 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers -Wireworms

4 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

5 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

6 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

Check the seedbed before planting and check the crop regularly and thoroughly for insect pests (see Figure 3 for critical inspection times). Spray only when the insect population exceeds the economic threshold and only use registered insecticides. [7]

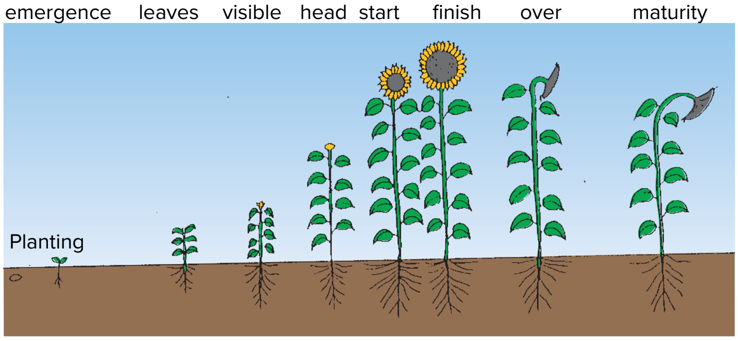

Figure 3: *Critical inspection times for sunflower pests.*

Source: Australian Sunflower Association

Recommended action:

- Check fields for insect activity and bait at planting if the level of activity warrants (see Figure 3 for critical inspection times).
- If baiting is not done at planting, continue to monitor closely during emergence; baiting during emergence can still be effective, either by ground or by air.

Recommended baits:

- Beetle Bait® is a pellet impregnated with chlorpyrifos. The pellet facilitates uniform distribution, and with the insecticide impregnated into the pellet, the product should be more effective over time.
- Bait can be prepared on the farm by mixing 100 mL Lorsban® 500 EC with 125 mL sunflower oil per 2.5 kg cracked wheat or cracked sorghum. [8]

For application rates see: Australian Sunflower Association - The New Big Black Sunflower Pack - Insect Management

MORE INFORMATION

[QDAF. How to recognise and monitor soil insects.](#)

[QDAF. Chemical control of insects – consideration and choices.](#)

[NSW DPI Management Guide. Summer crop production guide. Sunflower.](#)

[Australian Pesticides and Veterinary Medicines Authority - Public Chemical Information System Search](#)

[Better Sunflower Association – Insect Management Library.](#)

7 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

8 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

7.3 False wireworms

Striate false wireworm (*Pterohelaeus alternatus*), eastern false wireworm (*P. darlingensis*) (Figure 4) and southern false wireworm (*Gonocephalum macleayi*) are minor establishment pests in sunflowers, with frequent small populations. [9]

Adult false wireworms (Figure 5) emerge from the soil during spring and early summer. Eggs are laid singly in moist soil, usually under trash or low-growing weeds. Larvae feed on decaying vegetable matter and newly germinated seeds (e.g. cereals, cotton, soybeans and sunflowers). Both the seeds and growing points are damaged, resulting in patchy stands. [10]

Figure 4: *Eastern false wireworm larva and adult.*

Photo: QDAF

Figure 5: *Small false wireworm larva and adult.*

Photo: QDAF

9 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

10 QDAF (2010) Soil insects in Queensland. False wireworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/false-wireworm

7.3.1 Damage

Both adults and larvae attack sunflower, and the damage caused may necessitate replanting. Larvae feed on decaying vegetable and crop residues in the soil. They also feed on newly germinating seed and the growing points of seedlings, which results in patchy stands. Damage is most common in early-planted crops where crop residue has become scarce. During summer, adults may damage young plants by surface feeding or cutting of the plant at or near soil level. Larvae are more damaging in southern Queensland, whereas adults are the most damaging stage in central and northern districts. [11]

The risk from adults is highest in summer. For larvae, the risk is highest for early (September–October) planted crops. Damage may occur if early plant growth is slowed by cool, damp weather allowing larvae to remain in the moist root-zone. As soil dries, larvae retreat below the root-zone. However, if crops are grown into dry seedbeds, damage may be significant. [12]

False wireworm damage is similar to that caused by the wireworm; however, it is more prevalent in dry seedbeds. Wireworms are usually found at the interface between dry and wet soil. [13]

MORE INFORMATION

QDAF. How to recognise and monitor soil insects.

7.3.2 Thresholds for control

Detection of false wireworms can be difficult. The suggested method is either to hand-sift 10 soil samples (30 by 30 cm) or place 10 germinating seed baits (GSBs) monitoring for soil-dwelling insects throughout the paddock. One larva per sample warrants control. [14] [15]

7.3.3 Management

High mortality of false wireworms can be caused by cool, wet weather from autumn to spring.

False wireworm beetles are more damaging to sunflower seedlings where stubble is buried by cultivation than in crops that are directly drilled into the surface-retained stubble. This is because the surface-feeding beetles remain feeding on the stubble and not the crop.

Key points on managing false wireworms: [16]

- Check the seedbed prior to sowing.
- Prepare the ground for even and rapid germination.
- Using press-wheels at planting provides some control. [17]
- Clean cultivation during summer dries out the topsoil and eliminates weeds that provide food for adults.
- Larvae can be controlled by insecticide applications at planting or insecticide-treated seed.

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11 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

12 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

13 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

14 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

15 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

16 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

17 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

- Control of adults is obtained by baiting with insecticide-treated, cracked grain broadcast evenly over the surface at or immediately after planting.
- Where broadcasting is not possible, the bait may be laid in trials spaced no more than 2 m apart.
- Natural enemies provide little control.

See Table 1 below for further description of the species, damage caused, and management and control strategies.

Table 1: *False wireworm description and management summary.* [18]

Scientific name	*Pteroheláeus* spp., *Gonocephalum* spp.
Description	Larvae are up to 30 mm long, shiny and cream, yellow or tan with three pairs of legs just behind the head. They are hard-bodied, cylindrical and segmented with a rounded head. Adult beetles of *Pterohelaeus* spp. are 20 mm long and dark grey–black with a distinctive 'pie-dish' shape formed by flanges around the outline of the beetle. Adult beetles of *Gonocephalum* spp. are 9 mm long, dark grey–black, and often covered in soil. There are flanges around the outline of the thorax (behind the head).
Similar species	Several species of false wireworms may occur in any particular crop, depending on locality, soil type, organic matter and tillage practices: *Pterohelaeus* spp.—eastern false wireworm, striate false wireworm *Gonocephalum* spp.—small false wireworm, southern false wireworm, northern false wireworm
Life-cycle	Larvae feed on decaying vegetable matter and crop residues in the soil, as well as on newly germinated seed. They usually have a single generation per year.
Risk period	Larvae cause most damage to germinating crops during spring, whereas adults are most troublesome in summer.
Damage	Larvae feed on germinating seed and chew on seedling roots and shoots, resulting in patchy stands. Adults chew on seedlings at or above ground level, ring-barking or completely cutting the stem.
Monitoring	Use germinating seed baits (GSBs) or digging and sieving to detect larvae prior to planting.
Action level	Treatment is required if >25 wireworm larvae are found in 20 GSBs. For adults, apply bait to the whole field if the soil insect rating (SIR) is >6.
Control	**Chemical control.** For larvae, use seed dressings or in-furrow sprays. For adults, use cracked grain baits. See Pest Genie or APVMA for current chemical options. **Cultural control.** The false wireworm is mainly a pest in areas having heavy, black soils. It prefers cultivated soils rather than no-till. Use press-wheels at sowing, set at 2–4 kg per cm width after planting rain or 4–8 kg per cm in dry soil.
Pest status	Minor, widespread, regular.

MORE INFORMATION

NSW DPI Management guide.
Summer crop production guide.
Insecticide seed dressings table

7.4 True wireworm

True wireworms (*Agrypnus* spp.), whose adults are also known as click-beetles, are an establishment pest named for the supposed wire-like appearance of their larvae (Figure 6). True wireworm adults are elongated beetles that jump and click when disturbed (Figure 7). Larvae are similar to false wireworm larvae. They may also be mistaken for predatory larvae of other beetles. [19] See Table 2 for a more detailed description of true wireworms.

18 QDAF (2010) Soil insects in Queensland. False wireworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/false-wireworm

19 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

Figure 6: *True wireworm larva showing dark, flattened head.*

Photo: QDAF

Figure 7: *True wireworm adult.*

Photo: QDAF

MORE INFORMATION

QDAF. How to recognise and monitor soil insects.

7.4.1 Damage

Larvae bore into germinating seed and chew on seedling roots and shoots, resulting in reduced vigour or seedling death. [20]

7.4.2 Thresholds for control

Use the GSB [21] technique or soil sampling to detect larvae prior to sowing. Monitor crops after sowing until establishment. Treatment is required if >25 wireworm larvae are found in 20 GSBs (Table 2). [22]

7.4.3 Management

Seed dressings, in-furrow sprays and granular insecticides offer some control. For current chemical control options see Pest Genie or APVMA. [23]

Table 2: *True wireworm description and management summary.* [24]

Scientific name	*Agrypnus* spp.
Description	Eggs are ovoid, 0.6 by 0.5 mm. Larvae grow to 35 mm long, are shiny and cream, yellow or tan, with three pairs of legs behind the head. Unlike false wireworms, they are soft-bodied, and flatter in cross-section with a flattened head. Adult beetles are 25 mm long, grey to brown and are known as click beetles.
Similar species	Larvae are similar to false wireworm larvae.
Crops attacked	All field crops. True wireworms are omnivorous. They originally inhabited native grasslands but have adapted to feeding on cultivated crops including field crops and pastures. They are also predatory, feeding on soil invertebrates.
Life-cycle	Most individuals complete a single generation in a year, but a small number complete two generations in a year. In Queensland, adults emerge between late October and early February, with most emerging between November and early December. Adults shelter in refuges for several weeks, then move into the soil, where they may be found to a depth of 7 cm. Females lay eggs 3–4 weeks after emergence, either singly on the soil surface or in batches of 10–15 eggs in crevices to 5 cm deep in the soil. There are eight larval instars with a total average larval duration of 315 days; the last instar, the most damaging, occupies 48% of this time. Larvae pupate in cells in the soil during October–January. Adults emerge after 14 days. Adult females live for a maximum of 7 weeks in the field. Unlike several species of click beetles, sugarcane wireworm adults do not fly to lights. Adults and larvae feed in the soil on vegetation, including roots. Larvae may also feed on soil and invertebrates.
Risk period	Immediately after sowing and early seedling growth, especially if germination is delayed by cold, wet weather.
Damage	Larvae bore into germinating seed and chew on seedling roots and shoots, resulting in reduced vigour or seedling death.
Monitoring and action level	Use germinating seed baits (GSBs) or soil sampling to detect larvae prior to sowing. Monitor crops after sowing until establishment. Treatment is required if >25 wireworm larvae are found in 20 GSBs.
Chemical control	Seed dressings, in-furrow sprays and granular insecticides offer some control. For current chemical control options see Pest Genie or APVMA.
Natural enemies	Common brown earwig.

20 QDAF (2010) Soil insects in Queensland. True wireworm, click beetle or sugar-cane wireworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/true-wireworm

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

22 QDAF (2010) Soil insects in Queensland. True wireworm, click beetle or sugar-cane wireworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/true-wireworm

23 QDAF (2010) Soil insects in Queensland. True wireworm, click beetle or sugar-cane wireworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/true-wireworm

24 QDAF (2010) Soil insects in Queensland. True wireworm, click beetle or sugar-cane wireworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/true-wireworm

7.5 Cutworms

Cutworm (*Agrotis* spp.) is an establishment pest in sunflowers. The common name of cutworms is derived from the larval habit of severing the stems of young seedlings at or near ground level, causing the collapse of the plant (Figure 8).

Several species of cutworms, including *Agrotis munda* (brown cutworm), *A. infusa* (Bogong moth) and *A. ipsilon* (black cutworm) and *A. prophyricollis* (variable cutworm) attack a wide range of crops in Queensland. [25]

Figure 8: *Cutworm larvae on the soil.*

Photo: QDAF/J Wessels

7.5.1 Damage

Cutworms can severely damage crops during establishment (Table 3). [26] Crop areas attacked by cutworms tend to be patchy, and the destruction of seedlings in one area may cause cutworms to migrate to adjacent fields. [27]

Cutworms feed at night or on dull, overcast days. Cutworms seek shelter under the soil surface during the day. Large cutworms cut the stem off at ground level, and smaller cutworms eat the leaves. [28] Sometimes the young plant is partially dragged into the soil where the larvae feed on it. Larvae may also climb plants and browse on or cut off leaves.

The risk period is summer and spring—one generation per crop. [29]

7.5.2 Thresholds for control

There are no established threshold numbers in sunflower. NSW Department of Primary Industry recommends treatment at the first sign of damage. [30] Department of Agriculture, Fisheries and Forestry Queensland suggests treating seedlings when there is a rapidly increasing area or proportion of crop damage (>10% seedling loss) and treating older plants if >90% of plants are infested or >50% of plants have ≥75 leaf tissue loss. [31]

25 QDAF (2010) Soil insects in Queensland. Cutworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/cutworm

26 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

27 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

28 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

29 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

30 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

31 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

7.5.3 Management

Check crops late in the afternoon or evening and control if damage is obvious (Table 3). Control at an early stage is recommended because sunflowers do not have a compensatory mechanism such as tillering to recover from any stand losses. [32]

Chemical control may be cost-effective. Spot spraying of identified patches may suffice. Spray in the late afternoon, close to feeding time, for best results.

Controlling weeds prior to planting will reduce cutworm infestations.

Cutworms are attacked by a range of natural enemies including common brown earwigs, orange caterpillar parasite, two-tones caterpillar parasite, orchid dupe, spiders and Bt (*Bacillus thuringiensis*) bacteria. [33]

Table 3: *Cutworm description and management summary.* [34]

Scientific name	*Agrotis* spp.
Description	Larvae are up to 50 mm long, hairless with dark heads and usually darkish coloured bodies, often with longitudinal lines and/or dark spots. Larvae curl up and remain motionless if picked up. Moths are a dull brown–black colour.
Similar species	May be confused with armyworms and Helicoverpa larvae.
Crops attacked	All field crops. Crops are at most risk during seedling and early vegetative stages.
Damage	Young caterpillars climb plants and skeletonise the leaves or eat small holes. The older larvae may also climb to browse or cut off leaves, but commonly cut through stems at ground level and feed on the top growth of felled plants. Caterpillars that are almost fully grown often remain underground and chew into plants at or below ground level. They usually feed in the late afternoon or at night. By day, they hide under debris or in the soil.
Monitoring and action level	Inspect crop twice weekly in seedling and early vegetative stage. Larvae feed late afternoons and evenings. Chemical control is warranted when there is a rapidly increasing area or proportion of crop damage.
Life-cycle	Usually a single generation during early vegetative stages. Moths prefer to lay their eggs in soil in lightly vegetated (e.g. a weedy fallow) or bare areas. Early autumn egg-laying results in most damage to young cereals. Larvae hatch and feed on host plants right through to maturity. Mature larvae pupate in the soil. Under favourable conditions, the duration from egg-lay to adult emergence is 8–11 weeks, depending on the species.
Control	**Chemical control.** Insecticide application is cost-effective. The whole crop may not need to be sprayed if distribution is patchy; spot spraying may suffice. See Pest Genie or APVMA for current control options. **Cultural control.** Control weeds 3–4 weeks prior to sowing. **Natural enemies.** Cutworms are attacked by a number of predators, parasites and diseases.
Pest status	Minor, widespread, irregular.

MORE INFORMATION

QDAF. Insect pest management in sunflowers.

32 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

33 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

34 QDAF (2010) Soil insects in Queensland. Cutworm. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/cutworm

7.6 Black scarab beetles

At least two species of black scarab beetles, or black sunflower scarab, (*Pseudoheteronyx* spp.), are known to attack sunflowers (Figures 9 and 10). Black scarab beetles are an establishment pest and the life-cycle on sunflowers is one generation per year, with the adults damaging the crops in summer. [35]

Figure 9: *Black scarab beetle adults.*

Photo: QDAF

Figure 10: *Seedling damage caused by the adult black scarab beetle.*

Photo: QDAF

7.6.1 Damage

Black scarab beetle larvae feed on taproots, causing wilting and death of seedlings, whereas adult beetles can defoliate and kill plants up to 40 cm tall (Table 4). Adults often feed in a line across the field. Beetles hide in the soil during the day and emerge late afternoon to feed. [36]

35 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

36 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

7.6.2 Thresholds for control

Monitor the soil by digging and sieving for the presence of larvae prior to planting, and at all stages for adults. Look for feeding beetles just before sunset (Table 4). Four beetles per square metre can cause severe losses to young seedlings and may warrant control. [37]

7.6.3 Management

Limited control can be achieved by spraying, with registered chemicals, either side of the feeding line. Spray when beetles are active on the soil surface. Beetles can also be controlled by application of pelleted baits (lucerne or similar meal) at planting. Cracked grain baits do not control beetles.

Damage is most prevalent where sunflowers follow wheat, sorghum or grass pasture.

Removal of the host parthenium weed is advised.

Table 4: *Black scarab beetle description and management summary.* [38]

Scientific name	*Pseudoheteronyx basicollis*
Description	Larvae are creamy white with a grey rear end, brown head capsule and up to 25 mm long. They are C-shaped grubs with wrinkly bodies. Adult beetles are 13 mm long, shiny and black.
Similar species	White grubs/peanut scarabs
Distribution	Queensland
Crops attacked	Sunflower. Parthenium weed is a favoured host but the larvae can develop on the roots of numerous grasses and weeds.
Life-cycle	One generation per year, with adults damaging sunflower crops in summer.
Damage	Larvae feed on taproots, causing wilting and death of plants up to 400 mm high. Damage is most prevalent where sunflowers follow wheat, sorghum or grass pasture. Adult beetles feed on foliage, often in a line across the field.
Monitoring and action level	Check in the soil by digging and sieving for the presence of larvae prior to planting, and at all stages for adults. Particularly look for feeding beetles just before sunset. Four beetles per square metre can cause severe losses to young seedlings.
Control	**Chemical control.** Chemicals are registered but are of limited effectiveness. For current chemical control options see Pest Genie or APVMA. **Cultural control.** Removal of the host parthenium weed is advised. Damage is most prevalent where sunflowers follow wheat, sorghum or grass pasture.
Conservation of natural enemies	No effective natural enemies have been identified.

MORE INFORMATION

Australian Pesticides and Veterinary Medicines Authority - Public Chemical Information System Search

37 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

38 QDAF (2010) Soil insects in Queensland. Black sunflower scarab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/black-sunflower-scarab

7.7 Thrips

Several different species of thrips act as an establishment pest on sunflowers; these include onion thrips (*Thrips tabaci*; Figure 11, Table 5), tomato thrips (*Frankliniella schultzei*; Figure 12) and plague thrips (*Thrips imaginis*) (Table 6), and western flower thrips (*Frankliniella occidentalis*; Table 7). [39]

For many field crops (apart from beans), thrips are a significant pest only at the seedling stage. They infest the underside of cotyledons, young leaves and growing points. Adults and nymphs pierce the leaf and suck out sap. Affected areas are silvery-white, and younger leaves become distorted in shape and growing points can die. Damage is more significant if seedlings are not actively growing.

Flower thrips feed inside navy bean and mungbean flowers, causing flower abortion and pod distortion. Deformed pods may be difficult to thresh, resulting in further yield losses. [40]

Thrips are most abundant during a hot, dry spring following a mild dry winter. [41]

7.7.1 Onion thrips

Figure 11: *Onion thrips showing winged adults and nymphs.*

Photo: D Ironside, QDAF

39 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

40 QDAF (2010) Managing insect pests in field crops. Thrips in field crops. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/thrips-overview

41 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

Table 5: *Onion thrips description and management summary.* [42]

Scientific name	*Thrips tabaci*. Also known as cotton seedling thrips or tobacco thrips.
Description	Adult thrips are 2 mm long and are dark, cigar-shaped and have narrow wings folded along their back. Nymphs are smaller, lack wings and are pale. Thrips species can only be determined microscopically.
Distribution	Recorded in all Australian states.
Crops attacked	Cotton, navy bean, mungbean, cereals. sunflowers
Life-cycle	Adult thrips can infest a seedling's growing point as soon as it emerges from the ground. In cracking soils, seedlings may be infested before they emerge. Nymphs feed inside vegetative terminals. Populations typically peak within 4 weeks of plant emergence. Spring-planted crops are at greatest risk, especially those close to maturing cereal crops.
Damage	For many field crops (apart from beans), thrips are only a significant pest at the seedling stage. They infest the underside of cotyledons, young leaves and growing points. Adults and nymphs pierce the leaf and suck out sap. Affected areas are silvery-white, and younger leaves become distorted in shape and growing points can die. Damage is more significant if seedlings are not actively growing.
Monitoring and action level	Open and microscopically examine the plant's growing points; they can also be dunked in alcohol to dislodge thrips. There are no action level thresholds for seedling thrips.
Chemical control	For current chemical control options see Pest Genie or APVMA.
Cultural control	
Conservation of natural enemies	If a decision is made to control thrips, apply a narrow band spray over the seedlings to preserve predators such as spiders in the inter-row.

42 QDAF (2010) Thrips in field crops. Onion or cotton seedling thrips. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/thrips-overview/onion-or-cotton-seedling-thrips

7.7.2 Tomato thrips

Figure 12: *Adult tomato thrips.*

Photo: QDAF

Table 6: *Tomato and plague thrips description and management summary.* [43]

Scientific name	Tomato thrips, *Frankliniella schultzei* Plague thrips, *Thrips imaginis* (both in the flower thrips family).
Description	Adults are 2 mm long, cigar-shaped and range in colour from yellow–orange to grey–black. They have narrow wings folded along their back. Nymphs are similar in shape, pale yellow to orange–yellow, wingless and smaller.
Similar species	Other thrips species; differentiation is difficult in the field.
Distribution	Present in all Australian states.
Crops attacked	Flower thrips are common in the flowers of all summer pulses, as well as other crops, ornamentals and weeds.
Life-cycle	Flower thrips feed and breed inside the flowers. Crops are at greatest risk during flowering and podset.
Damage	Nymphs and adults feed in growing points and inside flowers. Thrips damage can result in flower abortion and pod distortion. Deformed pods may be difficult to thresh, resulting in further yield losses. Thrips may also vector (via pollen transfer) the damaging exotic Tobacco streak virus reported in mungbeans and sunflowers at Emerald in central Queensland.
Monitoring and action levels	Open and examine flowers for the presence of thrips. If flowers cannot be assessed immediately, store in 70% alcohol to dislodge thrips and prevent escape. Control thrips if >4–6 are found per flower.
Control	**Chemical control.** Except for western flower thrips, flower thrips are easily controlled with current systemic pesticides registered in pulses. For current chemical control options see Pest Genie or APVMA. **Cultural control.** Vigorously growing crops can usually compensate for flower abortion.
Conservation of natural enemies	Pirate bugs, lacewing larvae and ladybird beetles prey on thrips.

43 QDAF (2012) Thrips in field crops. Tomato and plague thrips. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/thrips-overview/tomato-thrips,-plague-thrips

7.7.3 Western flower thrips

Table 7: *Western flower thrips description and management summary.* [44]

Scientific name	*Frankliniella occidentalis*
Description	Adults are 2 mm long, cigar-shaped and range from yellow–orange to grey–black. They have tiny, narrow wings carried over the back. Nymphs are similar in shape, pale yellow to orange–yellow, wingless and smaller.
Similar species	Thrips species can only be determined microscopically. Thrips damage is distinguished from spider mite damage by the appearance of liquid faecal deposits, which cause dark green speckling, whereas spider mites produce black granules.
Distribution	A cosmopolitan species that has recently established and spread throughout Australia.
Crops attacked	Cotton, navy bean, mungbean, sunflower, canola and peanuts.
Life-cycle and risk period	Eggs are laid in slits made in leaves and growing points. There are two larval stages as well as a pre-pupal and pupal stage. Nymphs and adults feed in growing points and inside flowers. Pupation occurs in the soil. The life-cycle can be completed in as little as 10 days at 20°C. Populations decline at temperatures >30°C. Crops can be infested during the early vegetative stage but severe symptoms may not occur until much later in the crop's development. The earlier the thrips attack, the greater is the risk of damage.
Damage	Symptoms of the western flower thrips feeding include discoloration and indentation of the leaf surface. Damage to buds and flowers can result in deformed pods.
Monitoring and action level	Check seedling crops. Monitor flowering bean crops by peeling open the flower to look inside for thrips. Very few western flower thrips, which are resistant to most insecticides, are required to spread Tomato spotted wilt virus.
Control	**Chemical control.** Unlikely to be cost-effective. For current chemical control options see Pest Genie or APVMA. **Cultural control.** Late peanut plantings may help avoid western flower thrips damage.
Conservation of natural enemies	Using soft pesticides against other pests may conserve other thrips species, which, by competing with western flower thrips, may slow its population growth.

7.7.4 Damage

Both adults and nymphs feed on the leaves by rasping the surface tissues and sucking the exuded juices. Damage is normally insignificant; however, when there are high populations of thrips on seedlings, they cause distortion and browning of the cotyledons and leaves. Under these conditions seedlings can become stunted and die.

Thrips are an important vector for the pathogen Tobacco streak virus (TSV). [45]

7.8 Thresholds for control

For tomato thrips, control if 4–6 thrips are found per flower. [46] There are no action level thresholds for thrips on seedlings. [47]

44 QDAF (2012) Thrips in field crops. Western flower thrips. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/thrips-overview/western-flower-thrips

45 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

46 QDAF (2012) Thrips in field crops. Western flower thrips. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/thrips-overview/western-flower-thrips

47 QDAF (2010) Thrips in field crops. Onion or cotton seedling thrips. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/thrips-overview/onion-or-cotton-seedling-thrips

7.8.1 Management

Insecticides can be used if needed (see APVMA for listed insecticides). Thrips may require control in areas of known TSV outbreaks. If a decision is made to control thrips, apply a narrow band spray over the seedlings to preserve predators such as spiders in the inter-row. [48]

7.9 Wingless cockroaches

Wingless cockroaches (*Calolampra* spp.) are an establishment pest that eats seedlings of all field crops (Figures 13 and 14). Other native cockroaches are minor pests. [49] Wingless cockroach adults are large, shiny brown with yellow stripes and margins (Table 8). They are nocturnal, feeding at night and sheltering by day under trash. [50]

Figure 13: *Wingless cockroach adult. Adult males may be winged.*

Photo: D Ironside, QDAF

48 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

49 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

50 QDAF (2010) Soil insects in Queensland. Wingless cockroaches. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/wingless-cockroach

Figure 14: *Leaf damage caused by wingless cockroaches. Aboveground parts of seedlings are chewed and sometimes cut off.*

Photo: QDAF

MORE INFORMATION

QDAF. How to recognise and monitor soil insects.

7.9.1 Damage

Cockroaches are mainly a problem where seedlings are present in late summer and autumn. On small seedlings, they feed on cotyledons and stems, often severing the stem. On larger seedlings, they feed on the leaves and growing points. [51]

7.9.2 Thresholds for control

The use of GSBs is recommended, with the threshold for control being when at least one cockroach is present per two GSBs. [52]

7.9.3 Management

Nymphs and adults are found under stubble but congregate around volunteer plants in bare fallows. If the soil surface dries, they tend to move down to the moist soil layer. They feed at night and shelter under trash by day. They pose the highest risk where seedlings are present (Table 8).

Populations reach the highest densities under no tillage with stubble retained. Determine numbers with GSB. Take action when the threshold is reached (≥1 cockroach per two GSBs). Use insecticide-treated seed. See APVMA for chemical control options.

No effective natural enemies have been identified. A parasitic fly has been recorded parasitising nymphs. but parasitism percentages are low (<5%). [53]

51 QDAF (2010) Soil insects in Queensland. Wingless cockroaches. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/wingless-cockroach

52 QDAF (2010) Soil insects in Queensland. Wingless cockroaches. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/wingless-cockroach

53 QDAF (2010) Soil insects in Queensland. Wingless cockroaches. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/wingless-cockroach

Table 8: *Wingless cockroach description and management summary.* [54]

Scientific name	*Calolampra elegans* and *C. solida*
Description	Adult males and females of *C. elegans* are large (25–35 mm long) and shiny brown with yellow stripes and margins. The male of *C. solida* is fully winged, whereas the females are wingless. Nymphs are initially greyish-brown or tan, developing yellow markings when about half of adult size. Both species are Australian natives.
Similar species	House cockroach.
Pest status	Major, recorded as pests in Queensland's Central Highlands, irregular. Other native cockroaches, recorded as minor pests, are *Cosmozosteria* sp. and *Platyzosteria* sp.
Crops attacked	Omnivorous; food includes seedlings of all field crops.
Risk period	When seedlings are present.
Damage	On small seedlings, they feed on cotyledons and stems, often severing the stem. On larger seedlings, they feed on the leaves and growing points.
Monitoring and action level	Use germinating seed baits. Take action when there are one or more cockroaches per two germinating seed baits.
Control	**Chemical control**. Baiting with insecticide-treated cracked grain baits. For current chemical control options see Pest Genie or APVMA. **Cultural control**. Wingless cockroach populations reach highest densities under no tillage with stubble retained. **Conservation of natural enemies**. No effective natural enemies have been identified.

7.10 Black field earwig

Several earwig species are omnivorous. Their plant-feeding behaviour may result in plant damage but their predatory behaviour may also effectively control other crop pests. Black field earwigs (*Nala lividipes*) are a sporadic establishment pest of sunflowers (Figures 15 and 16, Table 9). [55]

Figure 15: *Three sizes of black field earwig.*

Photo: QDAF

54 QDAF (2010) Soil insects in Queensland. Wingless cockroaches. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/wingless-cockroach

55 QDAF (2010) Soil insects in Queensland. Black field earwig. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/black-field-earwig

Figure 16: *Black field earwig damage to germinating seed and young seedlings (in maize).*

Photo: QDAF

7.10.1 Damage

Black field earwigs eat newly sown and germinating seed and the roots of crops below ground, resulting in poor establishment (Table 9). Black field earwigs also chew the stems of newly emerged seedlings above ground.

7.10.2 Thresholds for control

The use of GSB, or digging and sieving, to detect adults and nymphs prior to planting is recommended. Crops should be monitored after planting until establishment. Controls should be implemented if >50 earwigs are found in 20 GSBs. [56]

7.10.3 Management

Grain baits containing insecticide applied at sowing offer the best protection from black field earwigs. Insecticide seed dressings provide some protection. In-furrow sprays are not effective in protecting against dense populations.

The black field earwig is mainly a pest in areas having heavy, black soils. Earwigs prefer cultivated soils rather than undisturbed soil (no-till).

Use press-wheels at sowing. [57]

MORE INFORMATION

[QDAF. How to recognise and monitor soil insects.]

56 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

57 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

Table 9: *Black field earwig description and management summary.* [58]

Scientific name	*Nala lividipes*
Description	Adults are 15 mm long, shiny black with a flattened body and a pair of curved pincers at the end of the body. Nymphs resemble adults but are wingless and paler.
Similar species	The common brown earwig (*Labidura truncata*), which grows to a larger size (24 mm) and is lighter in colour than the black field earwig.
Crops attacked	Wheat, sorghum, maize and sunflowers are the preferred hosts, but seedlings of most field crops are susceptible.
Life-cycle	The black field earwig normally feeds on decaying stubble in cultivation, with all stages (adults and immature stages) present during warmer months. In common with several earwig species, female black field earwigs lay eggs in a burrow in the soil and remain to care for the eggs and nymphs. Eggs hatch in 6–7 days at 29°C. The developmental time for five nymphal instars is about 7 weeks in clay soils, longer in sandy soils. Nymphs develop into adult females or major or minor males. Longevity is about 20 weeks.
Damage	The black field earwig eats newly sown and germinating seed and the roots of crops, resulting in poor establishment. Feeding on secondary roots may cause the plants to fall over as they get larger.
Monitoring	Use germinating seed baits or digging and sieving to detect adults and nymphs prior to planting. Monitor crops after planting until establishment.
Action level	Control if >50 earwigs in 20 germinating seed baits or if one earwig is found in 20 spade samples.
Control	**Chemical control**. Grain baits containing insecticide applied at sowing offer best protection. Insecticide seed dressings provide some protection. In-furrow sprays are not effective in protecting against dense populations. See Pest Genie or APVMA for current control options. **Cultural control.** The black field earwig is mainly a pest in areas with heavy, black soils. Earwigs prefer cultivated soils rather than undisturbed soil (no-till). Use press-wheels at sowing, set at 2–4 kg per cm width after planting rain, or 4–8 kg per cm in dry soil.
Distribution	Widespread in Australia, southern Europe, Asia, Africa and Hawaii.

7.11 Field crickets

Black field crickets (*Teleogryllus* spp.; Figure 17, Table 10) and brown field crickets (*Lepidogryllus* spp.) are minor, widespread and irregular establishment pests of sunflowers. [59]

Adult and nymph black field crickets feed on the leaves and stems of seedlings and may reduce a stand to the extent that replanting is necessary. They may damage cotton when present in plague numbers.

Both adults and immature stages shelter during the day in cracks in the soil or under trash. They come out at night and feed on weeds, grasses or crops. In sunflowers, the cricket feeds on the seedlings, on the back of the flower heads and on the maturing seeds on the face of the flower. [60]

58 QDAF (2010) Soil insects in Queensland. Black field earwig. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/black-field-earwig

59 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

60 QDAF (2010) Soil insects in Queensland. Black field cricket. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/black-field-cricket

Figure 17: *Black field crickets, adults and nymphs.*

Photo: D Ironside, QDAF

7.11.1 Damage

Black field crickets feed on the leaves and stems of seedlings, sometimes severing the stem at or above ground level. They may also attack more mature plants, feeding on the back of flower heads and on the maturing seed on the face of the head. [61]

7.11.2 Thresholds for control

Because crickets feed at night, it is suggested to inspect crops at dusk when they are most active (Table 10). Activity of black field cricket can be monitored with light traps. Use GSB to determine cricket numbers. One cricket (or more) per two GSBs requires control. [62]

7.11.3 Management

Field crickets are controlled using insecticide-treated, cracked grain baits. Control can be achieved with insecticide-treated grain baits. Weedy cultivation prior to planting may encourage crickets.

Natural controls such as disease, parasitic insects and predators (e.g. birds) have little impact on crickets. Nematodes are common parasites of brown field crickets in Central Queensland.

Cricket populations are regulated by weather conditions. [63]

MORE INFORMATION

QDAF. How to recognise and monitor soil insects.

61 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

62 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

63 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

Table 10: *Black field cricket description and management summary.* [64]

Scientific name	*Teleogryllus commodus*
Description	Adults are up to 30 mm long, winged, black or brown and have the head and mouthparts inclined downwards. The hind legs are large and modified for jumping, like grasshoppers. Nymphs are similar in shape but are smaller, paler and wingless. Small nymphs can have a white band across their back.
Distribution	Widespread in Australia, common in cracking soils.
Crops attacked	Many field crops, including most pulses.
Risk conditions	Crops can be attacked at any stage. Crops in heavier soils are at greatest risk. Most damage is caused by crickets already in the area at planting or by adults flying into crops.
Damage	Significant damage may be caused by adults and nymphs feeding on leaves, stems and pods. When black field crickets are present in plague numbers, seedling crops can be thinned to the point where replanting is necessary. At podding, adults chew into pods to reach the seeds.
Monitoring and action level	Crickets feed at night, so inspect crops at dusk when crickets are most active. Black field cricket activity can be monitored with light traps. Take action if significant cricket populations are present.
Control	**Chemical control**. Field crickets are controlled using insecticide-treated cracked-grain baits. For current chemical control options see Pest Genie or APVMA. **Cultural control.** Weedy cultivation prior to planting may encourage crickets.
Natural enemies	Natural control agents, including diseases, parasitic insects, and predatory birds and insects, appear to have little effect.

7.12 Rutherglen bug

The Rutherglen bug (RGB) (*Nysius vinitor*) is a major, widespread pest of crops throughout Australia (Figures 18 and 19). Grey cluster bug (*Nysius clevelandensis)* is a minor pest of sunflowers in Queensland and northern NSW. [65] These species are considered together as they are difficult to distinguish, are both establishment pests that cause similar symptoms, and have similar potential to reduce yield. In large populations, both have the capacity to reduce sunflower yield and oil contents dramatically. [66] RGB is the most likely and most damaging insect pest on sunflower. [67] [68]

The RGB and grey cluster bug are native species that can migrate into crops in very large numbers in favourable seasons. [69] Bugs can often appear in large numbers in a very short time and only in occasional seasons. Their invasion can occur in a very short time and be highly unpredictable, because they can migrate 200–300 km in a single night. [70]

MORE INFORMATION

Better Sunflowers Newsletter, March 2013
Feature Article: Is Weed Management the Key to Controlling Rutherglen Bug Pressure?

64 QDAF (2010) Soil insects in Queensland. Black field cricket. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/black-field-cricket

65 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

66 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

67 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

68 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

69 QDAF (2010) Managing insect pests in field crops. Rutherglen bug, grey cluster bug. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/rutherglen-bug,-grey-cluster-bug

70 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

Populations of RGB in cropping areas will breed on weeds, moving to available crops or weeds when hosts die off. Adults fly into crops, and flightless nymphs move by walking.

In seasons when RGB is a major pest, the population is dominated by migrants from outside the local cropping areas that are carried from inland breeding sites to eastern cropping regions. Depending on the time of planting, adults may be present during budding and flowering, and nymphs post-flowering. During summer, several overlapping generations develop and all stages may be present. [71]

Both species breed on a wide range of native and weed hosts, building up to large numbers in inland areas when winter and spring rainfall allows the growth of native herbs and weeds. In spring, as the hosts start to dry off, large numbers of adult bugs will move into the eastern cropping areas, migrating on the winds associated with storm fronts. [72] Winter and spring conditions that favour prolific weed growth, followed by a dry late spring, will force bugs off their host plants onto crops. [73]

Figure 18: *Rutherglen bug nymphs and adults.*

Photo: QDAF

Figure 19: *Rutherglen bug damaging sunflower plants.*

Photo: Drew Penberthy, Penagcon

71 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

72 QDAF (2010) Managing insect pests in field crops. Rutherglen bug, grey cluster bug. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/rutherglen-bug,-grey-cluster-bug

73 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

7.12.1 Damage

Adults congregate on the upper stems during budding and cause the head to wilt, become malformed or die. [74] After flowering, adults lay eggs in flower heads, in between individual flowers, with nymphs emerging in about 7 days to feed. [75] Both adults and nymphs feed on the seed, reducing grain yield, oil content, oil quality and seed germination. Damage is higher in moisture-stressed crops. Damage can occur until harvest depending on seed hardness. [76]

7.12.2 Monitoring

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

7.12.3 Thresholds for control

The critical times to monitor for RGB are at budding and seed-fill. To monitor for bug numbers, count adults on buds and heads at weekly intervals. During budding, bugs congregate on the upper stem and bud. During flowering, eggs are laid between individual flowers with nymphs emerging after about 7 days to feed on the young seeds.

Monitor and manage insect pests, especially RGB, which reduces sunflower yield and oil content by sucking the developing seed, reducing seed weight and changing oil composition. RGB damage is exacerbated in moisture-stressed crops; hence, dryland crops are more vulnerable than irrigated crops. [77] [78]

Table 11: Nysius *spp. thresholds (number of adult bugs per plant) in sunflowers.* [79]

Growth stage	Early-plant sunflowers (August–December)	Late-plant sunflowers (January–April)
Budding	10–15	20–25
Seed fill	20–25	50
Confectionery[A]	5	5

A The threshold is lower for confectionary sunflower due to the need to meet human consumption specifications. Brown marks on the seed from piercing make confectionary seed visually unattractive.

The thresholds (Table 11) are designed to prevent adults breeding in the crop; hence, thresholds are higher in late crops than in early crops, because higher prevailing temperatures promote more rapid RGB development. The thresholds proposed are based on field experience and knowledge that the adults will not lay eggs until the start of seed-fill. [80]

74 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

75 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

76 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

77 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

78 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

79 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

80 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

7.12.4 Management

Weed management

Remove host weeds and by ploughing a deep furrow around the crop, to prevent wingless bugs from migrating from weeds. Migration of RGB nymphs out of harvested canola crops and devastating sunflower and cotton crops is a significant problem.

Insecticide use

Understanding the life-cycle of the RGB when making spray decisions is helpful (Table 12). The aim is to prevent adults breeding; otherwise, population explosions will occur. Adults will not start breeding until a protein source is available, i.e. developing sunflower seed. Adults stop breeding in late February. [81]

If crops require spraying, best results are achieved before heads turn down toward the ground. Several synthetic pyrethroids are registered and they are the most effective pesticide for control. [82] However, they have limited residual effect and severely disrupt natural predator populations. As adults are winged, re-infestation can occur rapidly after treatment. [83] Multiple treatments are sometimes required. Sprays are best applied from budding onwards if the populations are high enough. This timing will normally prevent subsequent nymphal populations developing. Spray late in the afternoon when bees are less active. [84]

The 2008 project 'Sunflowers in Northern NSW and Southern Qld—Tools for Success' included benchmarking of 134 commercial crops across these regions supported by strategic replicated trials. This benchmarking study indicated a high degree of variability in insecticide application across the regions. Southern Queensland consistently recorded a lower proportion of insecticide applications, whereas in Gunnedah, ≥50% of crops were consistently sprayed. In the Moree region, application was seasonal-dependent. [85]

Insecticides were primarily targeted at controlling RGB. Secondary pests targeted include *Helicoverpa* spp. Insecticide use was dominated by synthetic pyrethroids. Trials carried out by Queensland Department of Primary Industries and Fisheries have shown pyrethroids to be the most effective chemicals in controlling RGB in sunflowers. [86]

Natural enemies

Egg parasitoids *(Telenomus spp.)* are sometimes important in hindering or preventing nymph infestations and reducing bug populations. Their potential contribution to population control will be limited in seasons when there are large influxes of adults. More than one species of egg parasitoid has been found. Parasitism of eggs is generally low, with the maximum recorded at 33.3%. Predation has rarely been recorded, but spiders may play a role. [87]

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81 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

82 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

83 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

84 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

85 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

86 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld.. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

87 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

Table 12: *Rutherglen bug and grey cluster bug description and management summary.* [88 89 90]

Scientific name	*Nysius vinitor*—Rutherglen bug (RGB), *Nysius clevelandensis*—grey cluster bug
Description	Adults are 3–4 mm long, mottled grey–brown–black, and have clear wings folded flat over the back. Nymphs are wingless, with a reddish-brown, pear-shaped body. *Nysius clevelandensis* and *N. vinitor* can be distinguished from each other with a hand lens or microscope; *N. vinitor* looks smooth, while *N. clevelandensis* is hairy.
Similar species	Brown mirid and brokenbacked bug. Nymphs are often confused with aphids.
Distribution	RGB is common in NSW, Queensland, South Australia, Victoria and southern Western Australia. Grey cluster bug is common in northern NSW and Queensland.
Crops attacked	Sunflower, sorghum, canola and safflower.
Life-cycle	RGB has 8 generations a year. In spring and summer, development from egg to adult takes 3–4 weeks. Adults will live up to 4 weeks, and females will lay up to 400 eggs in this period (which will hatch ~1 week after laying). The nymphs are wingless, with a pear-shaped body and reddish brown in colour. Nymphs develop over 3 weeks, before gaining wings, changing their shape and size, and becoming adults. They have rapid breeding capabilities, which mean 40 adults per plant at flowering can breed up into 1200 nymphs by harvest. [89] Females use the developing sunflower seed as a protein source to initiate egg laying. Eggs are laid between the seeds and dead florets up to 2 weeks post flowering. This means a second generation could be mature enough to lay a third generation by the time the crop reaches physiological maturity. Damage can continue until harvest depending on seed hardness. [90] Populations of RGB in cropping areas will breed on weeds, moving to available crops or weeds when hosts die off. Adults will overwinter, moving to available weeds and crops in spring and starting to breed. In seasons when RGB is a major pest, the population is dominated by migrants from outside the local cropping areas which are carried from inland breeding sites to eastern cropping regions.
Damage	In sunflowers, infestation during grain set and grain fill will reduce yield, oil content and oil quality. In seed crops, RGB will reduce germination of seed. Heavy infestations during budding may cause heads to distort. Impact is greater in moisture-stressed crops.
Monitoring	Sunflower and other oilseeds: from budding onwards.
Control	**Chemical control.** Repeated influxes of migrating adults can make repeat applications necessary, particularly in spring-sown sunflower. See Pest Genie or APVMA for current control options. **Cultural control**. Local management will have little impact on RGB in seasons when there are major influxes of bugs from outside the cropping region in spring. Managing weeds in and around paddocks prior to sowing can reduce the likelihood of bugs moving from dying weeds onto emerging seedlings.
Conservation of natural enemies	Egg parasitoids are the most commonly recorded natural enemy of RGB. Their potential contribution to population control will be limited in seasons when there are large influxes of adults. Predation has rarely been recorded, but spiders may play a role.

MORE INFORMATION

www.apvma.gov.au

7.13 *Helicoverpa* spp.

Two species of *Helicoverpa* are serious post-establishment pests of sunflowers in the northern grains region of Australia: the native budworm, *Helicoverpa punctigera,* and the corn earworm, *H. armigera* (Figures 20–24).

88 QDAF (2010) Managing insect pests in field crops. Rutherglen bug, grey cluster bug. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/rutherglen-bug,-grey-cluster-bug

89 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

90 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

Figure 20: Helicoverpa armigera*: male (left), female (right).*

Photo: Drew Penberthy, Penagcon

Helicoverpa armigera is generally regarded as the more serious pest because of its greater capacity to develop resistance to insecticides, broader host range, and persistence in cropping areas from year to year. [91] They usually occur from late budding until late seed fill. [92] [93]

The proportion of each species found on sunflowers depends on the time of planting in any particular year, and the population of *H. punctigera* in cropping regions fluctuates from year to year based on breeding conditions in inland breeding areas. [94] [95]

91 QDAF (2012) Managing insect pests in field crops. *Helicoverpa* species. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/helicoverpa/helicoverpa-species

92 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

93 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

94 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

95 QDAF (2012) Managing insect pests in field crops. *Helicoverpa* species. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/helicoverpa/helicoverpa-species

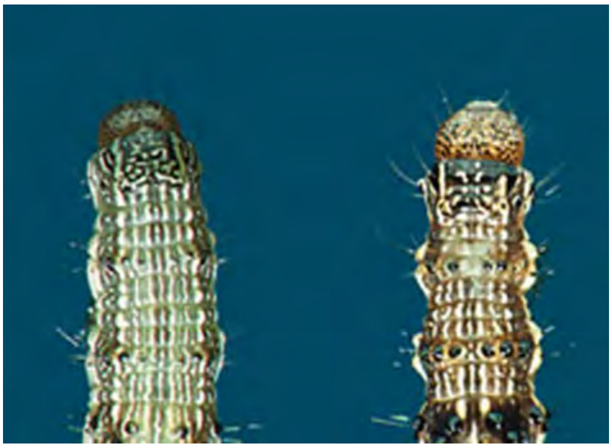

Figure 21: *Image showing key differences between* Helicoverpa punctigera *and* H. armigera *larva.*

Photo: QDAF

Figure 22: *Image distinguishing between adult moths of* Helicoverpa punctigera *and* H. armigera.

Photo: QDAF

Figure 23: *A row of* Helicoverpa *spp. coloured larvae in lucerne.*

Photo: QDAF

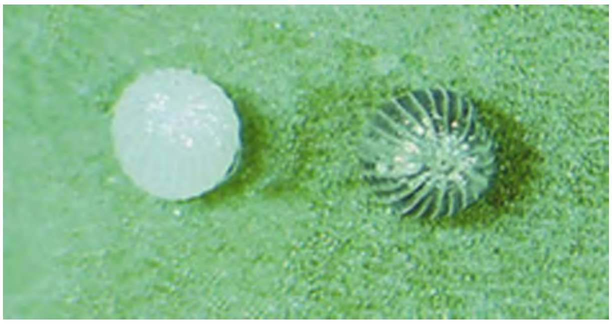

Figure 24: *Normal* Helicoverpa *egg on left, black parasitised egg on right.*

Photo: QDAF

7.13.1 Damage

Although damage from *Helicoverpa* is obvious and appears serious, they are not considered of major economic importance in sunflowers, because the plant is able to tolerate large infestations of *Helicoverpa* caterpillars and still produce a worthwhile yield. [96]

Caterpillars feed on the leaves, buds and petals or on the small green bracts surrounding the head. Damage to the developing seed is of little consequence unless infestations are very heavy. Heavy infestations during bud stage can result in severe damage.

Larval feeding can cause deformation of the seed head and sometimes loss of the head by larvae chewing into its connection with the stem. [97] Larvae are difficult to control when feeding on the sunflower face and under bracts, especially once the head turns over.

Feeding on the back of the head can predispose the crop to secondary head rots such as Rhizopus head rot [98] as well as quality downgrades.

7.13.2 Thresholds for control

Budding is the most vulnerable stage, because the whole bud can be eaten. Earlier recommendations were that populations of one medium or two small larvae per plant warranted control. [99] [100] However, natural mortality rates of 30% for larvae <5 mm in length should be taken into account. Therefore, by including expected mortality, the threshold for larvae in the size range 1–5 mm is six larvae per head. [101] [102]

From flowering to grainfill stage, the plant is able to tolerate larger populations. Damage to the back of the head may predispose the head to rot, but this is rarely

96 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

97 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

98 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

99 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

100 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

101 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

102 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

an economic reason to control *Helicoverpa*, as there are many other causal insects. [103] [104]

7.13.3 Management

At the bud stage, the caterpillars are concealed within the bud bracts and are difficult to control with insecticides.

When spraying is necessary, it is best to wait until the buds are just beginning to open and the yellow petals are becoming visible. Spraying earlier may result in poor control, and spraying later can affect pollination by bees. [105]

Helicoverpa armigera larvae are best targeted when <5–7 mm. Larvae are difficult to control when they are feeding on the sunflower face and under bracts [106]; therefore, insecticide applications are normally effective only until the heads turn to face the ground. [107]

The requirement for insecticide treatment in the post-flowering stage for the control of larvae in sunflower remains problematic. Trial results suggest that an initial population averaging 17 larvae per plant during the post-flowering stage of crop development caused no significant reduction in yield in the absence of secondary head rots. Insecticide spraying is unlikely to reduce head rots. [108]

The chemical to be used and the effectiveness of control will depend on the species of *Helicoverpa* present (Table 13). Therefore, consult an agronomist for a spray recommendation. [109] Select control options that are compatible with the insecticide-resistance management strategy for your region. [110] Avoid spraying when bees are active, and if bees are present, spray late afternoon. [111]

Helicoverpa have a large number of natural enemies such as egg and larval parasitoids, predators and various diseases. Parasitism can at times be >30%. [112]

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103 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

104 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

105 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

106 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

107 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

108 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

109 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

110 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

111 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Insect Management https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=7

112 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

Table 13: *Helicoverpa spp. description and management summary.* [113]

Scientific name	*Helicoverpa armigera*—cotton bollworm or corn earworm *Helicoverpa punctigera*—native budworm
Identification	Eggs are 0.5 mm in diameter and change from white to brown to a black head stage before hatching. Newly hatched larvae are light in colour with tiny dark spots and dark heads. As larvae develop, they become darker and the darker spots become more obvious. Both species look the same at the egg and small larvae stages. Medium larvae develop lines and bands running the length of the body and are variable in colour; *H. armigera* larvae have a saddle of darker pigment on the fourth segment and at the back of the head and dark-coloured legs, whereas *H. punctigera* larvae have no saddle and light-coloured legs. Large larvae of *H. armigera* have white hairs around the head; *H. punctigera* have black hairs around the head. Pupae are found in soil underneath the crop. Healthy pupae wriggle violently when touched; *H. armigera* pupal tail spines are more widely spaced than those of *H. punctigera*. Moths are a dull light brown with dark markings and are 35 mm long. Moths of *H. armigera* have a small light or pale patch in the dark section of the hindwing, whereas the dark section is uniform in *H. punctigera*. Forewings are brown in the female and cream in the male.
Similar species	Commonly confused species include armyworms and loopers. *Helicoverpa* larvae have a group of four pairs of 'legs' in the back half of the body, whereas loopers can have a group of 2, 3 or 4 pairs of legs at the rear and loop when walking. Armyworms also have 4 pairs of prolegs, but are smoother and fatter, with more coloured bands than *Helicoverpa*.
Life-cycle	Both *H. armigera* and *H. punctigera* take ~4–6 weeks to develop from egg to adult in summer, and 8–12 weeks in spring or autumn. Moths live for ~10 days, during which females lay 1000 eggs. Read more about Helicoverpa life-cycle and behaviour.
Crops attacked	The two *Helicoverpa* species prefer different hosts: *Helicoverpa punctigera* attacks broadleaf species (e.g. cotton, chickpeas, sunflowers, soybean, mungbean, navy bean, lucerne, canola, peanut, faba bean, safflower, linseed and azuki bean). It is not found on grass or cereal crops such as wheat, barley, sorghum or maize. *Helicoverpa armigera* will attack all field crops, but is less common in wheat and barley. Larvae feed on leaves but are most damaging when feeding on growing terminals, buds or squares, flowers, pods, seed and/or fruit. This includes direct losses through shedding and reduced quality. For more information see IPM in specific crops or visit The Beat Sheet blog.
Monitoring	*Helicoverpa* can be present in crops from the vegetative stage onwards. Very susceptible crops (e.g. cotton) need to be closely monitored from emergence to maturity for eggs and larvae; however, most field crops need to be monitored closely only from budding–flowering through to maturity. Eggs are most commonly laid on the top third of the plant and growing points.
Management	To manage *H. armigera* and *H. punctigera* well, it is important to understand the basic differences between the two species. Integrated pest management (IPM) strategies incorporating chemical, cultural and biological methods aim to restrict populations to below damaging levels. *Helicoverpa armigera* has developed resistance to a wide range of insecticides; however, a number of products are now registered for both species that have reduced impacts on natural enemies in the crop. Larvae are best targeted when <7 mm. Read more about key principles of helicoverpa management.
Natural enemies	All stages of the *Helicoverpa* life-cycle are attacked by a wide range of predators, parasitoids and pathogens, and conserving these in the crop through the avoidance of broad-spectrum insecticides can help to prevent or minimise the need for insecticide treatments. Read more about Helicoverpa's natural enemies.

MORE INFORMATION

QDAF. Integrated pest management – Helicoverpa.

7.14 Whiteflies

The four types of whitefly found in Australia are:

- the greenhouse whitefly (GHW), *Trialeurodes vaporariorum*
- the silverleaf whitefly (SLW), or B biotype, *Bemisia tabaci* species complex

113 QDAF (2012) Managing insect pests in field crops. *Helicoverpa* species. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/helicoverpa/helicoverpa-species

- the Australian native (AN) biotype of the *Bemisia tabaci* species complex, also known as the cotton whitefly.

The main distinguishing feature is the way they hold their wings. GHW has overlapping wings that form a heart shape. The *Bemisia* species hold their powdery wings more like the roof of a house that does not quite meet at the apex.

The SLW poses a greater pest threat than other whitefly because of their greater host range, quicker reproductive rate, and ability to rapidly develop resistance to insecticides. Under hot conditions, SLW can multiply on an area-wide scale to a point where management with insecticides is difficult. It is not possible to separate the two *B. tabaci* biotypes in the field.

7.15 Greenhouse whitefly

Greenhouse whitefly (Figures 25, 26) is a sporadic, post-establishment pest of sunflowers. [114] GHW adults are larger than *B. tabaci* (SLW) and have overlapping wings, which obscure the body when viewed from the top. [115]

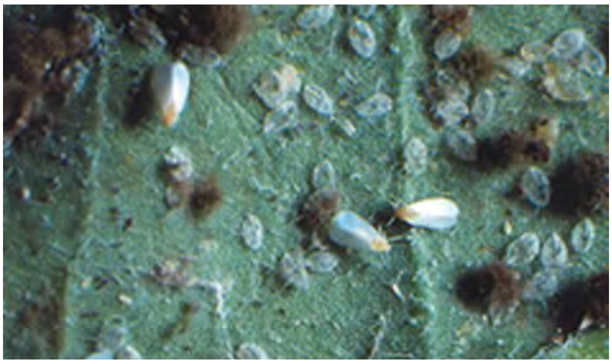

Figure 25: *Image showing adult greenhouse whitefly with white powdery wings and the pale yellow–green, scale-like nymphs.*

Photo: QDAF

Figure 26: *Greenhouse whitefly nymph.*

Photo: QDAF

114 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

115 QDAF (2010) Managing insect pests in field crops. Greenhouse whitefly. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/whitefly-overview/greenhouse-whitefly

7.15.1 Damage

Severe infestations of GHW can cause significant yield loss. Severe wilting and the appearance of a sticky, sooty, honeydew exudate on the leaves are common symptoms (Table 14). Crops may be killed but this is very rare; however, sunflower crops can also support large numbers of GHW with little effect. [116]

Nymphs and adults suck sap and excrete honeydew. A secondary infection develops when a black sooty mould fungus grows on the sticky honeydew. There are no visible damage symptoms with low numbers of GHW. Under very heavy infestations, plants lose vigour and damage is manifested under severe moisture stress, causing leaf wilting and failure to set seed. [117]

7.15.2 Thresholds for control

There are no established threshold numbers in sunflowers. [118]

7.15.3 Management

There are no insecticides registered for the control of whiteflies on sunflowers. Chemicals targeting other pests can affect parasitic wasps that provide effective control of whitefly. An introduced parasitoid is widespread in Australia and commonly attacks whitefly nymphs. [119]

Natural predators can effectively regulate whitefly populations. Whitefly populations can occur as mixed species, so aim to retain natural predator populations for as long as possible.

Table 14: *Greenhouse whitefly description and management summary.* [120]

Scientific name	*Trialeurodes vaporariorum*
Description	Adults are ~1.5 mm long and hold their white powdery wings flat, almost parallel to and obscuring the body when viewed from above. Nymphs are pale yellow–green, scale-like insects with long hairs protruding all over the body. Most nymph stages are immobile.
Similar species	Silverleaf whitefly.
Distribution	A pest in crops in Australia, Europe, Asia, Africa and the United States.
Crops attacked	Cotton, sunflower, soybean and navy bean.
Life-cycle	The greenhouse whitefly breeds throughout the warm months with a life-cycle of ~5–7 weeks. It can have up to 3 generations on a sunflower crop and 7 generations per year. Summer and autumn are the risk periods, with outbreaks favoured by warm weather and host availability.
Damage	Adults and nymphs suck on sap and excrete honeydew, which interferes with photosynthesis and discolours the lint in cotton. A secondary infection develops when a sooty black mould fungus grows on the sticky honeydew. Under very heavy infestations, plants lose vigour, causing leaf-wilting and failure to set seed.
Monitoring and action level	Usually found on the lower leaf surface. Affects all crop stages.
Control methods	**Chemical control.** None available. **Cultural control.** Removal of alternative weed hosts may be helpful, but weed-free environments may hinder the survival of natural enemies.
Conservation of natural enemies	Parasitic wasps (*Encarsia formosa*) commonly provide effective biological control.

MORE INFORMATION

QDAF. Chemical control of insects – consideration and choices.

116 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

117 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

118 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

119 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

120 QDAF (2010) Managing insect pests in field crops. Greenhouse whitefly. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/whitefly-overview/greenhouse-whitefly

7.15.4 *Bemisia tabaci* whitefly complex

The *Bemisia tabaci* species complex is represented in Australia by three distinct biotypes: Australian Native (AN), SLW (or B biotype), and Q biotype (a recently identified biotype of SLW).

The AN biotype is quite common but causes no problems. SLW was first discovered in Australia in 1994. It is a pesticide-resistant strain from overseas (most likely the United States). The Q biotype was reported in Queensland and north-western NSW in 2009. [121] The *B. tabaci* biotypes in Australia are morphologically indistinguishable and can only be differentiated using chemical (enzyme) or DNA techniques.

Hosts of SLW and Q biotypes include at least 500 crops and ornamental plants worldwide and it is a pest on many of these.

During the 2001–02 season, large populations of SLW (Figures 27 and 28) were found on sunflowers in Central Queensland. However, infested sunflower crops suffered little damage. [122]

Figure 27: *Adult silverleaf whitefly (*Bemisia tabaci*) viewed from above; note the gap between the wings.*

Photo: B Scholz, QDAF

121 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

122 QDAF (2011) Managing insect pests in field crops. *Bemisia tabaci* species complex—Silverleaf whitefly (SLW) or B biotype and Australian native (AN) biotype. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/whitefly-overview/silverleaf-whitefly-biotype-b-and-native

Figure 28: *Silverleaf whitefly (*Bemisia tabaci*) nymph.*

Photo: P de Barro, QDAF

7.15.5 Damage

Silverleaf whitefly poses a greater threat than GHW to broadacre crops. SLW has a very wide host range, a high reproductive capacity and an ability to develop resistance to insecticides within 2–3 generations (Table 15). Hence, the further north it occurs, the shorter the timespan between generations and the greater the number of generations possible each season. SLW caused significant damage to a wide range of broadleaf crops including sunflower, mungbean, soybean, peanut and cotton in the 2001–02 season in the Emerald Irrigation Area. [123]

SLW is usually found on the lower leaf surface and affects all crop stages. SLW has a high reproduction rate and a short generation time, and the large numbers generated can retard plants simply by feeding. The insect secretes large quantities of honeydew, which interferes with photosynthesis and can reduce plant vigour. [124]

7.15.6 Management

There are no registered insecticides for SLW in sunflowers.

Cultural control options include:

- breaks in the cropping cycle
- elimination of alternative hosts
- conservation of natural enemies [125]

Natural enemies can provide good control of SLW and stabilise populations as long as they are not disrupted by the overuse of non-selective insecticides. [126] Immature SLW are susceptible to attack by several predatory wasp species. Parasitic wasps commonly provide some level of biological control, with other beneficial species including big-eyed bugs, green lacewing larvae, brown lacewing larvae, spiders and ladybird beetles. Maintaining beneficial insects in sunflowers can therefore play an important role in reducing the number of SLW. Maintenance of clean fallows and consideration of nearby host crops also play a role in managing SLW. [127]

123 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

124 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

125 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

126 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

127 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

Table 15: Bemisia tabaci *species complex description and management summary.* [128]

Scientific name	*Bemisia tabaci* species complex, B biotype—silverleaf white fly (SLW) *Bemisia tabaci* species complex, AN biotype—cotton whitefly
Description	Adults of both biotypes are both 1.5 mm long and cannot be separated visually. Adults hold their white powdery wings like the roof of a house that does not quite join at the apex, so when viewed from above, the body can be seen between the wings. Nymphs are pale yellow–green and flat, scale-like insects that attach to the underside of the leaves of their host plant. Most nymph stages are immobile. Once SLW becomes established in a location it tends to displace the AN biotype.
Similar species	Greenhouse whitefly, *Trialeurodes vaporariorum*; other biotypes of the *Bemisia tabaci* species complex.
Distribution	SLW is a pest of crops in Australia, Europe, Asia, Africa and the United States. SLW has been recorded in cotton crops from all areas in eastern Australia and from Katherine in the Northern Territory. Only in central Queensland has it reached levels regularly requiring the use of insecticides, and occasional insecticide control is required in the Darling Downs, Byee and St George areas.
Crops attacked	Cotton, soybean, peanut and many broadleaf weeds.
Life-cycle	SLW eggs are laid haphazardly on the underside of leaves. The eggs are yellow–green, changing to dark tan as they are about to hatch. Leaves with high populations of eggs often have a dark patch on the underside. The life-cycle from egg to adult can be as little as 18 days in summer, but longer in cooler weather.
Damage	SLW can cause damage in several ways. With a high reproduction rate and a short generation time, the large numbers generated can retard plants simply by feeding. The insect secretes large quantities of honeydew. This interferes with photosynthesis and causes problems with cotton fibre processing. SLW is a carrier of viruses such as Cotton leaf curl virus in Pakistan and the United States. These viruses are not known in Australia but should they enter the country, SLW is now available to spread them.
Monitoring and action level	Proper identification and regular estimates of the number of adults and nymphs are important. SLW is usually found on the lower leaf surface and it affects all crop stages.
Control	**Chemical control** By permit only. A significant problem in the management of SLW is its ability to develop resistance very quickly to many insecticides when used repeatedly. There is variation for resistance in cotton varieties, and breeding for host-plant resistance is under way in other countries. For current chemical control options see Pest Genie or Australian Pesticides and Veterinary Medicines Authority (APVMA). **Cultural control** SLW management in Queensland cotton will be based on a number of integrated controls such as: breaks in the cropping cycle and elimination of alternative hosts use of economic thresholds to determine whether control action with an insecticide is necessary use of appropriate insecticides such as insect growth regulators (IGRs) as required conservation of natural enemies an insecticide management to conserve susceptibility
Conservation of natural enemies	Parasitic wasps (*Encarsia* spp. and *Eretmocerus* spp.) commonly provide some level of biological control. Predators include bigeyed bugs , lacewing larvae and ladybirds. A management strategy needs to preserve and promote the activity of predators and parasites. Avoid early-season use of broad-spectrum insecticides, particularly pyrethroids and organophosphates.

128 QDAF (2011) Managing insect pests in field crops. *Bemisia tabaci* species complex—Silverleaf whitefly (SLW) or B biotype and Australian native (AN) biotype. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/whitefly-overview/silverleaf-whitefly-biotype-b-and-native

7.16 Loopers

Tobacco looper (*Chrysodeixis argentifera; Table 16*), vegetable looper (*Chrysodeixis eriosoma; Table 17*) and soybean looper (*Thysanoplusia orichalcea; Figures 29 and 30; Table 18*) are an occasional post-establishment pest of sunflower.

Loopers have attracted a lot of interest and concern with regard to sunflower crops in 2012. Primarily, the looper involved in defoliating sunflower crops has been soybean looper caterpillars (*T. orichalcea*). [129]

Loopers can be distinguished from *Helicoverpa* by:

- their 'looping' action when walking
- their body, which tapers towards the head
- their two pairs of hind legs, as opposed to four for *Helicoverpa* [130]

Larvae are green with white and/or dark stripes and can reach 50 mm in length. Soybean looper larvae are more prominently striped than the vegetable and tobacco loopers. The eggs are similar in shape to *Helicoverpa* eggs but are more flattened and are a pale, yellow–green. *Thysanoplusia* (soybean looper) moths are brown with large golden markings on their forewings. *Chrysodeixis* spp. (tobacco and vegetable loopers) moths are brown with small silver markings on the forewings. [131]

MORE INFORMATION

QDAF. Managing insect pests in field crops. Loopers in field crops.

7.16.1 Tobacco looper

Table 16: *Tobacco looper description and management summary.* [132]

Scientific name	*Chrysodeixis argentifera*
Description	Eggs are pale yellow–green, ribbed and are flatter than *Helicoverpa* eggs. Larvae move with a distinctive looping action and have only two pairs of ventral prolegs. Their body tapers towards the head. Very small larvae are pale green all over; larger larvae are green with white stripes. Tobacco loopers have a darker green line along the middle of their back, flanked by two white stripes. Their sides have parallel white lines and sometimes a row of black spots. Larvae can reach 40 mm in length. Larvae usually pupate under leaves in a thin silken cocoon. Pupae are dark above and pale underneath. The moth's forewings are dark brown with small silver 'figure-8' markings. On tobacco looper, these markings are fused, whereas on the vegetable looper they are separated. Tobacco looper also has a small, silver, S-shaped mark above the figure-8 on each forewing.
Similar species	Tobacco loopers may be confused with soybean loopers but are not as prominently striped.
Distribution	The tobacco looper is common throughout mainland Australia and Tasmania.
Crops attacked	Tobacco loopers damage flowers and pods of mungbeans, navy beans, azuki bean and the leaves of soybeans.
Life-cycle	Looper eggs hatch in 3–6 days. There are six larval stages. Larvae take 2–3 weeks to develop before pupating under leaves in a loose silken cocoon.
Risk period	Crops can be attacked at any stage but are at greatest risk during flowering and podding. Summer legumes are least tolerant of defoliation at these stages, and in some crops, flowers and young pods are at direct risk of looper attack. In subtropical regions, crops are at greatest risk from mid–late summer. However, in the tropics winter-planted 'summer legumes' may also be at risk.

129 AOF (2012) The Better Sunflower e-Newsletter. May 2012. Australian Oilseeds Federation, Australian Sunflower Association, Grains Research and Development Corporation, http://www.australianoilseeds.com/__data/assets/pdf_file/0010/8875/Better_Sunflowers_-_Issue_1_May_2012.pdf

130 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers -Wireworms

131 QDAF (2010) Managing insect pests in field crops. Loopers in field crops. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/loopers

132 QDAF (2010) Managing insect pests in field crops. Tobacco looper. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/loopers/tobacco-looper

Damage	Small larvae feed on only one side of the leaf, leaving translucent 'feeding windows'. As larvae develop, they chew holes in the leaf and then feed from the leaf margin. Larvae are primarily foliage feeders in soybeans but will attack the flowers and developing pods in azuki beans, mungbeans and navy beans. Looper damage is different from *Helicoverpa* damage, with the feeding holes being angular rather than rounded.
Monitoring and action level	**Monitoring.** Inspect crops weekly during the vegetative stage and twice weekly from very early budding onwards, until crops are no longer susceptible to attack (late podding). Beat-sheet sampling is the preferred sampling method for looper larvae. Crops should be scouted for looper eggs and moths to pinpoint the start of infestations and to increase the chance of success of biopesticides such as *Bacillus thuringiensis* (Bt). **Action level.** In pre-flowering crops, looper control is warranted if defoliation exceeds (or is likely to exceed) 33%). Tolerable defoliation drops to 15–20% once flowering and podding commences. In azuki beans, mungbeans and navy beans, where flowers and pods are attacked the threshold is set at three looper larvae per square metre.
Control	**Chemical control.** Loopers can be controlled with most pesticides targeting *Helicoverpa*, but are not controlled by products containing the naturally occurring biopesticide NPV (nucleopolyhedrovirus). Small loopers (<12 mm long) can be controlled with Bt; more than one application may be required. For current chemical control options, see Pest Genie or APVMA. **Cultural control.** Vigorously growing plants will be better able to compensate for flower and pod damage, and damaged leaves will be replaced more quickly. **Conservation of natural enemies.** Loopers in summer pulses are attacked by numerous predators and parasites. The use of Bt for looper control will help preserve beneficial insects and reduce the risk of subsequent whitefly and mite attack.

7.16.2 Vegetable looper

Table 17: *Vegetable looper description and management summary.* [133]

Scientific name	*Chrysodeixis eriosoma*
Description	Eggs are pale yellow–green and ribbed and are flatter than *Helicoverpa* eggs. Larvae move with a distinctive looping action and have only two pairs of ventral prolegs. Their body tapers towards the head. Larval colour can vary considerably. Very small larvae are pale green all over; larger larvae are green with white stripes. Larvae can reach 40 mm in length. These looper larvae usually pupate under leaves in a thin silken cocoon. Pupae are dark above and pale underneath. The moth's forewings are dark brown with small silver figure-8 markings. Male vegetable loopers have long, orange, hair-like scales on either side of the abdomen.
Similar species	*Chrysodeixis* species (vegetable and tobacco loopers) may be confused with soybean loopers but are not as prominently striped.
Distribution	*Chrysodeixis eriosoma* (vegetable looper) occurs throughout northern and eastern Australia, and as far south as central NSW.
Crops attacked	The vegetable looper damages flowers and pods of azuki beans, mungbeans and navy beans, as well as soybean leaves.
Life-cycle	Looper eggs hatch in 3–6 days. There are six larval stages. Larvae take 2–3 weeks to develop before pupating under leaves in a loose silken cocoon.
Risk period	Crops can be attacked at any stage but are at greatest risk during flowering and podding. Summer legumes are least tolerant of defoliation at these stages, and in some crops, flowers and young pods are at direct risk of looper attack. In subtropical regions, crops are at greatest risk from mid to late summer; however, in the tropics winter-planted 'summer legumes' may also be at risk.
Damage	Small larvae feed on only one side of the leaf, leaving translucent 'feeding windows'. As larvae develop, they chew holes in the leaf and then feed from the leaf margin. Larvae are primarily foliage feeders in soybeans but will attack the flowers and developing pods in azuki beans, mungbeans and navy beans. Looper damage is different from *Helicoverpa* damage, with the feeding holes being angular rather than rounded.

133 QDAF (2010) Managing insect pests in field crops. Vegetable looper. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/loopers/vegetable-looper

Monitoring and action level	**Monitoring**. Inspect crops weekly during the vegetative stage and twice weekly from very early budding onwards, until crops are no longer susceptible to attack (late podding). Beat-sheet sampling is the preferred sampling method for looper larvae. Crops should be scouted for looper eggs and moths to pinpoint the start of infestations and to increase the chance of success of biopesticides such as *Bacillus thuringiensis* (Bt). **Action level.** In pre-flowering crops, looper control is warranted if defoliation exceeds (or is likely to exceed) 33%. Tolerable defoliation drops to 15–20% once flowering and podding commences. In azuki beans, mungbeans and navy beans, where flowers and pods are attacked, the threshold is set at three looper larvae per square metre.
Control	**Chemical control**. Loopers can be controlled with most pesticides targeting *Helicoverpa*, but are not controlled by products containing the naturally occurring biopesticide NPV (nucleopolyhedrovirus). Small loopers (<12 mm long) can be controlled with Bt; however, more than one application may be required. For current chemical control options, see Pest Genie or APVMA. **Cultural control.** Vigorously growing plants will be better able to compensate for flower and pod damage, and damaged leaves will be replaced more quickly. **Conservation of natural enemies**. Loopers in summer pulses are attacked by numerous predators and parasites. The use of Bt for looper control will help preserve beneficial insects and reduce the risk of subsequent whitefly and mite attack.

7.16.3 Soybean looper

Figure 29: *Soybean looper, light phase.*

Photo: Better Sunflowers Newsletter

Figure 30: *Soybean looper, dark phase.*

Photo: Better Sunflowers Newsletter

Table 18: *Soybean looper description and management summary.* [134]

Scientific name	*Thysanoplusia orichalcea*
Description	Eggs are pale yellow-green, ribbed and are flatter than *Helicoverpa* eggs. Larvae move with a distinctive looping action and have only two pairs of ventral prolegs. Their body tapers towards the head. Larval colour can vary considerably. Very small larvae are green all over but medium larvae usually have prominent dark and white striping. Large larvae are usually green with white stripes. Larvae can reach 45 mm in length. Soybean looper larvae usually pupate under leaves in a thin silken cocoon. Pupae are dark above and pale underneath. The moth's forewings are very distinctive: brown with a large, bright gold patch. The hind wings are fawn-coloured, darkening towards the outer margins.
Similar species	Soybean loopers may be confused with vegetable and tobacco loopers (*Chrysodeixis* spp.) but are more prominently striped.
Distribution	Africa, Asia, Papua New Guinea and Australia. First reported in Queensland in 1976, now recorded in NSW and Tasmania but most likely more widespread.
Crops attacked	Soybeans, mungbeans, navy beans, azuki bean, sunflowers.
Life-cycle	Looper eggs hatch in 3–6 days. There are six larval stages. Larvae take 2–3 weeks to develop before pupating under leaves in a loose silken cocoon.
Risk period	Crops can be attacked at any stage but are at greatest risk during flowering and podding. Summer legumes are least tolerant of defoliation at these stages, and in some crops, flowers and young pods are at direct risk of looper attack. In subtropical regions, crops are at greatest risk from mid to late summer. However, in the tropics winter-planted 'summer legumes' may also be at risk.
Damage	Soybean looper is a more serious pest in mungbeans and navy beans than soybeans. Small larvae feed on only one side of the leaf, leaving translucent 'feeding windows'. As larvae develop, they chew holes in the leaf, and then feed from the leaf margin. Larvae are primarily foliage feeders in soybeans, but will attack the flowers and developing pods in azuki beans, mungbeans and navy beans. Looper damage is different to *Helicoverpa* damage, with the feeding holes being angular rather than rounded.

134 QDAF (2010) Managing insect pests in field crops. Soybean looper. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/loopers/soybean-looper

Monitoring and action level	**Monitoring.** Inspect crops weekly during the vegetative stage and twice weekly from very early budding onwards, until crops are no longer susceptible to attack (late podding). Beat-sheet sampling is the preferred sampling method for looper larvae. Crops should be scouted for looper eggs and moths to pinpoint the start of infestations and to increase the chance of success of biopesticides such as *Bacillus thuringiensis* (Bt). **Action level.** In pre-flowering crops, looper control is warranted if defoliation exceeds (or is likely to exceed) 33%. Tolerable defoliation drops to 15–20% once flowering and podding commences. In azuki beans, mungbeans, and navy beans, where flowers and pods are attacked the threshold is set at three looper larvae per square metre.
Control	**Chemical control.** Soybean loopers can be controlled with most pesticides targeting *Helicoverpa*, but are not controlled by products containing the naturally occurring biopesticide NPV (nucleopolyhedrovirus). Small loopers (<12 mm long) can be controlled with Bt; more than one application may be required. For current chemical control options, see Pest Genie or APVMA. **Cultural control.** Vigorously growing plants will be better able to compensate for flower and pod damage, and damaged leaves will be replaced more quickly. **Conservation of natural enemies.** Soybean loopers in summer pulses are attacked by numerous predators and parasites. The use of Bt for looper control will help preserve beneficial insects and reduce the risk of subsequent whitefly and mite attack.

7.16.4 Damage

Larvae feed on leaves. Tissue damage is insignificant when larvae are small, but increases with larger loopers. Large, irregular shaped holes in the leaves usually coincide with the appearance of large larvae (Figure 31). Severe defoliation is uncommon. [135]

The following points are useful in making decisions to control loopers:

- Yield loss will occur if the top third of leaves is not retained through budding and grainfill (based on leaf loss from powdery mildew data).
- Loopers will consume 80% of their total food intake in the final two instars before pupating. Consequently, the rate of defoliation will speed up as larvae reach maturity.
- Loopers do not usually feed on the buds or developing heads in sunflowers.
- Large larvae (25–40 mm) will be close to maturity and likely to stop feeding and pupate within a few days. [136]

135 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

136 AOF (2012) The Better Sunflower e-Newsletter. May 2012. Australian Oilseeds Federation, Australian Sunflower Association, Grains Research and Development Corporation, http://www.australianoilseeds.com/__data/assets/pdf_file/0010/8875/Better_Sunflowers_-_Issue_1_May_2012.pdf

Figure 31: *Pre-flowering defoliation by loopers.*

Photo: J Wessels, QDAF

7.16.5 Thresholds for control

Although loopers can occur anytime throughout the growing season, they normally feed almost exclusively on leaves and do not usually warrant control. Under some conditions, populations can flare to damaging levels as high as 150 per square metre. Control should be considered if leaf loss is likely to be >33% in the vegetative stage, or 20% from flowering onwards. [137]

No local trial data are available because severe looper infestations in sunflowers occur so rarely. In the US, looper control in sunflowers is recommended if defoliation reaches 25% of leaf area, and larvae are still small and the crop is flowering or grain is filling. When defoliation was >50%, yield losses were incurred. [138] Damage on the Liverpool plains has been measured by local consultants at 25% under high pressure.

7.16.6 Management

Looper infestations are often controlled by parasitoids, predators and diseases before they cause too much damage.

Control is usually unwarranted, but caterpillars causing severe damage late in crop development can be controlled with insecticides if warranted. Crops should be scouted for looper eggs and moths to pinpoint the start of infestations and to increase the chance of success of biopesticides such as *Bacillus thuringiensis* (Bt). [139]

Loopers appear susceptible to all insecticides used for Helicoverpa control, with the exception of Gemstar® and Vivus® (NPVs), which only act against *Helicoverpa*. Dipel (Bt) is far more effective against loopers than against *Helicoverpa* but thorough coverage is required for best results. [140]

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137 QDAF (2010) Managing insect pests in field crops. Loopers in field crops. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/loopers

138 AOF (2012) The Better Sunflower e-Newsletter. May 2012. Australian Oilseeds Federation, Australian Sunflower Association, Grains Research and Development Corporation, http://www.australianoilseeds.com/__data/assets/pdf_file/0010/8875/Better_Sunflowers_-_Issue_1_May_2012.pdf

139 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

140 QDAF (2010) Managing insect pests in field crops. Loopers in field crops. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/loopers

7.17 Green vegetable bug

Green vegetable bugs (GVBs) (*Nezara viridula*) are a minor post-establishment pest of sunflowers. Adult life spans vary from several weeks to 4 months, with summer reducing their longevity.

7.17.1 Damage

Green vegetable bugs have a wide host range and cause damage by sucking sap. GVBs tend to feed on the upper stems and heads and when present in large numbers, cause shrivelling, wilting and deformed heads. If they gather around the peduncle, water and nutrient supply to the developing head will be reduced. GVB are occasionally known to feed on developing seed. [141]

7.17.2 Thresholds for control

The current threshold is one mature bug or fifth instar nymph per plant. Females lay 30–130 eggs in a raft on the leaf surface, and these hatch in 5–21 days. It takes 30 days to progress through the five nymphal instars. [142]

7.17.3 Management

Chemical control is warranted if large populations of GVB are present.

There are several natural enemies of GVB. GVB eggs are frequently parasitised by a tiny introduced wasp, *Trissolcus basalis* (green vegetable bug egg parasite). Parasitised eggs are easily recognised because they turn black. Parasitised GVB eggs may be confused with eggs of the predatory shield bugs but lack the spines that ring the top of the eggs of these species.

GVB nymphs are attacked by ants, spiders and predatory bugs. Final (fifth) instar and adult GVB are parasitised by the recently introduced tachinid fly, the green vegetable bug parasitic fly (*Trichopoda giacomellii*). [143]

141 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

142 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

143 QDAF (2011) Insect pest management in sunflowers. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/sunflowers - Wireworms

Nematode control

In the northern grain region, the predominant root-lesion nematode (RLN), *Pratylenchus thornei* (*Pt*), costs the wheat industry AU$38 million annually. Including the secondary species, *P. neglectus* (*Pn*), RLN is found in three-quarters of fields tested. [1]

As information on nematode incidence and species type becomes available, the use of sunflowers as a management tool for nematodes is likely to increase because of the crop's resistance to both *Pt* and *Pn*. RLN are widespread in central and northern NSW, with *Pt* generally having a much higher distribution (69% of random paddocks) than *Pn* (32% of random paddocks). [2]

8.1 Resistant crops

Growing resistant crops such as sunflowers is the main tool for managing nematodes. In the case of crops such as wheat or chickpea, choose the most tolerant variety available and rotate with resistant crops to keep nematode numbers at low levels. Information on the responses of crop varieties to RLN is regularly updated in grower and Queensland Department of Agriculture, Fisheries and Forestry planting guides. Note that *Pt* and *Pn* may prefer different crops (see Table 1) or varieties. [3] Choose resistant crops to keep RLN numbers at low levels, avoid or limit the use of susceptible crops, and choose tolerant varieties to maximise yields.

MORE INFORMATION

GRDC The current and potential costs from diseases of wheat in Australia

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

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Latest-nematode-summer-and-winter-crop-rotation-results

MORE INFORMATION

GRDC Update Paper: Managing grain crops in nematode infested fields to minimise loss and optimise profit

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

2 L Serafin, S Belfield, D Herridge (2011) Sunflower yield performance and agronomy: Where and when do they fit best in the northern grains region? GRDC Updates Papers 13 Sept. 2011. http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Sunflower-yield-performance-and-agronomy-Where-and-when-do-they-fit-best-in-the-northern-grains-region

3 QDAF (2009) Root-lesion nematodes. Management of root-lesion nematodes in the northern grain region. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

Table 1: *Crop responses to Pratylenchus species.*

Crop	*P. thornei*	*P. neglectus*
Winter crops		
Barley	MS–MR	MS–MR
Canary seed	R	MS
Canola	R	S
Chickpea	S	S
Durum wheat	R	MS
Faba bean	S	R
Linseed	R	R
Oats	MR	MR
Triticale	MR	R
Wheat	S	S
Summer crops		
Black gram	S	R
Cotton	R	—
Cowpea	S	R
Lablab	R	R
Maize	MR	MR
Millet Japanese Pearl Siberian White French	 R MR R MR	–
Mungbean	S	R
Navy bean	S	MR
Panicum Foxtail Panorama Pearl	 R R R	–
Pigeon pea	R	–
Sorghum, grain	R	S
Sorghum, forage	R	S
Soybean	S	R
Sunflower	R	R

R, Resistant; S, susceptible; M, moderately; –, not tested.

MORE INFORMATION

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

MORE INFORMATION

http://www.grdc.com.au/uploads/documents/GRDC_FS_Sunflowerdisease.FINAL.pdf

http://regional.org.au/au/gcirc/3/430.htm

Diseases

9.1 Principles of disease management

9.1.1 IPM and biological control

Integrated pest management is sometimes confused with classical biological control. Classical biological control involves the importation and release of exotic control agents (predators and parasites) to control (usually) exotic pests. This practice is used because there are no native control agents, or because the native ones are (or are thought to be) ineffective.

Most plants are immune or resistant to almost all plant pathogens. This immunity is normal. However, occasionally a pathogen develops the ability to either bypass or overcome the inbuilt resistance mechanisms of a plant. When this occurs, the **host** is considered **susceptible** to the pathogen and the **pathogen** is described as being **virulent** on that host.

When a virulent pathogen comes across a susceptible host and the environmental conditions are suitable, a disease develops in the host and characteristic symptoms are produced.

The disease triangle of interactions between the host, pathogen and environment determines the initial severity of the disease outbreak (Figure 1).

Integrated disease management (IDM) involves the selection and application of a range of control measures that minimise crops losses, maximise returns, and ideally have minimal impact on the environment, flora and fauna. [1]

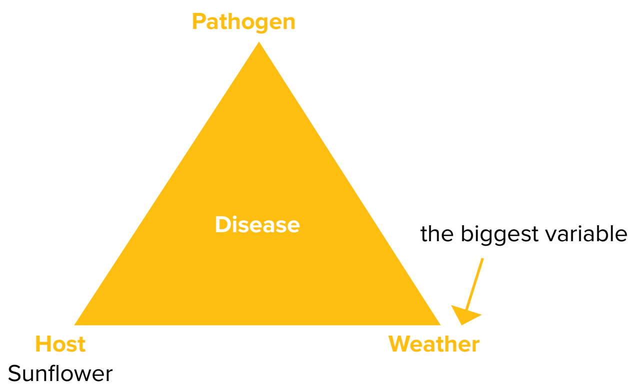

Figure 1: *Interactions between host, pathogen and weather determines disease severity.*

1 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

MORE INFORMATION

GRDC Tips and Tactics: Sunflower disease management

9.2 Integrated disease management at the farm or crop level

Effective IDM should be integrated with that of the whole farm. Basis strategies should be implemented regardless of whether or not a significant disease problem exists. Prevention or minimisation of disease risk is the key to effective IDM.

Best practice strategies include:

- ***Disease awareness.*** Ensure you have up-to-date information on the incidence and biology of current disease outbreaks, and on whether incidence/severity of outbreaks is increasing each season.
- ***Staff training.*** Educate staff on possible disease incursions and encourage pro-active feedback on unusual symptoms and plant growth habits.
- ***Farm hygiene.*** Minimise movement of pathogens between paddocks and between farms. Remember many pathogens survive in the soil and plant debris and can easily be transferred on tyres, machinery, boots or plant matter such as hay.
- ***Resistant varieties.*** Use whenever available. Source information on hybrids of different genetic backgrounds to assist with minimising the build-up of specific pathogens; for example, rust races have specific virulence genes which will overcome some hybrids and not others.
- ***Crop nutrition.*** A healthy crop is more able to express its resistance/tolerance than a crop under stress. Be aware that some pathogens such as powdery mildew are more virulent on crops that have been grown under conditions of excess nitrogen.
- ***Management of crop residues and weeds.*** This minimises carryover and build-up of pathogens; for example, nearly all weeds host *Sclerotinia*.
- ***Developing a sound crop rotation strategy.*** Repeated plantings of sunflowers will lead to the build-up of soilborne pathogens including *Sclerotinia, Phoma, Phomopsis*, and *Verticillium*.
- ***Regular crop monitoring.*** Regularly check your crops for anything out of the ordinary. Do not hesitate to get a second opinion. Walk through the crop in a 'W' pattern; this will minimise the risk of missing disease hotspots and allow you to gauge any possible edge effects or disease gradients.
- ***Knowledge update.*** Ensure you understand the biology of the pathogens that will potentially infect your crop. Monitor according to risk analysis based on infection timing; for example, *Phoma* and *Phomopsis* species symptoms rarely become obvious before budding or flowering. Monitor regularly for powdery mildew, as in ideal conditions the short life-cycle can result in an epidemic, which could severely affect the crop within 2–3 weeks (Figure 2). [2]

2 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

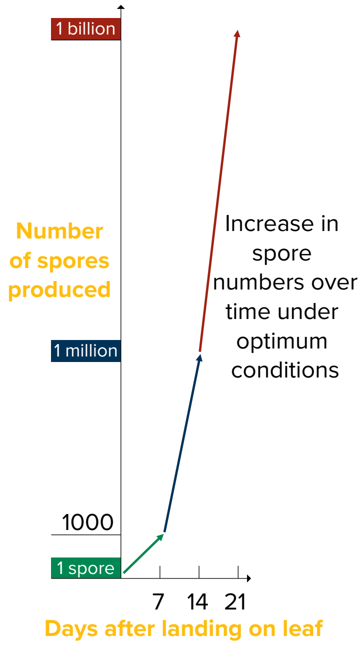

Figure 2: *Potential exponential increase in powdery mildew spore numbers in a 2–3-week timeframe.*

9.3 Steps to effective disease management

9.3.1 Risk assessment

Assessment of disease risk relies on the knowledge base of the end user (grower or advisor) with respect to their paddock history, their confidence in forecasts of both weather and possible price, their willingness to educate themselves about pathogen biology, and their tolerance for accepting risk.

Some disease management decisions can be made pre-planting; for example, a paddock with a history of heavy *Sclerotinia* infection in chickpeas would not be a good choice for sunflowers in the next rotation since both crops are susceptible to this pathogen. A cereal crop would be the best choice.

Other disease management risk factors involve both pre- and post-planting decisions. For example, pre-planting knowledge of the powdery mildew pathogen's preference for cooler weather means the grower understands that crops growing in the cooler ends of the planting season are more likely to suffer powdery mildew infection than crops growing in the middle of summer. Soil moisture levels permitting, planting times can be adjusted accordingly if a cool season is forecast.

Post-planting decisions would involve a risk assessment of allowing a powdery mildew outbreak to progress further up the plant than the bottom third, without chemical control measures. This is currently a difficult decision as yield loss threshold data are not available and the use of fungicides is the least desired control option.

Each crop/disease risk analysis will:

1. Identify the factors that determine risk.

- ***Pathogen:*** pathogenicity, survival, transmission and infection mechanisms, availability of control measures, is it widespread or sporadic?
- ***Host:*** vulnerability, varietal reactions, availability of resistant lines, multiple hosts, seed dressings.
- ***Agronomy:*** row spacing, soil conditions, cultural practices, plant residues, nutritional interactions, irrigation, dryland, herbicides, time of planting.
- ***Weather:*** weather forecasts including possible temperature variation, rainfall, relative humidity. Climatic conditions affect both plant growth and pathogen's biological responses. A stressed plant is vulnerable to disease outbreaks.
- ***Risk management:*** assess level of risk, contemplate ease of implementing management plan, assess costs of implementation, assess value of possible returns over known risk factors

2. Analyse specific known risk factors

- ***Pathogen:*** virulence level against particular hybrid, level of inoculum in air/soil/seed, known paddock history, alternative weed hosts for either the pathogen or its vector, e.g. parthenium weed and the *Tobacco streak virus* (TSV) thrips vector.
- ***Host:*** susceptibility to pathogen, stress reactions to herbicides, nutritional disorders.
- ***Agronomy:*** weather outlook, time of planting, effectiveness of cultural control methods prior to planting, airborne inoculum levels built up during season.
- ***Weather:*** water storage in profile, long term forecast for rain or abnormal conditions, potential for water stress during growing season.
- ***Risk management:*** ensure strategy is flexible and adjust as necessary.

3. Acknowledge your own acceptable risk level

- ***Low:*** crop failure would seriously affect the farm's economic situation, not necessarily a good time to try new and untried cropping options.
- ***High:*** a risk of substantial losses if potential returns/financial rewards are high, a failure in the rotation would not unduly affect the potential earning capacity of the farm. [3]

9.4 Providing an accurate diagnosis

9.4.1 Observations

Diagnosing plant diseases is not always quick or easy. Unlike insect pests, which are relatively easy to identify, the accurate diagnosis of plant diseases requires patience and, at times, a microscope.

A number of sunflower pathogens produce similar and confusing symptoms, so the diagnostician needs to keep an open mind until all aspects of the host–pathogen interaction are considered. It is possible that multiple causal organisms are involved, as was the case with a recent Phoma black stem and Phomopsis stem canker outbreak.

However, some pathogens do show characteristic symptoms, and with experience, a network of other specialists and suitable reference material, a reasonably quick diagnosis can be achieved. There is no substitute for having a hands-on approach to sunflower disease management—each season will bring its own unique mysteries to solve.

- **Be observant.** Analysing plant symptoms is just the first step in the diagnostic process. Attention to detail is essential.
- **Make a list.** List all possible culprits as you observe symptoms. Most will be discounted as you progress through your diagnostic analysis.

3 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

- **Recognise a healthy plant.** This seems obvious, but some varieties display idiosyncrasies which can be mistaken for early stages of a disease; for example, varieties with certain genetic backgrounds may display apparent swelling at the nodes, raising questions of possible viral infection or herbicide injury. Leaf colour variations may be confused with symptoms of viruses; long, leafy bracts or tubular-shaped petals may be genetic but excessive bract development may also be caused by herbicide injury or a phytoplasma. Ask your seed company representative or breeder about specific traits, if concerned.
- **Check all parts of the plant.** Leaf symptoms can be the result of leaf pathogens, vascular tissue infection or a pathogen invading the roots.
- **Note extent of the symptoms.** Is the issue widespread, only an individual plant or clumps. Soilborne pathogens will often affect plants individually or smaller clumps (Figure 3).

Figure 3: *Soilborne pathogens such as* Sclerotinia minor*,* Sclerotinia sclerotiorum *and* Sclerotium rolfsii *infect individual plants or clumps if infection is severe. Basal lesions on these plants are typical of* S. minor.

Photo: S. Thompson, QDAF

- **Are the symptoms uniform throughout the paddock?** If so, are there any abiotic (non-living) reasons why the crop would be uniformly affected: for example, was a particular herbicide used in the previous rotation that may not have broken down as quickly as expected if weather conditions were particularly dry; was the appropriate rate of fertiliser applied or could the symptoms indicate a nutritional disorder; was a chemical applied off-label or in a mix that caused phytotoxicity? Could drift have been a factor?
- **Widespread and even symptoms indicate abiotic factors.** These might include soil conditions (deficiencies, toxicities, pH, excess salt in irrigation water), adverse climatic conditions (hail, drought, floodwaters, cold or heatwaves), toxic chemicals (inappropriate chemical usage, experimental products, growth regulators), human error.
- **Pathogens take time to build up in a crop.** Regular monitoring for insects and diseases, and weed hosts, will decrease the chances of unpleasant surprises later in the season. For example, damage caused by a high population of *Helicoverpa* at budding or flowering can lead to a high incidence of head and stem rots later in the season.
- **Check for distinctive visual or smell symptoms.** Is there ooze or an unpleasant odour? Bacterial infections such as *Erwinia* are most likely to be secondary and infect after damage by insects. However, under extremely wet conditions, bacterial infection may be the culprit (Figure 4).

Figure 4: *Sucking insects such as green vegetable bug can lead to secondary bacterial infections.*

Photo: S. Thompson, QDAF

- **Do the affected plants follow the row or are they randomly distributed across the paddock?** Wilted plants along a row can be the result of mechanical damage where the scarifier has nicked the roots or stem at soil level allowing pathogens to colonise. Plants dotted through the paddock are more likely to indicate a soilborne pathogen such as *Sclerotinia, Verticillium, Macrophomina or Phomopsis*.
- **Is there a disease gradient into the paddock?** If so, has a neighbouring paddock or laneway had chemical applied that may be phytotoxic to your crop; or is a weed growing alongside your crop that may be host for a vector such as the thrips species, which transfer TSV.
- **Is the problem restricted to one paddock?** Is it across varieties, are plants at a certain growth stage affected, and did the previous crop show any similar symptoms? Some pathogens, e.g. *Sclerotinia, Macrophomina,* TSV, have a broad host range.
- **Geographical distribution.** Occasionally, pathogens are restricted to certain cropping areas. For example, to date TSV has only been recorded in sunflower in central Queensland (CQ) because the thrips vectors requires particular infected weed hosts which have not yet been found in the southern Qld and NSW cropping areas.
- **Vigilance is essential.** Do not assume that TSV will not be found outside CQ; as research on weed hosts continues, more hosts are being identified and it is possible TSV will eventually be identified elsewhere. Inter-farm hygiene is essential to limit the possibility of infected weed seeds/insects being transferred from CQ—clean contract headers, muddy ute tyres, boots, machinery.
- **Know your pathogens.** Understanding the life-cycles of the pathogens can help enormously with getting an accurate diagnosis.
  Example 1. Some pathogens do not show symptoms until budding–flowering, e.g. *Verticillium, Phoma* and *Phomopsis.* If a young plant is displaying a stem lesion prior to late budding–flowering, it is unlikely to be *Phoma* or *Phomopsis* infection—look for Sclerotinia base rot, insect damage and subsequent secondary rots, or TSV.
  Example 2. TSV is commonly found in CQ and less likely to be found in southern

Qld and NSW due to the lack of weed hosts for the vector, but keep an open mind. TSV, its thrips vectors and weed hosts could easily be found outside CQ; stem streaks are usually black, rather than brown. Do not hesitate to send any suspected TSV samples for testing to either the Plant Pathology team in Toowoomba or the virologists at Indooroopilly.

Example 3. Macrophomina phaseolina (charcoal rot) may have infected the roots and lower stem early in the season but will not cause the plant to wilt or lodge until the plant is under stress during the head filling stage or during hot, dry weather conditions. Check pith in the lower stem for peppery, dark-coloured microsclerotia; stems often have a bleached appearance. If light brown or orange basal lesions are present, check for *Sclerotinia minor* or *Sclerotium rolfsii.*

Example 4: Patches of poor emergence or damaged seedlings? Disease, poor vigour or lack of moisture may not be the cause. Mice will dig up freshly planted seeds retrieving seeds along many metres of row per night; rabbits, birds, cutworms and cockroaches will chew off newly emerged seedlings at ground level.

- **Use your hand lens and knife/secateurs.** Sacrifice an infected plant. Cut through stems. Discoloration of the pith–vascular tissue usually means a pathogen is present somewhere in the plant (Figure 5). Sclerotia or microsclerotia may be observed with a hand lens or with the naked eye if the pathogen is *Sclerotinia*. Check roots for discoloration, pruning and 'right-angle root syndrome'.

Figure 5: *Black sclerotia of* Sclerotinia minor *inside stem base.*

Photo: S. Thompson, QDAF

- **Check new growth** (Figure 6). Does the new growth have symptoms, or are the symptoms progressing as the plant ages, e.g. plants affected by low rates of herbicides such as SpraySeed® may produce very evenly spaced lesions and symptom-free growth as the plant ages.

Figure 6: *New growth growing away from symptoms of early herbicide drift. Note top leaves are free of symptoms.*

Photo: N. Stevenson, Spackman & Associates

- **Know your herbicides.** Chemical injury can easily be confused with disease symptoms; e.g. the twisting and stunting caused by 2,4-D damage is similar to the distortion of stems and leaves caused by TSV infection. Look for black streaks to assist with TSV field diagnosis (Figure 7).

Figure 7: *Twisting of upper stem caused by TSV can be confused with herbicide damage.*

Photo: M. Sharman, QDAF

- **Check watering schedules.** Herbicides can accumulate in tail ditches of paddocks. Is there a gradient of symptoms up from the end of the paddock? Could these plants be waterlogged? Waterlogging can lead to nutritional deficiencies.
- **Look for signs of fungal growth.** Cut through the lower stems to look for sclerotia; the pith will have a peppery appearance if *Macrophomina* is present, large black sclerotia will point to Sclerotinia stalk rot, and caramel-coloured sclerotia at soil level will indicate an infection of Sclerotium base rot (Figure 8). Mycelium (fungal threads) growing on the heads may indicate Rhizopus head rot—check for insect damage. If roots are soft or dark coloured, pruned or poorly developed, a fungus is probably present although waterlogging can also be a culprit.

Figure 8: *Mycelium (fungal threads) and protruding black sclerotia at the base of the plant. Sclerotinia base rot caused by* Sclerotinia sclerotiorum.

Photo: M. Ryley, QDAF

- **Symptom variability can lead to an improper diagnosis.** Environmental conditions, varietal differences and multiple pathogens infecting the one plant can cause symptom variability. Inspect a number of plants and note common irregularities. If in doubt, get a second opinion.
- **Check soil compaction.** Compacted soils and plough pans will often lead to ‘right-angle root syndrome’ (Figure 9). Roots are unable to penetrate through the impacted layers, and therefore grow horizontally. With poor root development, plants can develop symptoms of water stress, nutritional deficiencies and herbicide damage. Poor root development means plants are unable to access water and nutrients adequately and may show symptoms of a deficiency even though fertiliser may have been applied. In compacted soil areas, herbicides applied to prior crops may be unable to leach away. Products applied to the current crop may be concentrated in a small area of the root-zone and result in unexpected herbicide injury.

Figure 9: *Compaction leads to 'right-angle root' syndrome.*

Photo: K. McCosker, QDAF

- **Ask questions** (Figure 10). The more information you can gather about a site and affected crop, the better—crop rotational history, variety, herbicide, insecticide and fungicide applications for both this crop and previous crops, fertiliser applications, chemical applications in nearby paddocks. Wind and inversion layers can cause serious herbicide damage to non-target crops.

Figure 10: *Diagnostics is the result of a two-way flow of information.*

Photo: S. Thompson, QDAF

- **Listen, be aware.** Many disease outbreaks occur in tandem with outbreaks in other cropping areas; for example, powdery mildew outbreaks in sunflower in 2008–09 were mirrored by unusually severe powdery mildew infection in tomatoes in the Burdekin, vegetables in the Lockyer and mungbeans in CQ. Although multiple powdery mildew species were involved in these outbreaks, all were favoured by the same environmental conditions. Being aware of changes in environmental conditions alerts the diagnostician to potential disease outbreaks.
- **Ask for help.** Don't hesitate to contact other specialists. Working together will enhance the chances of an accurate diagnosis.

So, what would you diagnose for the sample in Figure 11?

- Is this pith damage the result of intense *Phoma* infection or early stage *Phomopsis* infection?
- Or is the black stem discoloration early TSV infection?
- Is the lesion roundish, black and shiny, and therefore possibly *Phoma*?
- Or is it more brown than black, irregular or oval at the nodes and possibly *Phomopsis* infection?
- Then there is Sclerotinia stem rot—is the lesion the right colour and are sclerotia present? If so, what colour?
- Or could it be insect damage with secondary *Erwinia* bacterial infection?

Figure 11: *What diagnosis would you give?*

Photo: S. Thompson, QDAF

A field diagnosis can be difficult. Symptoms may be confusing. If unsure of a diagnosis, send samples to a diagnostician (Figure 12). Sometimes, only laboratory isolations will provide the answer. (Regarding Figure 11, this stem lesion was identified as Phomopsis stem canker even though the lesion was very dark in colour—typical *Phomopsis* lesions are brown.) [4]

4 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

Figure 12: *Laboratory analysis may be necessary to confirm identification.*

Photo: M. Ryley, QDAF

9.4.2 Samples

- **Provide more than one sample if possible.** Discuss with the diagnostician the type of sample required, i.e. whole plants or plant parts. For small plants, send whole plants. If practical, send an unaffected plant for comparison (not always necessary or practical).
- **Send information sheet with the samples.** The more information given on the crop/location/environmental conditions/chemicals, fertilisers, insects, rotations etc., the easier it is for the diagnostician to make an accurate diagnosis. Send in a Disease Enquiry Sheet with each sample.
- **Provide samples in good condition.** Laboratory testing relies on good quality samples. A piece of stem or leaf that has been in the back of the ute all week is unlikely to retain viable fungal material.
- **Phone or email your diagnostician.** Samples sent can then be tracked if lost in transit. Samples inadvertently 'lost' in reception areas can be rendered non-viable if not refrigerated as soon as possible after arrival.

Sending infected plant tissue

Rust spores rapidly loose viability and die if samples are left in plastic, or if leaves sit in direct sunlight on the seat of a car in any temperatures particularly over 25°C. Send rusty leaves in paper bags only—never store in plastic.

Phoma and ***Phomopsis*** are relatively resilient in old dry stems, hence the length of time they remain a source of inoculum in the field. Cut lengths of infected stem and post/courier in paper envelope or box. Send head or seed sample with infected plant samples if mature. Both *Phoma* and *Phomopsis* species can be seedborne.

TSV, like all viruses, is difficult to detect, so good quality samples are essential for an accurate diagnosis. Place cut samples into a paper bag or newspaper, dampen the paper and then place the sample into a plastic bag before posting or sending by courier.

Keep samples cool and send as soon as possible. Send more than one sample. For seedling death, include a healthy specimen. Email photos if possible.

Caution: store samples in a fridge or Esky until posted or sent by courier. Try to avoid a situation where a sample may sit in the post office or courier's shed over the weekend. Wet or damp samples rot rapidly while in transit—if possible avoid collecting in the rain; paper towel is useful for drying samples if necessary. [5]

9.5 Tools of the trade

Ute guides. Even specialists who work with plant diseases on a daily basis need reference material; symptoms can be variable and atypical under some environmental conditions and reference material is invaluable for comparison of symptoms. [6]

Hand lens, magnifiers. These are essential when looking for fruiting bodies in lesions such as *Phoma, Phomopsis, Sclerotinia, Macrophomina.*

Knife or secateurs. These are invaluable for checking for damage to the pith (*Phomopsis, Macrophomina*) or vascular system infection (*Verticillium, Erwinia*).

Paper and plastic bags. Generally, placing a sample in a plastic bag and keeping it cool will be adequate to keep the pathogen alive until lab testing can be completed. If the sample has to be posted, ensure overnight delivery or the sample may rot in a plastic bag. If in doubt, use both plastic and paper bags. Note: for rusty leaves, always use paper bags or the moisture in the leaf will cause the rust spores to be non-viable if stored in plastic.

Esky and cooler bricks. Even if it is impractical to carry cooler bricks around, having a small cheap Esky in the car greatly increases the chances of the samples arriving at their eventual destination with the pathogen still viable. At the very least, keep all samples out of the sun.

GPS. Provides accurate location data. Samples sent on to the Queensland Herbarium provide important records of Australia's biodiversity and are a useful tool for monitoring disease spread and the potential locations for biosecurity outbreaks.

Felt pens. If more than one sample is collected from the site or multiple locations, having effective writing tools for the sample bags helps avoid later confusion. Biros and sunscreen infused paper bags cause undue frustration and biros invariably punch holes in plastic when trying to write a label. Keep a pencil handy.

Clipboard and sample information sheets. Collect the grower's details, crop variety and paddock history as soon as possible. Observe weeds in the vicinity for symptoms, e.g. wild sunflowers will often carry *Phoma*/*Phomopsis* lesions and rust; parthenium weed growing near a crop will indicate that TSV infection is possible.

Remember: fill in a Plant Disease Enquiry Sheet and send it with your sample. [7]

9.6 Sunflower diseases: biology, symptoms, management

9.6.1 Rust (*Puccinia helianthi*)

Economic importance

Current hybrids generally have good levels of resistance so in recent years, serious losses due to rust have been uncommon (Figure 13). However, the pathogen is continually changing and resistance can be overcome. Without adequate resistance in hybrids, rust levels can quickly build causing severe epidemics and high yield

5 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

6 GRDC (2011) Sunflower disorders: the ute guide. Ground Cover Direct, GRDC.

7 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

losses. Therefore, changes in the rust spectrum are constantly monitored by the QDAF and seed companies, with researchers at QDAF having identified over 115 rust races (pathotypes) to date. Breeding rust resistant hybrids is an ongoing process greatly assisted by gene pyramiding techniques.

Figure 13: *Selected rust-resistant hybrids.*

Photo: S. Thompson, QDAF

Survival and spread

In Australia, rust survives on volunteer sunflower plants and in the wild sunflower populations. Wild sunflowers are not only the source of inoculum at the start of each cropping season but also host a huge range of races (pathotypes) which survive at low frequency until a susceptible hybrid provides them with the ideal host and rust infection levels escalate.

Rust spores are air-borne and can be transported many hundreds of kilometres.

Significantly, although wild sunflowers are a source of new rust races, they are also a valuable source of disease resistance and utilised by plant breeders in Australia and internationally (Figure 14).

Figure 14: *Wild sunflowers such as Helianthus debilis are a source of rust and resistance genes.*

Photo: G. Kong, QDAF

Conditions for infection

Temperatures ~18–25°C favour development of the disease. Free water or dew on the surface of leaves is essential for infection. With adequate moisture and favourable temperatures, infection can occur within 12 hours but pustules containing the reddish brown spores do not develop for 7–12 days, depending on host and weather conditions. Successive cycles of wet weather or dews cause rapid development of the disease.

- Rust-resistant hybrids and recent drier climatic conditions can give the illusion that rust is no longer a disease issue in sunflowers. However, monitoring of the rust races present in wild sunflower populations, seed company nurseries and on susceptible hybrids such as confectionary lines indicates that pathotypes virulent on current hybrids are ticking over and could quickly increase to epidemic proportions given the right conditions.
- The re-releasing of some older hybrids which have little or no rust resistance may lead to an increase in rust incidence—monitor these crops carefully because, given the right conditions, their susceptibility means they are vulnerable to infection by multiple races which, like in past years, could result in severe yield losses (Figure 15).

Caution: planting rust susceptible varieties will lead to increased rust infection under favourable conditions.

Figure 15: *Severe rust infection leads to yield losses.*

Photo: S. Thompson, QDAF

Symptoms

Small reddish-brown pustules will be seen on both the upper and lower leaf surfaces and sometimes on leaf petioles and flower bracts (Figure 16). Very high levels of infection can cause eventual death of leaf tissue. In some varieties, resistance declines at or following flowering and low levels of infection can occur. Unless severe infection occurs early, yield loss generally results from smaller, rather than fewer, seeds.

Figure 16: *Small reddish brown rust pustules; heavy infection can blight the leaf.*

Photo: S. Thompson, QDAF

Control

If practical, plant a mix of rust-resistant hybrids. Select varieties according to the planting time and the region. Avoid successive plantings of the same or susceptible varieties. [8]

9.6.2 Powdery mildew (*Golovinomyces cichoracearum*)

Economic importance

The incidence of powdery mildew infection in sunflower has increased significantly in the past 5 years (Figure 17).

Sunflower is the only crop known to be attacked by *G. cichoracearum.* All other hosts are other members of the Asteraceae family such as wild sunflowers and ornamentals, e.g. *Zinnia*, *Dahlia*. Two other species of powdery mildew infect sunflowers overseas.

No data are available for economic yield loss thresholds caused by sunflower powdery mildew under Australian conditions. However, overseas literature suggests that under ideal disease conditions where infection levels are high, yield losses do occur. Plant death can also result if early infection is left untreated in young plants.

MORE INFORMATION

GRDC Update Paper: Disease control in summer crops and management strategies to minimise financial losses

8 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

Figure 17: *Grey-white fungal colonies on leaf surface.*

Photo: S. Thompson, QDAF

Survival and spread

All hosts of sunflower powdery mildew are members of the Asteraceae family particularly the wild sunflower. Spores are wind-borne and will remain viable after spreading long distances under cool conditions. Spread up the plant can be rapid due to the short life-cycle and high rate of sporulation. Powdery mildew infection levels can develop from mild to epidemic proportions within three weeks under ideal conditions of cool weather and high humidity.

Conditions for infection

- Infection is favoured by high humidity, low light and temperatures of 20–25°C.
- Spores geminate within 2–4 h under ideal conditions.
- Short life-cycle of 5–7 days under ideal conditions.
- Spores disperse by wind leading to rapid movement between leaves and crops.
- Free water (rain or irrigation) on the leaf inhibits spore germination but the resulting humidity favours infection once leaves dry.

Symptoms

Fungal colonies first appear on the lowest leaves as powdery, greyish white spots on the upper leaf surface. Much of the fungal growth remains on the upper surface, the powdery appearance being the result of the production of conidia (spores). Although primarily a leaf pathogen, colonies can be found on stems and heads and bracts if infection is severe (Figure 18).

Figure 18: *Powdery mildew infection on stems.*

Photo: S. Thompson, QDAF

Strategies to minimise powdery mildew buildup

1. Cultural control

- Time of planting may influence the speed of disease build-up within the crop—cooler temperatures at the beginning and end of the growing season can lead to increased infection.
- Avoid growing crops under conditions of high humidity—not often a practical option.
- Irrigate in the mornings to limit the buildup of humidity in the crop overnight (Figure 19)
- Overhead irrigation where the entire crop canopy becomes wet will lead to higher humidity within the crop—use droppers if possible.
- Overseas recommendations are that good air circulation within the crop can minimise disease development and heavy planting rate and narrow row spacing can lead to heavier disease pressure.
- But in Australia, conversely, experience gained while working on a number of fungicide trials in Queensland since 2009 has indicated that heavier plantings can be advantageous as dense plant stands ensure the leaves remain wet longer, thus helping minimise powdery build-up. It is often also noticeable that plants on the crop edges where air movement is highest carry more infection than those deeper in the crop. These findings are the opposite of those recorded overseas.
- These observations on the role of plant density on powdery mildew build-up under Australian environmental conditions need further investigation.

Figure 19: *Morning watering helps to limit humidity build-up overnight.*

Photo: S Thompson, QDAF

2. Chemical control. The APVMA has granted an Emergency Use Permit (PER12045) for the fungicide TILT® 250EC (propiconazole) until 30 June 2014. Rate: 250–500 mL product/ha.

- Maximum two (2) sprays per crop.
- Application timing: 21–28 days between applications.
- Last application: no later than at 5% ray floret emergence.
- Recommended timing and rate: under conditions of low to moderate infection, if powdery mildew is present in the bottom third of the canopy and moving into the middle third, then a single application of **500 mL/ha applied at the 5% ray floret emergence** stage will protect the crop until physiological maturity.
- When deciding whether to apply TILT®, consider the inoculum load in your own crop and surrounding crops, future weather conditions plus the crop stage cut-off for applications of 5% ray floret emergence. [9]

MORE INFORMATION

www.apvma.gov.au

MORE INFORMATION

GRDC Update Paper: Disease control in summer crops and management strategies to minimise financial losses

9.6.3 Stem canker (*Diaporthe/Phomopsis* spp.)

Economic importance

Phomopsis helianthi is not recorded in Australia.

The first serious outbreak of Phomopsis stem canker in Australian sunflowers occurred in NSW and Queensland during the 2009 growing season. Current research has revealed that a number of previously undescribed *Phomopsis* species are responsible. Three newly described species have been named as: *Diaporthe (Phomopsis) gulyae* (highly virulent), *D. kongii* and *D. kochmanii* (low to moderate virulence) (refer Thompson et al. 2011). [10]

Phomopsis helianthi is an exotic pathogen, not recorded in Australia but known to cause substantial yield losses overseas. To date, the isolates tested have NOT been identified as *Phomopsis helianthi*; however, our virulent Australian species appear to display almost identical symptoms (Figure 20). Mid-stem lodging and the associated loss of yield is the most significant impact of *Phomopsis,* with losses of 40–60% recorded overseas for *P. helianthi* outbreaks. Oil content can also be affected.

Vigilance is encouraged in all situations where *Phomopsis* outbreaks occur—the aim is to limit the spread of these pathogens, determine the extent of infected cropping

9 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

10 Thompson SM, Tan YP, Young AJ, Neate SM, Aitken E, Shivas RJ (2011) Stem cankers on sunflower (*Helianthus annuus*) in Australia reveal a complex of pathogenic *Diaporthe* (*Phomopsis*) species. Persoonia 27, 80–89.

area and continue to identify the complex of pathogens responsible. Biosecurity Awareness is essential.

Figure 20: Phomopsis *infection leads to mid-stem lodging, lesions at multiple nodes, yield loss.*

Photo: L. Serafin, NSW DPI

Dispersal and spread

Phomopsis survives in plant debris with small black/brown pycnidia (fruiting bodies) developing in the dry stalks as conditions become favourable. Spores can be dispersed by wind over short distances with raindrop splash and irrigation enhancing spread (Figure 21).

Phomopsis can be seedborne, so seed production nurseries should be monitored for any signs of this disease.

Queensland researchers have found that, depending on the *Diaporthe* species, living volunteer plants of crop hosts and living plants of weeds in paddocks and adjacent areas can act as the 'green bridge' between highly susceptible crops, while colonised dead plants and stubble of crop and weed hosts can act as the dead or 'brown bridge' between major crops. Almost 30 months after the severe *Diaporthe* lodging event in sunflower crops on the Liverpool Plains, *D. gulyae* was isolated from the 'brown bridge' of sunflower and Noogoora burr stubble lying on the soil surface after zero till farming practices and two cereal crops planted into the sunflower stubble. [11]

The study revealed that *Diaporthe/Phomopsis* species have wider host ranges than previously thought and it is considered likely that the same will be found for other groups of pathogens such as the *Fusarium* species which are also opportunistic colonisers of both live and dead plant tissues.

It is apparent that these fungi form a group of pathogens/saprophytes that are potentially capable of surviving on both 'brown' and 'green' bridges between growing seasons in the northern region and that the role of weed stubble in aiding survival has been largely unrecognised. Since the introduction of zero and minimum-tillage systems, crop and weed stubble is commonly found across the various cropping

11 S Thompson, S Neate, YP Tan, R Shivas, E Aitken (2016) Weeds and crop stubble as a pathogen 'host' or reservoir. What species are involved with what crop impact—implications for management. GRDC Update Paper 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Weeds-and-crop-stubble-as-a-pathogen-host-or-reservoir

systems of the northern region. An inoculum reservoir can be found in these residues regardless of the presence of the primary crop host.

The impact of strategic tillage on the survival of these groups of pathogens in crop and weed residues under Australian conditions is largely unstudied. Crown rot researchers, (Simpendorfer et al. NSW DPI) have looked at the role of tillage for the *Fusarium* crown rot pathogen in Australia and multiple tillage investigations have been completed by overseas researchers.

A GRDC funded project has been initiated with the aim of looking more intensively at alternative hosts and survival of the *Fusarium* species on sorghum as well as early studies on the impact of burial on infected sorghum. [12]

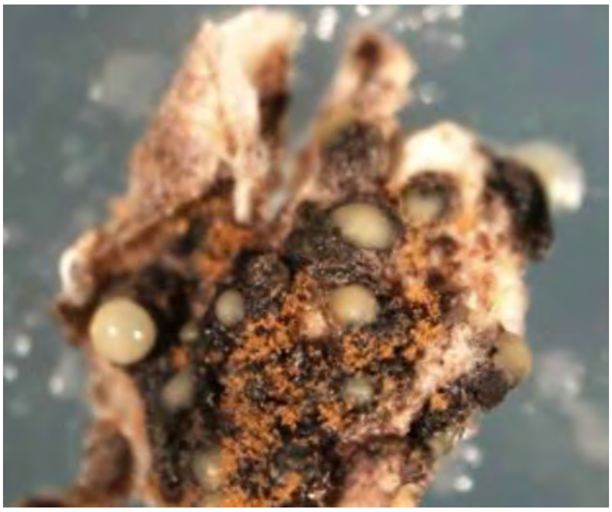

Figure 21: *Spores oozing from* Phomopsis-*infected pith.*

Photo: S. Thompson, QDAF

Symptoms

The first symptoms appear on the lower or middle leaves around the leaf margins usually around the time of budding or flowering. Small necrotic areas, sometimes showing a chlorotic border, quickly merge and infect the leaf veins. Leaves die off rapidly as the infection moves down the leaf petiole to the node where the characteristic light brown lesion develops.

Lesions are always centred on the axils and start as small brown sunken spots, which can rapidly develop into an elongated, light tan to dark brown lesion, up to 20 cm in length. Lesions may appear water-soaked and vary in colour from olive greenish brown (often water-soaked) to pale caramel brown to dark brown with a black edge (Figures 22, 23).

Small black fruiting bodies (pycnidia) may be visible in the lesion if infection is advanced.

The fungus rots the pith behind the lesion eventually leaving the stem hollow. This results in stem weakness, sometimes wilting and leaf necrosis if infection is severe, and subsequent lodging as the head fills if pith damage is advanced.

12 S Thompson, S Neate, YP Tan, R Shivas, E Aitken (2016) Weeds and crop stubble as a pathogen 'host' or reservoir. What species are involved with what crop impact—implications for management. GRDC Update Paper 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Weeds-and-crop-stubble-as-a-pathogen-host-or-reservoir

Figure 22: Phomopsis *pale brown stem lesions.*

Photo: S. Thompson, QDAF

Figure 23: Phomopsis *brown black stem lesions.*

Photo: S. Thompson, QDAF

MORE INFORMATION

http://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Thompson_PhomopsisStemCancer_edited_paper.pdf

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-106-Sept-Oct-2013/Fungus-poses-new-sunflower-disease-threat

Infection conditions

Phomopsis infection is favoured by wet conditions from late budding through to flowering. Disease severity depends primarily on climatic conditions and plant growth stage. Optimal temperatures are 23–25°C but the fungus will grow at temperatures 14–32°C. Characteristically, plants display brownish lesions dotted regularly up the stems at the nodes. Symptoms usually occur from budding through flowering to maturity. Depending on the severity of infection, mid-stem lodging may occur, not necessarily at a node or the site of infection.

Control

- *Phomopsis* survives on plant debris so effective cultural control methods are essential.
- Burying crop residues minimises inoculum build-up.
- Avoid consecutive plantings of sunflowers.
- Use non-susceptible crop rotations.
- Ensure no infection is present in seed production blocks.
- Excess nitrogen encourages *Phomopsis* incidence.
- In Australia, no products are registered for the chemical control of *Phomopsis* on sunflower.
- Some tolerance has been identified in screening trials overseas.

Important note. Infected seed will appear normal until after favourable weather conditions occur—fruiting bodies (pycnidia) will then develop on the seed coat (Figure 24). Laboratory testing is necessary to determine whether *Phomopsis* or *Phoma* infection is present. Mixed infections of *Phoma* and *Phomopsis* can occur - symptoms can be confusing. Send samples for laboratory identification. Send suspect samples to the QDAF Plant Pathology Laboratory, Toowoomba, Queensland (203 Tor St, Toowoomba, Qld).

Remember: *Phomopsis* can be seedborne. Ensure seed production blocks are disease-free.

Figure 24: *Pycnidia on infected seed may spread infection to new sites.*

Photo: S. Thompson, QDAF

Caution: *Phoma* and *Phomopsis* lesions can be difficult to tell apart. Field diagnostics can be confusing with lesion colours and sizes varying according to lesion age and crop susceptibility.

As a general rule: *Phoma* lesions are black, shield-shaped and shiny; limited, if any pith discoloration. *Phomopsis* lesions are more oblong, brown or brown/black, sometimes have a water-soaked appearance; may have pith damage behind the lesion (Figure 25). [13]

Figure 25: *Pith damage behind a* Phomopsis *lesion.*

Photo: S. Thompson, QDAF

9.6.4 Phoma black stem (*Phoma* spp.)

Economic importance

Although previously recorded as a minor pathogen of sunflower crops in Australia, an outbreak of a mix of *Phoma* and *Phomopsis* species (Figure 26) occurred in both NSW and Qld sunflower crops in the 2009 growing season.

Generally, *Phoma* produces a surface lesion that causes minimal damage to the crop. Researchers overseas report that this pathogen has been known to cause some damage to the pith and subsequent lodging but this is not usually seen under Australian conditions.

The economic importance of this pathogen is considered low unless infection occurs in conjunction with other pathogens such as *Phomopsis* spp., *Fusarium* spp. or bacterial pathogens. When pith damage occurs due to secondary infection, plants may lodge.

13 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

Figure 26: *Black shield-shaped lesions dot the stems at the nodes, mixed infections of* Phoma *and* Phomopsis *can occur.*

Photo: S. Thompson, QDAF

Conditions for infection

Disease severity depends primarily on climatic conditions and plant growth stage. Most sunflowers are susceptible but a degree of tolerance can be observed in some lines.

Phoma infection is favoured by moist conditions from late budding through to flowering. Raindrop splash and irrigation enhance spread. Insects may also spread the pathogen particularly if they drill into the stem or leaf petiole.

Many *Phoma* spp. have been reported as seedborne but the pathogen will also survive for long periods on infected stubble or trash.

Dispersal and spread

Phoma overwinters as small black pycnidia and/or mycelium in infected stubble, and can be transmitted by seed. Optimum temperature for spore germination is 25°C with conditions of high moisture for 24 h being optimal. At lower temperatures, longer periods of free water are required. Spores will germinate at temperatures of 5–30°C as long as free water is consistently present.

Phoma spores travel for short distances on the wind and are more easily transported by rain splash. Overseas, leaf-feeding insects have been recorded overseas as transmitting the pathogen.

Symptoms

Phoma infects via the leaves as wind-blown or rain-splashed spores. Leaf spots merge until they meet the veins, which then turn black. The infection travels down the petiole to the stem where a shiny, jet-black, round to oval shaped lesion develops centred on the node. Lesion size ranges from 1 to 5 cm, usually only affecting the epidermal layer and does not penetrate the pith. Recent studies from Russia indicate that the pith may become damaged in some circumstances.

Small black pycnidia, tiny fungal fruiting bodies, may be visible in the lesion using a hand lens but often laboratory isolations may be necessary to make a diagnosis.

If field inoculum levels are high, *Phoma* may infect the roots of young seedlings leading to a girdling lesion at the soil line. Girdling may result in stunted plants, smaller heads, blackened pith and poor seed set if the plant does not succumb to lodging.

Caution: *Phoma* infection may be confused with *Phomopsis* symptoms. *Phoma* produces smaller, darker (black) lesions than *Phomopsis* (Figure 27, 28), causing minimal damage to the pith and does not usually lead to lodging. *Phoma* infection may also be confused with early TSV infection—both can form black lesions at the node (Figures 27, 29 and 30).

Figure 27: *BLACK shield-shaped* Phoma *lesion.*

Photo: S. Thompson, QDAF

Figure 28: *Early-stage BROWN* Phomopsis *lesion, often elongated with a darker edge.*

Photo: S. Thompson, QDAF

Figure 29: Phoma *surface lesion.*

Photo: S. Thompson, QDAF

Figure 30: *TSV petiole and node infection—note blackening of pith and streak forming below node.*

Photo: S. Thompson, QDAF

Control

- *Phoma* survive on plant debris so effective cultural control methods are essential.
- Burying crop residues minimises inoculum build-up.
- Avoid consecutive plantings of sunflowers.
- Use non-susceptible crop rotations.
- Ensure no infection is present in seed production blocks.
- Excess nitrogen encourages *Phoma* incidence.
- No totally resistant sunflower lines are available, to date, but some resistance/ tolerance has been observed in some wild *Helianthus* spp. and sunflower cultivars (Figure 31).
- In Australia, no products are registered for the chemical control of *Phoma* on sunflower. [14]

14 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

Figure 31: *Wild sunflower host* Phoma *and* Phomopsis *species.*

Photo: S. Thompson, QDAF

9.6.5 Tobacco streak virus

Economic importance

Prior to 2009, a severe sunflower decline disease, now known to be caused by Tobacco streak virus (TSV), caused significant losses across the sunflower industry in CQ. [15] GRDC research has found with careful management of potential disease sources around crops and the use of tolerant cultivars, the risk of TSV in CQ can be largely minimised. However, TSV remains a significant concern for CQ sunflower growers with the potential for infection levels of 20–60% in susceptible cultivars if environmental conditions are conducive to disease outbreaks. TSV has not been found in sunflowers outside of CQ and as such should not currently be considered a risk in other regions.

Conditions for infection

TSV is transmitted only in pollen and seed of some hosts. It infects healthy plants via the feeding wounds of thrips, which allow TSV-infected pollen to enter. TSV disease is favoured by climatic conditions that enable high thrips populations to develop, and large amounts of infective pollen to be produced by host plants such as parthenium. These conditions generally occur during warmer months, and are highly dependent on rainfall and weed growth patterns.

The life-cycle of thrips is shorter during summer months, which allows population numbers to increase rapidly. Thrips populations will generally increase as weed growth increases following intermittent rainfall, while prolonged periods of rain over

15 QDAF (2006) Central Queensland sunflower disorder—*Tobacco streak virus*. Fact Sheet 2006. Department of Agriculture, Fisheries and Forestry, Queensland.

many days may reduce thrips populations. The highest rates of virus transmission will occur when thrips numbers are high and there are large areas of a flowering, virus host plant, such as parthenium. These conditions can result in high TSV disease rates in susceptible crops as large quantities of virus infected pollen is moved rapidly into crops by high numbers of thrips. Plants are most susceptible at the seedling stage.

TSV disease incidence is generally much lower during the dryer, cooler months of the year as thrips numbers are lower, their reproduction slows significantly and there is less virus-infected pollen produced by alternative weed hosts. TSV disease incidence has also been much lower during the very wet summers of 2010–11 and 2011–12 when grasses have been dominant over parthenium in many regions. Thrips populations also appear to have been reduced by regular, large rain events. Summers of intermittent rain following dry winters appear to be most favourable for development of large populations of both parthenium and thrips, which results in more TSV disease.

Dispersal

TSV-infected pollen may be dispersed significant distances by wind or thrips (Figure 32). TSV is seed-transmitted in some alternative hosts such as parthenium, crownbeard, cobbler's pegs and fleabane. In particular, TSV is seed transmitted in parthenium at high rates and may remain viable for several years in ungerminated seed in the soil. There is significant risk of long distance dispersal if infected parthenium seed is moved with machinery or harvested goods. Research to date indicates that TSV is not seed-transmitted in sunflower.

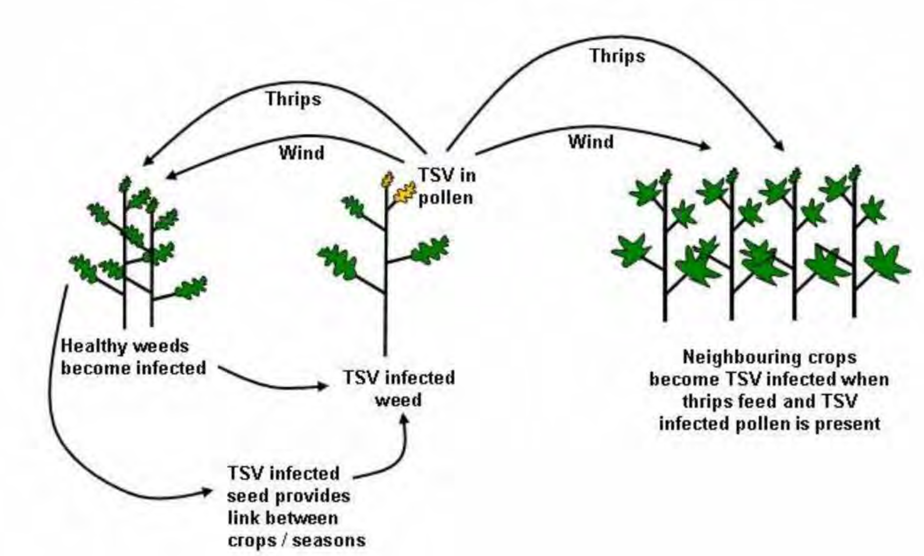

Figure 32: *Disease cycle of TSV.*

Survival

TSV can survive only in living plant hosts or in seed of some of those hosts (e.g. parthenium). It can survive in pollen grains but the length of time is unknown and probably varies depending on the host plant and climatic conditions. It does not survive in soil or on dead plant material.

Symptoms

The symptoms of TSV on sunflowers include: black streaks on the stem and leaf stalks, stunted growth, deformed growing tip, yellow and/or necrotic blotches on leaves, shortened internodes, plant death (especially in plants that become infected in early stages of development) and lodging of older plants due to weakened stems and blackened pith (Figures 33, 34, 35, 36).

Figure 33: *TSV leaf symptoms.*

Photo: M. Sharman, QDAF

Figure 34: *Characteristic black streak caused by TSV. The dark necrotic streaks running down the stem and the curling over and necrosis of terminal growth is distinctive.*

Photo: M. Sharman, QDAF

Figure 35: *TSV causes twisted stems and deformed heads.*

Photo: M. Sharman, QDAF

Figure 36: *Early stages of stem necrosis caused by TSV with streaks starting from the leaf nodes. TSV usually causes dark streaks below and above the node. Can be confused with* Phoma *infections, which cause dark shield-shaped lesions at the node (see Figure 23).*

Photo: M. Sharman, QDAF

Control

Planning:

- All research indicates that TSV is currently only a problem for sunflowers grown in CQ where the key alternative host, parthenium weed, is common. However, there is a real risk that TSV can be moved to new regions via infected seed of alternative hosts such as parthenium or fleabane, so vigilance in all regions is recommended for suspect symptoms in sunflowers and the appearance of parthenium.
- Determine and where possible, avoid areas of high risk such as locations either with a history of TSV or next to areas with a high density of parthenium (e.g. neighbouring grazing paddocks). Planting upwind of high risk areas may help to reduce transmission of TSV into crops; higher rates of disease are commonly seen downwind of these high-risk areas.

Hybrid tolerance:

- GRDC funded research has demonstrated that there can be significant differences between some sunflower hybrids in their tolerance to TSV infection. Rating for susceptibility in these trials was based on whether plants could produce harvestable seed; hence, only severely affected plants were rated as susceptible. Trials are continuing. For further information please refer to the September 2009 issue of Cropping Central Magazine or the article 'Sunflowers—a real option for 2012', Cropping Central, Issue 52, p. 6–8 or contact the QDAF Virology unit.

Ground preparation:

- Maintain crop hygiene; particularly control of parthenium in or upwind of the crop both prior to planting and during the early stages of the crop.

In-crop:

- It is unlikely that in-crop applications of insecticides for thrips control will to provide effective control of TSV transmission into the crop and may disrupt effectiveness of integrated insect management systems. QDAF trial results on various seed treatments showed no significant difference to TSV transmission by thrips. [16]

MORE INFORMATION

GRDC & QDAF Crop Note: Central Queensland sunflower disorder.

QDAF Sunflower Production: Sunflower disorder (Tobacco streak virus or TSV).

9.6.6 Alternaria blight (*Alternaria helianthi*, *A. alternata*)

Economic importance

Under favourable conditions, Alternaria blight can defoliate plants within a week and cause yield losses as high as 70%. Fortunately, conditions favouring epidemics of Alternaria blight occur infrequently and tend to be more common in subtropical regions such as CQ.

Dispersal and spread

Alternaria spores are airborne. The pathogen survives in wild sunflower populations, volunteer plants or on infected plant debris. Epidemics of *Alternaria* infection will rapidly blight and defoliate crops under suitable wet, warm conditions.

Conditions for infection

Development of the disease is favoured by warm (26–30°C) wet weather. Infection is highly dependent on long periods of leaf wetness. Rain periods lasting for several days cause the disease to develop rapidly. Airborne spores produced on necrotic (dead) tissue initiate new infections. Seedling and flowering plants are highly susceptible. Older (lower) leaves are more susceptible.

16 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

Symptoms

Roughly circular, dark brown to black necrotic lesions develop on leaves, petioles, stems, flower bracts and petals (Figures 37, 38, 39). Lesions on leaves may be surrounded by a yellow halo (Figure 37). Under favourable conditions, lesions expand rapidly and coalesce to form large dead areas, commonly described as blighting (Figure 38). Petiole infections can result in rapid leaf death. Infections generally cause premature leaf senescence.

Figure 37: *Alternaria leaf lesions—a yellow halo may surround lesions.*

Photo: S. Thompson, QDAF

Figure 38: *Severe infection will blight the leaf.*

Photo: G. Kong, QDAF

Figure 39: *Alternaria stem lesions.*

Photo: S. Thompson, QDAF

Control

- Select those hybrids which show some level of tolerance. (Currently, there is no immunity in hybrids).
- Avoid successive plantings.
- Ensure infected, older standing stubble is removed quickly if younger crops are growing nearby.
- Practice effective cultural control methods where infected stubble is buried.
- Be aware that periods of sustained leaf wetness—warm, drizzly weather—are ideal for rapid spread of this disease. [17]

9.6.7 Sclerotinia rot (*Sclerotinia sclerotiorum*, *S. minor*)

Economic importance

Losses due to this disease can be quite high, but its occurrence is generally restricted to late plantings because the disease develops at low temperatures.

MORE INFORMATION

GRDC Update Paper: Disease control in summer crops and management strategies to minimise financial losses

17 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

Survival and spread

Both species of *Sclerotinia* produce hard black sclerotia composed of compacted fungal strands and can survive many years in the soil.

Sclerotia can be physically transported in plant debris, boots, machinery and floodwaters.

Sclerotia can germinate in two ways: (1) by producing mycelium (fungal threads) which infect roots and lower stem leading to base rot (Figures 40, 41); or (2) by producing a fruiting body (apothecium, dish-like) which fires spores out into the crop when triggered by relative humidity and temperature (Figure 42). These airborne spores are responsible for stem and head rot.

Sclerotia formed in the heads can be transported with seed and be difficult to sieve out from a seed sample if clumped together.

Figure 40: Sclerotinia minor *basal lesion and stalk shredding.*

Photo: S. Thompson, QDAF

Figure 41: *White mycelium growing on stem lesion caused by* Sclerotinia minor.

Photo: M. Ryley, QDAF

Figure 42: *Apothecium produced by a sclerote to fire spores out into the crop.*

Photo: M. Ryley, QDAF

Conditions for infection

Cool (<18°C) moist conditions favour the germination of sclerotia in the soil, which can either directly infect roots or produce airborne spores that infect flowers and sometimes stems and petioles.

Symptoms

Plants with infected roots wilt and die. Fluffy white mycelium and hard black sclerotia are formed at the base and inside the stems of infected plants (Figure 43, 44).

Infected heads show a light brown rot on the back of the head, which may extend down the stalk. Rotted heads eventually fall apart, leaving only the fibrous strands of the stalk (Figure 45). Sclerotia form in the rotted tissue.

Figure 43: *Sclerotia in infected stem.*

Photo: S. Thompson, QDAF

Figure 44: *Hard black sclerotia of* Sclerotinia sclerotiorum *will sometimes be accompanied by white mycelial growth.*

Photo: G. Kong, QDAF

Figure 45: *Shredding of head after infection by* Sclerotinia sclerotiorum*; sclerotia fall to the ground.*

Photo: G. Kong, QDAF

MORE INFORMATION

Better Sunflowers – Disease Management Library.

Better Sunflowers - Disease Management Library. *Population structure of Sclerotinia sclerotiorum on sunflower*

Better Sunflowers – Disease Management Library. *Genotype-isolate interaction for resistance to Sclerotinia sclerotiorum in sunflower.*

Control

Adopt a planting strategy that avoids paddocks with a history of *Sclerotinia* and ensure the crop is not flowering during cool weather.

Sclerotinia is a pathogen of many broadleaf crops and weeds—soybeans, french beans, cowpea, broccoli cauliflower and other vegetables and legumes . If a crop becomes infected, plant cereal crops in that area for at least 4–5 years.

Ensure seed production nurseries are kept free of *Sclerotinia* to avoid transferring the disease to all cropping areas. [18]

9.6.8 Sclerotium base rot, crown rot (*Sclerotium rolfsii*)

Economic importance

Sclerotium rolfsii is currently considered a pathogen of low importance as usually only scattered plants in a field are affected. Hot, dry weather and lighter soil types can predispose plants to infection particularly if the crop is planted into undecomposed residues. Irrigated crops can also be severely affected as sclerotia are easily spread by water.

Dispersal and spread

Sclerotia survive in the soil for many years. Infected crop residues are the most significant source of infection. Repeated plantings of sunflower in the one paddock lead to an increase in inoculum in the soil. Good farm hygiene and rotations helps limit the spread of this disease.

Symptoms

A rot develops at ground level and it is usually covered by whitish fungal threads in which small caramel–brown-coloured sclerotia form (Figures 46, 47). The white mycelium can spread over the soil at the base of the infected plant (Figure 48). Plants eventually wilt and die.

Figure 46: *Distinctive orange–brown lesion and white mycelium at soil level and on the roots.*

Photo: M. Ryley, QDAF

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Figure 47: *Caramel–brown-coloured sclerotia in infected tissue.*

Photo: S. Thompson, QDAF

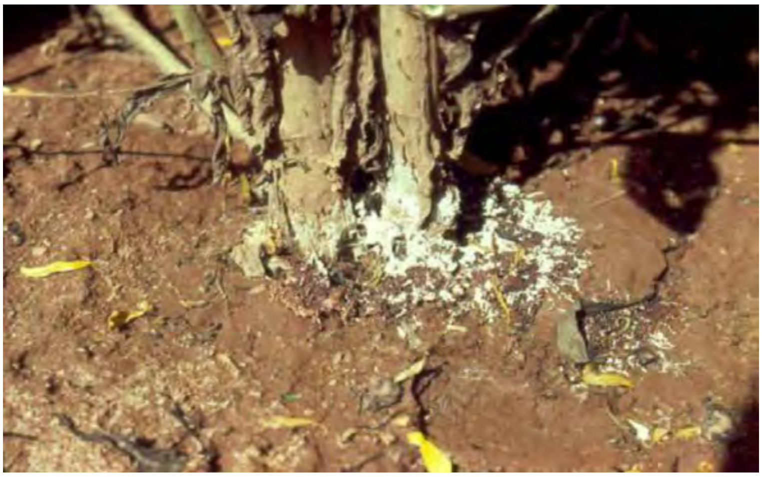

Figure 48: *Mycelium (fungal threads) may grow across the top of the soil.*

Photo: T. Gulya, USDA

Infection conditions

Sclerotium rolfsii is a common soilborne pathogen and is most serious in warm humid weather with optimal temperatures of 27–30°C. Planting sunflowers into undecomposed residues presents the highest risk. Root damage also leads to increased infection levels. High temperatures and high relative humidity favour infection.

Control

Control is difficult as *S. rolfsii* has a host range of >500 species across 100 plant families, both mono and dicots. It effectively colonises non-host plant debris and can live as a saprophyte until a more favourable host is planted.

- Rotate with less susceptible crops such as cereals.
- Bury stubble/residues.
- Control highly susceptible weeds. [19]

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9.6.9 White blister (*Albugo tragopogonis*)

Economic importance

Sunflower appears to be able to sustain high levels of leaf infection (up to 50%) without significant yield loss. Epidemics of white blister are infrequent, due to the specific environmental conditions required for infection. However, in recent years, there has been a trend to cooler conditions both early and late in the growing season so *Albugo* is a pathogen that may become more significant in Australian crops. Overseas, crop losses occur due to both lodging and head infection. The 2005–06 season was the most recent season where white blister was significant in northern NSW.

Survival and spread

Albugo survives in infections in wild sunflower populations, volunteer plants or resistant oospores in infected plant debris. The oospores germinate and produce zoospores, which then infect young seedlings. White spores are produced in large numbers on the leaves and are spread by wind and rain.

Conditions for infection

Cool (<20°C) moist conditions, either from rainfall or dew, are required for infection. These factors have usually limited the occurrence of white blister in Australia, when cool wet conditions do not often occur during the growing season.

Symptoms

Raised pustules containing the whitish spores develop on the underside of leaves, causing the leaf surface above the pustules to have a blistered yellowish-green appearance (Figure 49). Stems and petioles can also be infected, but pustules do not develop. Instead, infected areas have a grey bruise-like appearance due to the presence of oospores, the overwintering phase of the fungus (Figures 50, 51). Severe stem infections have not been recorded in Australia, but in South Africa, lodging is not uncommon (Figure 52).

Because *Albugo* is so sensitive to cool weather conditions, bands of infection may be found in layers up through the crop as infection develops only when cool wet conditions prevail.

Figure 49: *Upraised blisters on upper leaf surface.*

Photo: R. Kloppers, Pannar Seeds, Republic South Africa

Figure 50: *Head infection.*

Photo: G. Kong, QDAF

Figure 51: *Greyish coloured Albugo stem infection (blisters) can lead to lodging.*

Photo: G. Kong, QDAF

Figure 52: *Severe infection of Albugo causing lodging in susceptible line, Republic of South Africa.*

Photo: G. Kong, QDAF

Control

Many Australian hybrids have high levels of resistance to *Albugo*. Avoid early planting, although infections that occur early in the life of a crop will not progress as temperatures increase through the growing season. [20]

9.6.10 Charcoal stem rot (*Macrophomina phaseolina*)

Economic importance

This pathogen is found worldwide, has a wide host range, and is present in most sunflower-growing areas. Yield losses in sunflowers are usually due to a reduction in head diameter and/or seed weight, premature plant death and occasionally lodging. Oil composition can also be affected.

Survival and spread

Macrophomina produces microsclerotia, which will survive for many years in the soil. Sclerotia in the soil or on infected plant debris can be easily spread by poor farm hygiene practices.

Conditions for infection

Infection levels may become serious when excessive heat or drought follow periods of good growth, i.e. a stressed crop with high soil temperatures (>35°C).

Sclerotia in the soil or on infected plant debris are the primary source of inoculum. Soil temperatures of 30–35° favour disease development with mycelium colonising the roots after the sunflower plants reach anthesis and invades both xylem and phloem of the lower stem, growing upwards if conditions are ideal.

Symptoms

Symptoms usually appear after flowering when plants can die rapidly particularly is the plant is stressed. High soil temperatures and low soil moisture leads to more severe disease symptoms.

20 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

Small black sclerotia form on the inside of the stem resulting in the distinctive peppery appearance to the pith (Figure 53). An ashy grey to silvery grey stem discoloration may be present although some lesions may be darker (Figure 54). Stalk fibres become shredded and covered with very small black sclerotia and pycnidia, which form on the outside of the stem. If infection is particularly severe heads may be infected and display the characteristic peppery appearance throughout the entire head (Figures 55, 56).

Sclerotia and pycnidia can also be found on seed of both infected and healthy plants, the seed from healthy plants being infected from airborne pycnidiospores. Infected seed in soil at 35°C will result in severe damping off of the seedlings. If the soil is cool, healthy seedlings will be produced. Infected plants die prematurely with discoloured, bleached or ash grey stalks.

Figure 53: *Microsclerotia producing the distinctive 'salt and pepper' appearance of the pith.*

Photo: S. Thompson, QPIF

Figure 54: *Bleached stems: severe* Macrophomina *infection in a water-stressed crop.*

Photo: S. Thompson, QDAF

Figure 55: *Charcoal rot infection in the back of a sunflower head.*

Photo: G. Kong, QDAF

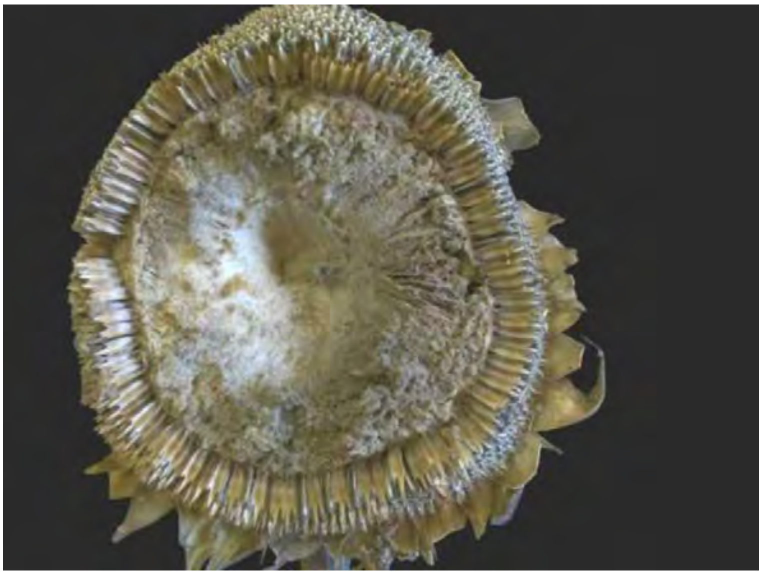

Figure 56: *Severe charcoal rot infection of the head.*

Photo: G. Kong, QDAF

Control

- Avoid any cultural practices that stress the crop. Any stress will predispose sunflowers to attack by *Macrophomina*—herbicide damage, water stress, leaf loss, excess nitrogen, low potassium.
- Sources of resistance/tolerance have been identified overseas including a number of drought-resistant hybrids.
- Fungicides can act as effective seed treatments.
- Because *Macrophomina* has an extensive host range of >300 genera (both monocots and dicots), eradication of this pathogen is not practical. However, host preference has been recorded, indicating it is possible that, for example, corn, sorghum following a sunflower crop would assist with limiting the build-up of the pathogen.
- Avoid very susceptible crops in your rotation if you have had a problem with *Macrophomina.* Soybean, navy bean, mungbeans are very susceptible and could cause more inoculum build-up. [21]

9.6.11 Rhizopus head rot (*Rhizopus* spp.)

Economic impact

This disease rarely causes economic losses but some infected heads can be observed in most crops following rain periods. Seed from infected heads are often lighter, are lower in oil content and higher in free fatty acids. Hulls and embryos can be discoloured.

Survival and spread

Rhizopus spores are airborne and readily infect any damaged tissue. *Rhizopus* is a common and widespread fungus that can attack many hosts under most summer crop growing conditions.

Conditions for infection

Rhizopus infects the head through damage caused by insects such as *Helicoverpa* and Rutherglen bugs as well as by birds and hail (Figures 57, 58). Humid wet weather favours infection and large numbers of spores are spread on the wind.

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Symptoms

Brown, sunken, water-soaked lesions develop on the back of the head around wounds (Figure 59). As the mycelium invades the tissue, the interior of the head becomes soft, rots and turns brown.

Black sporangia will give the inside of the head a peppery appearance and is a diagnostic feature that distinguishes *Rhizopus* infection from that of *Botrytis* and *Sclerotinia* (Figure 60). To add to the confusion, head infections of *Macrophomina* (charcoal rot) appear similar when sclerotia are embedded in the head.

Infected heads dry prematurely, may shrivel and appear to shred. Fungal threads may form on the shredded material. If rot is severe, the head may fall off. In extremely hot conditions, the head may mummify.

Figure 57: *Insect damage can lead to* Rhizopus *infection after wet conditions.*

Photo: S. Thompson, QDAF

Figure 58: *Severe* Helicoverpa *damage followed by bird damage caused while searching for* Helicoverpa, *and then* Rhizopus *infection.*

Photo: S. Thompson, QDAF

Figure 59: Rhizopus *head rot.*

Photo: S. Thompson, QDAF

Figure 60: *Rhizopus infection showing black sporangia.*

Photo: T. Gulya, USDA

MORE INFORMATION

Better Sunflowers – Disease Management Library.

Control

- Controlling insect pests at or before flowering is the most effective way to minimise disease incidence.
- Varieties with more upright heads are more prone to infection.
- Sources of genetic resistance have been identified but incorporating the resistance into commercial hybrids has not been considered a priority. [22]

9.6.12 Botrytis head rot or grey mould (*Botrytis cinerea*)

Economic importance

Botrytis usually does not cause significant losses although long periods of cool wet weather will increase the incidence.

Survival and spread

Botrytis can survive as infection in many hosts, as sclerotia in soil or infected seed. Sclerotia and seed can easily be spread by farm equipment, boots and irrigation.

Conditions for infection

Cool wet conditions favour the pathogen with 17–27°C being the optimal temperature range. Free water is required and germination is stimulated by exudates from pollen. If sunflowers are infected pre-bloom, an infection can remain latent for up to 9 weeks.

Symptoms

Head infection is the most characteristic symptom of *Botrytis* on sunflower (Figure 61). Soft brown spots form on the back of the head or bracts usually during maturation. In conditions of high humidity, a fuzzy, grey mycelial growth may cover the back of the

22 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

head giving the disease its common name of grey mould (Figure 62). Heads develop into a spongy rot. Characteristically, no sporulation occurs within the head.

Severe *Botrytis* infection can cause petiole lesions, stalk lesions and wilted leaves. Infected seeds will result in pre- and post-emergence damping off with characteristic grey mycelium on the dead seedlings as a diagnostic feature.

This disease is easily confused with early head infection caused by Sclerotinia head rot and Rhizopus head rot. *Botrytis*-infected heads do not disintegrate during the advanced stages of the disease but the hulls and infected seeds are highly flammable when driers are used.

Figure 61: *Botrytis symptoms occur at flowering.*

Photo: T. Gulya, USDA

Figure 62: *Grey mycelial growth—grey mould.*

Photo: T. Gulya, USDA

Control

- Late infections closer to harvest have little effect on yield due to the fungal infection remaining superficial.
- If levels of *Botrytis* infection in the crop are initiated at flowering and are excessively high, early desiccation at ~30% moisture is recommended if suitable driers are available. Flammability of infected seed can be an issue.
- Chemical control is unfeasible.
- Some research groups have reported differences in susceptibilities between hybrids and wild sunflower species but no resistant hybrids are available. [23]

9.6.13 Verticillium wilt (*Verticillium dahliae*)

Economic importance

Losses from *Verticillium* in Australia are usually not significant although many confectionary lines lack resistance and could show more susceptibility.

Survival and spread

Verticillium is both seedborne and soilborne and can survive for many years in the soil without a host. Small microsclerotia in plant residue will remain dormant until root exudates break dormancy as the roots advance. Microsclerotia will also contaminate the seed coat and mycelium can be found inside the seeds therefore ensuring seed transmission is a significant source of infection.

Conditions for infection

Verticillium is a soilborne pathogen of low importance but can infect at temperatures up to 30ºC and cause early plant death. Root systems can become infected by secondary invaders—the disease is usually only found in isolated plants or small clumps.

Symptoms

Characteristic yellow-brown mottling between the veins appears around the time of flowering (Figure 63). Leaves wilt and rapidly dry out as the pathogen infects the vascular tissue in the stem and releases toxins. Earliest symptoms appear on the lower leaves as pale yellow, chlorotic spots, which enlarge, turn brown and become necrotic, often with halos surrounding the necrotic tissue. Caution: may be confused with leaf symptoms of boron deficiency.

Severely diseased plants will be stunted and have a smaller head diameter. The vascular tissue of the stems will show a brownish discoloration (Figure 64) and roots may be poor. The plant may remain upright with only the leaves wilting but the leaf mottle will become more severe and move up the plant.

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Figure 63: *Characteristic* Verticillium *leaf symptoms.*

Photo: G. Kong, QDAF

Figure 64: *Discoloration and infection of the vascular tissue.*

Photo: T. Gulya, USDA

Control

- Crop rotations may not control *Verticillium* as the microsclerotia are so long-lived. Immune crops such as corn, grain sorghum, barley and lucerne (alfalfa) have little impact on *Verticillium* levels in the soil as the pathogen will often survive superficially on the roots of non-hosts as well as surviving in the soil for long periods.
- Soil fumigation is effective but not practical for sunflowers in a broad-acre situation.

- Seed treatments offer effective control of seedborne infection but do not protect the plant from soilborne infection. [24]

9.6.14 Septoria leaf spot (*Septoria helianthi*)

Economic importance

This pathogen rarely causes economic damage in Australia. Infection may become severe in warm moist conditions.

Survival and spread

Septoria survives on crop debris, volunteer plants and wild sunflowers. Spores produced in small black fruiting bodies on the leaf are spread during wet and windy weather.

Infection conditions

Warm moist weather favours this pathogen.

Symptoms

Characteristic angular, diamond or angular necrotic lesions (Figure 65) appear brown on the upper leaf surface (Figures 66, 67) and a lighter grey-brown on the lower leaf surface. Lesions may develop dark margins and light centres, which are often surrounded by a yellow halo. With use of a hand lens, small black fruiting bodies may be visible in the necrotic tissue.

Lowest leaves are infected first, then infection spreads to the upper leaves. Spots may coalesce, producing large, irregularly shaped dead areas of leaf, which can wither and dry.

Figure 65: *Grey-brown angular lesions on underside of leaf.*

Photo: G. Kong, QDAF

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Figure 66: *Brown-coloured* Septoria *leaf symptoms with darker edge and halos.*

Photo: G. Kong, QDAF

Figure 67: *Distinctive brown lesions:* Septoria *can be confused with* Alternaria *infection if halos are present (as in Figure 66), but* Alternaria *lesions are black.*

Photo: S. Thompson, QDAF

Control

- Destroy volunteer plants and ensure plant debris is incorporated. Crop rotations help limit disease build-up.
- Can be seedborne—use clean seed. [25]

9.7 Biosecurity awareness: potential disease threats for Australian sunflower

9.7.1 Downy mildew (*Plasmopara halstedii*)

Economic importance

Australia is the only sunflower-growing continent that has not recorded downy mildew as a sunflower pathogen. Losses vary according to the percentage of infected plants in the crop and are due to plant death, smaller heads, lighter seed weights and lower oil content. Downy mildew is seedborne and soilborne, with its oospores (survival structures) capable of surviving for as long as 8–10 years in the soil. Although seedborne infection is uncommon and results in a very low percentage of systemically infected plants, vigilance is essential when importing sunflower seed into Australia from overseas. The disease would be extremely difficult or impossible to eradicate once it is established.

The impact on native species has not been determined.

Survival and spread

Plasmopara halstedii is mainly a soilborne pathogen that survives in seed, soil and plant debris. Oospores in the soil or plant debris germinate to produce spore-bearing structures called sporangia. Zoospores that are released from the sporangia germinate and serve as primary inoculum infecting young sunflower seedlings via the roots.

Infection is possible via seed but this is uncommon; most of the seed from an infected plant is non-viable and not all seeds are infected.

Conditions for infection

Cool moist conditions and poorly drained soils, especially clay soils, favour the development of this disease. Moisture and temperature are the most important environmental factors affecting infection and spread. Zoospores require free water to retain viability and actively move towards infection sites with the aid of a flagella or tail. Consequently, rainfall or intensive irrigation is a prerequisite for the initiation of primary infection.

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Figure 68: *Downy mildew leaf infection.*

Photo: G. Kong, QDAF

Symptoms

The type and severity of symptoms will depend on the inoculum load, plant part attacked (Figure 68), age of host at the time of infection and environmental conditions. Symptoms are usually classified as either systemic or localised.

Root and seedling infection is usually the result of systemic infection (Figure 69). Damping off (pre-emergent seedling death) and seedling blight (post emergence death) result from soil infection and cool waterlogged soils.

Systemic root infection leads to stunted plants and chlorotic puckered leaves (Figure 70). If systemically infected plants reach maturity, the head bears few, if any viable seeds and the heads face vertically upwards (Figure 71).

A white layer of downy growth may be produced on the underside of leaves. Sporangia are produced on the downy mycelial growth and are dislodged by rain and wind leading to localised or secondary infection within the crop. Lesions are angular, delimited by veins, chlorotic, and with age turn necrotic and may coalesce.

Soilborne inoculum is the major source of infection; infection can be carried from wild sunflower populations near crops, irrigation water runoff or by wind.

Figure 69: *Downy mildew infection on seedlings.*

Photo: G. Kong, QDAF

Figure 70: *Downy mildew symptoms—chlorotic twisted leaves and deformed head.*

Photo: G. Kong, QDAF

Figure 71: *Stunted head, twisted and discoloured leaves.*

Photo: G. Kong, QDAF

Control

- Roguing of infected plants helps to reduce inoculum build-up.
- Seed treatments such as fungicides containing metalaxyl are used effectively overseas. [26]

Plant breeding for resistance is ongoing overseas as a number of races of this pathogen have been identified [27]. Multiple sources of resistance have been identified including *Helianthus argophyllus* recently collected from the only known Australian site at Yeppoon, Queensland by QDAF researchers. Even with the use of resistant cultivars, seed dressing with fungicides is highly recommended to prevent underground infection of the seedlings.

Overseas, chemical control of downy mildew involves a combination of seed dressings and systemic foliar fungicides containing metalaxyl and related compounds. [28]

9.7.2 Broom rape (*Orobanche* spp.)

Prohibited import: *Orobanche cumana* not recorded in Australia.

Economic importance

- If introduced to Australia, the economic impact would be significant.
- Australian sunflower cultivars lack resistance.
- There are limited in-crop herbicides options available for *Orobanche* control.
- Contaminated land has limited cropping options.
- The potential host range of Australian native species is unknown.
- Host plants are deprived of nutrients and water and will become stunted or die. Yield losses would occur.

26 Virányi F, Oros G (1991) Developmental stage response to fungicides of *Plasmopara halstedii* (sunflower downy mildew). Mycological Research 95, 199–205. http://www.sciencedirect.com/science/article/pii/S0953756209810125

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28 Australian Oilseeds Federation (2012) Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

- The impact on crops would vary according to which species of *Orobanche* was introduced.

Survival and spread

Enormous numbers of small seeds are produced by each parasite. Wild sunflower populations and volunteer plants would assist migration of the parasite through the sunflower growing areas. The seed is small and light—easily dispersed by wind, water and livestock.

Conditions for Infection

Orobanche is a parasitic weed that obtains all its nutrients through contact with the root systems of its host plant. *Orobanche cumana* germinates at 15–20°C. *Orobanche* have evolved to germinate in response to host plant root exudates. Huge numbers of seed are produced by each parasitic plant; survival time is estimated to be up to 10 years.

Symptoms

A single stem grows upwards to ~38 cm in height, has no chlorophyll, yellow alternate leaves and off-white to yellow flowers borne in a spike (Figure 72). Multiple stems may develop (Figure 73). Flowers continue to produce seed after the plant has been removed from its host.

Figure 72: Orobanche *species parasitise their host. Not recorded in Australia.*

Photo: G. Kong, QDAF

Figure 73: *Multiple stems of* Orobanche *may parasitise a plant.*

Photo: T. Gulya, USDA

Control

- Dig up parasite and host plant—the host will help identify the species of *Orobanche*.
- Mark the site and inspect regularly for regrowth.
- Fumigate the soil.
- Clean any machinery and ensure boots and clothing are free of seeds.
- Herbicides may be effective but *Orobanche* has developed resistance.
- *Orobanche* has also overcome resistance bred into crops.
- Physical and cultural control measure should be strictly enforced. [29]

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Plant growth regulators and canopy management

Not applicable for this crop.

Crop desiccation/spray out

MORE INFORMATION

www.apvma.gov.au

https://grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Stahlman_Saflufenacil_edited_paper.pdf

Crop desiccation is not a common practice in sunflowers; however, it has been used in some seasons to speed up or to even out maturity of a crop. Diquat is the only product registered for use as a harvest aid in sunflowers.

Desiccation of a sunflower crop can only commence once the crop has reached physiological maturity. A sunflower plant has reached physiological maturity when the bracts surrounding the head have turned brown. At this point, the seed should be mature and the moisture content <35%. [1]

For an uneven crop, or where harvest needs to be brought forward, desiccation is recommended with: [2]

- product: diquat 200 g/L, Reglone®
- rate: 2–3 L/ha
- timing: when seeds are mature and of <35% moisture content

Reglone® is the only herbicide registered for pre-harvest desiccation in sunflowers. However, the APVMA has approved a minor use permit (PER13118) to allow the use of glyphosate for sunflower desiccation and late in-crop weed control in all States. This permit is valid until 31st March 2015.

Drying

Sunflower is easily dried due to the large air spaces and low grain density permitting an easy airflow. Care needs to be taken with samples that contain a lot of fines, which will readily ignite when exposed to direct heat. Always be prepared with fire equipment and act quickly in the event of a fire.

Because high temperatures are not usually necessary, a temperature of 45º–50ºC is preferred to reduce fire risk. If the moisture content is close to 9%, aeration only will be required. [3]

1 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

2 Australian Sunflower Association (2004) Harvesting and storage. The New Big Black Sunflower Pack. p. 30. Australian Oilseeds Federation

3 Australian Sunflower Association (2004) Harvesting and storage. The New Big Black Sunflower Pack. p. 30. Australian Oilseeds Federation

VIDEOS

Sunflower grower and Chairman of the Australian Sunflower Association Kevin Charlesworth comments on sunflower harvest preparation and pitfalls. GCTV13: Harvesting sunflowers

Harvest

Sunflower harvesting is best carried out as close to 9% seed moisture content as possible. There is a tendency to overestimate moisture content of a sunflower crop, meaning harvest is often delayed until moisture contents are on average 7%. This results in a loss in yield and more difficulty in obtaining a clean sample. As sunflowers become drier and more brittle, the bracts, and parts of the head break into small pieces which are difficult to separate from the seeds. As a result admixture levels are usually higher when moisture contents are lower at harvest. [1]

12.1 Physiological maturity

Physiological maturity signifies when the maximum seed weight has been reached. The crop can then be harvested at any time, however sufficient drydown needs to occur to reach a moisture content suitable for storage or delivery.

Physiological maturity is identified when the bracts surrounding the sunflower head change to brown, preceding this they will change from green to yellow and eventually to brown. The seed moisture content at physiological maturity is usually between 30–40% and the crop is suitable for desiccation to aid in quicker drydown. [2]

Figure 1: *Physiological maturity is identified when the bracts surrounding the sunflower head change to brown. The heads turn from green to yellow to brown.*

Photo: Drew Penberthy, Penagcon

12.2 Machinery setup

Machinery setup can have a big impact on the quality of the sample harvested and the speed at which a crop may be harvested. Headers with 'head snatchers' and sullivan reels are a popular choice. These adaptations allow the sunflower heads and approximately 20 cm of stalk only to be fed through the header. This means a large reduction in the amount of material which needs to be threshed and reduces the likelihood of excessive trash and admixture in the sample. Sunflower trays are also a useful addition for retaining heads and seeds in the header front.

1 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

2 DPI (2008) Sunflower Production Guidelines for the Northern Grains Region – Northern NSW and Souther QLD. L Serafin, S Belfield. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

Harvesting sunflowers when they are too moist leads to problems with threshing the heads which retain a significant amount of moisture, particularly in the pith. Slow drum speeds aid in harvest. Speeds of around 450 rpm for conventional headers and 250–350 rpm for rotary headers are suggested. Fan speeds should be fairly fast, but will often depend on the size of the seed. [3]

A survey of 48 sunflower crops grown during 2005–06 showed that the average moisture at delivery was 7% which is a loss of 2 tonne in 100 tonnes. The moisture ranged from 4.5–12%.

Conversely harvesting above 9% moisture means storage of sunflowers is potentially dangerous due to the risk of fire in the silo and downgrading due to mould. [4]

Harvesting at low moisture contents (< 6%) may cause an increase in admixture as the plant stalks and heads become dry and brittle, shattering easily into small pieces. This added trash is difficult to separate by grading and penalties apply for excess admixture. [5]

12.2.1 Header set up

Conventional headers need alterations to harvest sunflowers effectively. The most common changes include:

- Sunflower trays – are attached below the cutter bar to catch sunflower seeds falling out of the heads during the harvesting process.
- Sullivan reel and headsnatcher – are designed to minimise the amount of plant material entering the front reducing potential contamination. Both remove the sunflower head just below the peduncle, causing minimal disturbance to the rest of the plant. These modifications allow the ability to harvest at higher moisture contents and whilst some green leaf remains.

Prior to commencing harvest, fan and concave settings should be adjusted to ensure sunflower heads are properly threshed, retaining the maximum amount of seed and the least amount of trash. [6]

12.2.2 Harvesting hints

The Australian Sunflower Association provides the following harvesting hints from experienced sunflower growers. [7]

- Header attachments that are strongly recommended:
  - » **Sunflower trays** – to retain heads and seeds in the header front these are essential.
  - » **Sullivan reel** – works at the machine's ground speed to help prevent blockages and reduce seed shattering.
  - » **Head snatcher** (push bar under the cutter bar) – to speed harvesting and reduce trash levels in the sample. Not as important when using a rotary header.
- The use of a neighbour or contractor is preferable to harvesting without these attachments, particularly sunflower trays.
- Care at planting—a uniform crop is easier to harvest so a uniform, even plant stand is the best start.

3 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

4 DPI (2008) Sunflower Production Guidelines for the Northern Grains Region – Northern NSW and Souther QLD. L Serafin, S Belfield. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

5 DPI (2008) Sunflower Production Guidelines for the Northern Grains Region – Northern NSW and Souther QLD. L Serafin, S Belfield. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

6 DPI (2008) Sunflower Production Guidelines for the Northern Grains Region – Northern NSW and Souther QLD. L Serafin, S Belfield. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

7 Australian Sunflower Association (2004) The New Big Black Sunflower Pack

- Don't wait until all heads are black. Commence harvest when some 10% of heads are still soft (cream colour on the back). This will reduce trash levels and enable a faster harvest speed. Moisture at this stage should be 9% or less.
- For an over-ripe crop—harvest at night, early morning
- Use a slow drum speed, +450 rpm for conventional headers and +350 rpm for rotaries.
- Each crop and variety is different and fine tuning is normally necessary with every change.
- Do not try to retain small seeds in the sample as trash is a companion of these small seeds. Aim to have the head largely intact out the back of the header with any small centre seeds still present.
- Fan speed as fast as practical without lifting seed over the sieve. A common fault in sunflower harvesting is to use insufficient air for fear of losing the small seeds which are of little value.
- If the header width is the same as the planter, make the guess rows about 20% wider to allow for any header movement without crop damage. Most growers have guidance on headers.
- Dragging chains behind the header may help prevent static and the fine dust that accumulates on the header when stripping sunflowers which are highly flammable. Make sure a firefighter is ready and close.
- Desiccation will speed dry-down and time to harvest in times of poor weather conditions, bird or mice damage. Desiccation should be carried out at physiological maturity if it is to be most beneficial. At physiological maturity the backs of the heads are yellow, bracts are brown and seed moisture content is about 40%. Harvest can commence in 7 to 14 days.
- Do not delay harvest to 9% moisture if weather conditions or pests numbers are likely to reduce yield and quality. Harvesting can commence anytime after physiological maturity.
- Sunflower harvested above 10% moisture content will require drying.
- Admixture above 4% can be refused acceptance or attract a penalty.

MORE INFORMATION

NSW DPI Management guide. Summer crop production guide. Receival standards (p. 92)

http://www.graintrade.org.au/commodity_standards

12.3 Receival standards

There are certain rules and regulations that producers need to meet when delivering sunflower seeds. These standards have been developed by the Australian Oilseed Federation Standards Committee. For new growers or growers returning to sunflower, these standards are reviewed annually, so it is important to revisit the guide for current information on oil bonus or discounts and potential deductions for admixture. The standards for monounsaturated, polyunsaturated and bird seed sunflower can be found in more detail at http://www.graintrade.org.au/commodity_standards. [8]

Sunflowers should be delivered at a moisture content of 9% or below. The normal premium/discount system of 1.5% of price for each 1% of oil above/below 40% oil content applies. Growers should be aware that admixture discounts also apply. Test weights are normally around 40 kg/hL, but the receival standard is 32 kg/hL. [9]

8 The Better Sunflower e-Newsletter. May 2012. Australian Oilseeds Federation (AOF), Australian Sunflower Association (ASA) & the Grains Research and Development Corporation (GRDC). http://www.australianoilseeds.com/__data/assets/pdf_file/0010/8875/Better_Sunflowers_-_Issue_1_May_2012.pdf

9 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

MORE INFORMATION

http://www.australianoilseeds.com/__data/assets/pdf_file/0016/1258/harvest_storage.pdf

VIDEOS

Specialist grain storage agronomist Philip Burrill commenting on the safe storage of sunflower seed. GCTV: Stored Grain: Sunflower Storage

MORE INFORMATION

NSW DPI Management guide. Summer crop production guide. Grain storage (p. 93)

Storage

13.1 Storing oilseeds

Choosing to store oilseeds on-farm requires attention to detail, because limited tools are available compared with cereal grain storage.

To retain the market value of sunflowers, care must be directed at maintaining oil quality, visual appearance, and freedom from moulds, insect pests and unregistered chemicals. [1]

13.2 How to store sunflowers on-farm

For safe storage, the seed needs to be <9% moisture (40% oil), kept cool and with low (<4%) trash levels. Samples with high oil contents need lower moisture content, e.g. 50% oil–7.5% moisture. The sample also needs to have a low level of damaged seed.

Ensure that silos and storage areas are clean and free of other grain residues that could harbour storage insects. No storage chemicals are registered for sunflower, so good hygiene with adequate aeration is essential. Avoid contamination of areas to be used for sunflower storage with chemical residues.

Seed that has been hot-air-dried to reduce moisture content needs to be cooled, with aeration and moisture content levels checked carefully over the first few days. Samples taken immediately out of a drier can give a misleading reading.

Storage contracts are available, providing an opportunity for growers to capitalise on available on-farm storage. Grain for safe storage must meet the specifications outlined above, have a low percentage of damaged seed, and be monitored weekly for temperature and grain moisture. Moist or hot grain needs to be immediately turned and aerated. (Note: use only registered products for storage insect control.) [2]

Aeration to promote uniform, cool storage conditions is a key strategy for maintaining oil and seed quality. During autumn, aim for stored sunflower temperatures in the range 18–23°C. For the winter months, 10–18°C is achievable. [3]

13.3 Seed quality and moisture content at storage

Timing of harvest and header settings—drum speed, concave gap, and fan speed—have a significant impact on minimising trash and impurities and broken seed. If admixture in the seed sample is high, fines can concentrate directly below the storage fill-point, leading to heating and fire risk. Larger pieces of crop trash with high moisture content may also concentrate along silo walls, leading to heating and mould development.

The presence of broken seeds is attractive to storage pests such as the rust-red flour beetle (*Tribolium castaneum*).

Safe storage moisture content depends on temperature and oil content. The higher the oil content and storage temperature, the lower the seed moisture content must be for safe storage.

1 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

2 Australian Sunflower Association (2004) Harvesting and storage. The New Big Black Sunflower Pack. p. 30. Australian Oilseeds Federation

3 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

The oil content of oilseed sunflower is ~40%. Birdseed and confectionery sunflower varieties usually have lower oil content of ~35% owing to a higher proportion of hull to kernel. All three have a trading standard and safe maximum storage moisture content of 9% (Grain Trade Australia (GTA) Standard).

Cooling seed temperatures in storage to ~20°C or lower is a key aid to reliable storage of sunflowers. [4]

13.4 Types of storage

Ideal storage for sunflowers is a well-designed, cone-based, sealable silo fitted with aeration (Figure 1).

Ease of cleaning and hygiene maintenance for empty storages and suitability for effective use of aeration cooling is important. For seed-handling equipment (augers, etc.), the aim is to minimise damage to seed when moved.

If seed requires control of insect pests, the silo is then sealed (gas-tight) for the required period as stated on the label (usually 7–10 days) to enable an effective fumigation with phosphine.

For all storage types, extra caution should be taken to prevent storm rain or other water ingress into storages. [5] Also, take care to prevent mice, rats and birds from entering storages.

Figure 1: *Aerated, sealable silo.*

13.5 Hygiene—structural treatment

Most insecticide storage-surface treatments are not to be used on storages for holding sunflowers. Warning: if unregistered chemical residues are detected by grain buyers, this can have serious long-term consequences for domestic and export markets.

4 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

5 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

Inert dust or diatomaceous earth (DE, amorphous silica) is a naturally occurring mined product with insecticidal properties. Products such as Dryacide® can be applied as a dust or slurry spray onto internal surfaces of storage areas and equipment. Once grain residues have been physically removed or washed out of storages and equipment, Dryacide® can be applied as a non-chemical treatment to reduce insect pest carryover.

Insects survive in any sheltered place with grain residues: in grain hoppers, augers, field bins and inside headers. All of these attractive locations require attention.

Some pyrethrin + piperonyl butoxide based products (e.g. Rentokil's Pyrethrum Insecticide Spray Mill Special® or Webcot's SPy Natural Pyrethrum Insecticide®) are registered for moth control in oilseed storage areas or storage sheds. They can be used as a structural surface spray or fogging–misting treatment. These are not to be applied as a grain treatment. Use only as labels direct. [6]

13.6 Aeration

Aeration should be considered an essential storage tool for sunflowers.

Correctly managed, it creates uniform, cool conditions in the seed bulk and slows most quality-deterioration processes.

Aeration provides storage benefits by:

- maintaining oil quality: free fatty acid, rancidity, colour and odour
- reducing the risk of 'hot spots', moisture migration and mould development
- slowing or stopping storage insect pest breeding cycles by maintaining grain temperatures <20°C (e.g. rust-red flour beetle breeding cycle ceases at 20°C)
- maintaining seed germination and vigour for longer when seed is kept cool and dry [7]

MORE INFORMATION

GRDC Fact Sheet: Safe storage of sunflower seed — aeration drying and cooling

13.6.1 Aeration cooling

Fan/s providing low airflow rates of ~2–4 litres per second per tonne (L/s.t) can cool seed and provide uniform seed temperature and moisture conditions in the storage. If managed correctly, aeration also allows safe storage of seed at moisture levels a little above receival standards for several weeks.

Well-managed cooling aeration typically sees seed temperature fall safely to ~20°C and below within a few days.

Regular checking of sunflowers in storage is essential. Make visual inspections, check seed moisture, use a temperature probe to monitor bulk seed temperature, and sieve for insects. [8]

VIDEOS

Specialist grain storage agronomist Philip Burrill commenting on aeration cooling of sunflower seed in on-farm storage. GCTV: Stored Grain: Sunflower cooling

13.6.2 Automatic controllers

Often 'aeration cooling' fans are simply turned on and off manually, or a timer clock is used.

However, there is a lot to be gained by investing $5000–7000 in an automatic controller that selects the optimum run-times and ambient air conditions to have fans turned on. The controller continually monitors air temperatures and relative humidity (RH) and may select air from only 2 or 3 days in a week or fortnight. One unit has the capacity to control fans on multiple silos. [9]

6 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

7 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

8 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

9 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

13.6.3 Standard aeration fans operation

- Run fans continuously during the first 3–5 days when grain is put into the silo. This removes the 'harvest heat'. Smell the air coming from the silo top hatch. It should change from a warm, humid smell to a fresh, cool smell after 3 days. The first cooling front has moved through.
- For the next 5–7 days, set the controller to the 'Rapid' or 'Purge' setting. This turns fans on for the coolest 9–12 h of each day to further reduce the seed temperature.
- Finally, set the controller to the 'Normal' or 'Protect' mode. The fans are now turned on for approximately 100 h per month, selecting the coolest air temperatures and avoiding high humidity air. [10]

VIDEOS

1Specialist grain storage agronomist Philip Burrill commenting on the use of aeration drying of sunflower seed. GCTV: Stored Grain: Sunflower drying

13.6.4 Aeration drying

Well-designed, purpose-built, high flow-rate aeration drying systems with airflow rates of 15–25 L/s.t can dry seed reliably. During aeration drying, fans should force large volumes of air through the grain bulk for longer periods. This ensures that drying fronts are pushed quickly through so seed at the top of the silo is not left sitting at excessive high moisture contents (Figure 2).

Sunflower seed is well suited to this form of drying, because air of moderate–low RH will reduce seed moisture content to safe storage levels over 5–9 days. It is, however, important to have long run-times for fans (17–22 h/day) in the first 3–5 days of aeration drying. Monitor regularly and take care that seed in the silo base is not over-dried. Seek advice on the appropriate equipment and procedures.

Do not rely on aeration-cooling equipment with small fan and low airflow rates of 2–3 L/s.t to dry high-moisture seed.

Automatic aeration-drying controllers are also available to run fans at optimum ambient air conditions. Some controller models provide the option to switch to either cooling or drying functions. Ensure that the controller is fitted with a good quality RH sensor. [11]

10 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

11 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

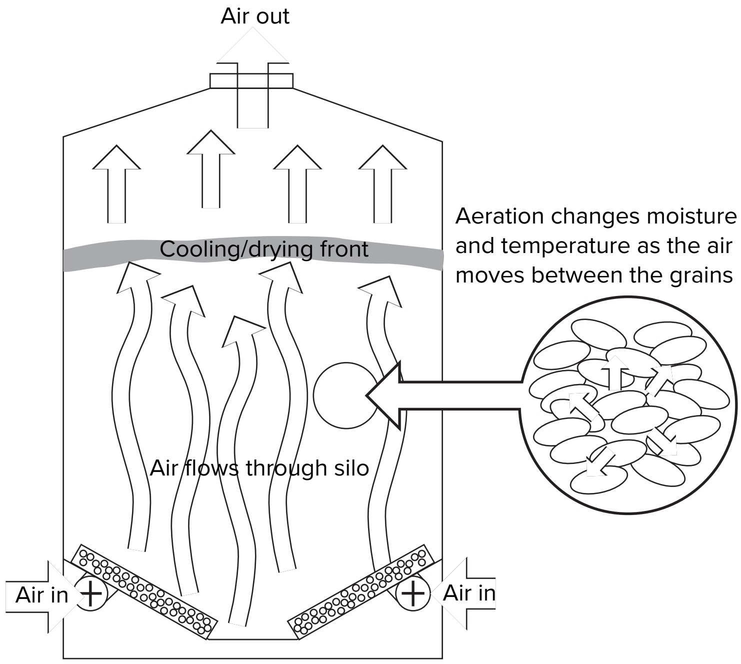


Figure 2: *Cooling–drying fronts in the aeration process. (C. Newman, Department of Agriculture and Food, WA).*

13.6.5 Drying with heated air

For hot-air-drying of sunflower seed, fixed batch, recirculating batch or continuous flow dryers are all suitable for reducing moisture content. Also, consider the seed-blending option with aeration if low-moisture sunflower seed is available.

Sunflower seed dries very rapidly compared with the cereal grains, so close attention must be given to temperature control and duration to ensure that the seed is not over-dried. A precaution is to use the minimum amount of additional heat.

- Use air temperatures in the range 40–50°C.
- Stay nearby and monitor moisture content every 15 min.
- Moisture content can fall from 11.5% to 9.0% in <1 h.
- For batch dryers when moisture content readings reach 10.5%, turn off the heat source and move to the seed-cooling phase with fan only. Retest once cooled.
- Over-dried sunflowers seeds split very easily when moved.
- Run the auger full when moving sunflower seed to reduce seed damage and dehulling, or use tubeveyors.
- Aim to make good use of cooling aeration fans, throughout storage and especially during the harvest period [12]

13.6.6 Fire risk

The dust and admixture associated with sunflower seed presents a serious fire risk. Harvesting and drying are high-risk operations where constant vigilance is required. Good housekeeping in and around equipment and keeping a close eye on problem sites reduces the threat.

12 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

Be prepared for fire; ensure that appropriate equipment is at hand and a plan of action understood by operators.

Without careful management, sunflower seeds with high moisture content and/or high levels of admixture pose a risk of mould formation, heating and fire through spontaneous combustion [13]

13.7 Insect pest control

Several insect pests will infest stored oilseeds, usually favouring the grain surface. These are the rust-red flour beetle (*Tribolium castaneum*), Indian meal moth (*Plodia interpunctella*), warehouse moths (*Ephestia* spp.) and psocids (*Liposcelis* spp.)

These pests multiply rapidly, given food, shelter and warm, moist conditions. They can complete their full life-cycle in about 4 weeks under optimum breeding temperatures of ~30°C.

Only a few treatments are registered for insect control in oilseeds: phosphine, pyrethrins, DE, and ethyl formate as Vapormate®. Use of pyrethrins and DE is limited to storage-area treatments, and Vapormate® is restricted for use by licensed fumigators only. This leaves phosphine as the key farm storage treatment for oilseed storage pests.

Phosphine fumigation must take place in a gas-tight, well-sealed silo. If the silo passes a standard, 3-min pressure test, it demonstrates there are no gas leakage points. Given this, phosphine gas can be held at high enough concentrations in the silo for enough time to kill all of the life stages of the pest (eggs, larvae, pupae, adults).

Several manufacturers make aeratable, sealable silos that pass the Australian Standard (AS 2628–2010) for sealable silos.

Like most oilseeds, sunflower seed has the ability to adsorb phosphine gas, and so it is important to use the full, correct label dose rate.

By using phosphine bag-chains, belts or blankets, placement and removal of the treatment is simplified. If using the standard phosphine tablets, ensure that the tablets are kept separate from the sunflower seed by using trays; the spent tablet dust can then be removed following fumigation.

If aeration cooling has been in use and the seed temperature is <25°C, ensure that the fumigation exposure period is ≥10 days. See label for details. Follow all safety directions.

Once the fumigation exposure period is completed, release the seal by carefully opening the top silo lid. Vent the gas using the aeration fan for the required period, and return the stored sunflowers to aeration cooling management. [14]

MORE INFORMATION

http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

http://www.australianoilseeds.com/__data/assets/pdf_file/0006/4110/Oilseeds_Flyer.pdf

http://www.grdc.com.au/uploads/documents/GRDC_StorageFS_SthNth_131009.pdf

http://www.australianoilseeds.com/commodity_groups/australian_sunflower_association/

ttp://www.grdc.com.au/uploads/documents/aeration2004_2.pdf

13 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

14 P Burrill (2010) Safe storage. Better Sunflowers Agronomy Training Package, Module 7. Australian Oilseeds Federation, http://storedgrain.com.au/wp-content/uploads/2013/06/SUNFLOWER-storage-note-Nov-2010.pdf

Environmental issues

14.1 Adverse effects on growth and development

There are many factors which can have an adverse effect on sunflower growth and development. These factors can influence yield by reducing the number of seeds set, the weight of each seed, the ratio of kernel to hull, as well as influencing oil content and quality. Several of these factors are discussed below. [1]

MORE INFORMATION

GRDC Tips and Tactics: Managing frost risk - Northern Southern and Western Regions

14.1.1 Frost

Sunflowers are reasonably tolerant of frost at certain growth stages. Newly emerged seedlings are frost tolerant (to –5°C) until the 6 to 8 leaf stage but are frost sensitive from the 6 leaf stage until the seed ripening stage. Sunflower buds are susceptible to frost damage and also a significant drop in air temperature can be detrimental at this stage.

Frosting during the bud development stage can result in distortion of the bud, failure to set seed and even a complete lack of flower production. This may also be seen as blackening or purpling around the edges of the head. Frosts of 2°C prevent flowers opening and subsequently reduce the seed set. Frosts of –2 °C to 0 °C during grainfill can significantly reduce yield. [2]

14.1.2 Hail

Hail may damage sunflowers in several ways, including plant death, physical injury to the stem or head and leaf defoliation. All of these may reduce yield.

The growth stage when hail damage occurs has a major impact on the effect on yield. Hail in the early vegetative stages can greatly reduce yield if the terminal bud is damaged, generally plants with damaged terminals will tiller and these tillers produce small heads. Defoliation from the stages of R1 (the terminal bud forms a miniature floral head rather than a cluster of leaves; when viewed from directly above, the immature bracts form a many-pointed star-like appearance) to R6 (flowering is complete and the ray flowers are wilting) appear to be most sensitive, since much of the photosynthate produced at this time is directed to head development.

Plant death is a common occurrence when plants are small. If the plant population is reduced significantly, the remaining plants will compensate if the damage occurs early in the growth stages (e.g 2–8 leaf stage). However beyond this stage the plants cannot compensate enough and yields may be reduced.

Injured plants may also suffer terminal bud damage or stem breakage or bruising. If plants are injured but unable to contribute to yield, they will still use water and nutrients, an unfavourable situation. [3]

1 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Plant Growth and Development https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

2 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Plant Growth and Development https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

3 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Plant Growth and Development https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

MORE INFORMATION

http://www.australianoilseeds.com/conferences_workshops/sunflower_conferences/2003_Sunflower_Conference

http://www.australianoilseeds.com/__data/assets/file/0009/1215/Development_of_Drought_Tolerant_Sunflower.pdf

14.1.3 Drought

Dryland sunflowers have reasonable drought tolerance, particularly if planted into a full profile of moisture. Extreme drought will reduce the plant height, leaf area and head diameters, resulting in reduced yields. Additional information on drought can be found under moisture stress in the water use section in the agronomy module. [4]

14.1.4 Heat stress

High temperatures during flowering and seed set will reduce yields and oil contents. Head and seed temperatures usually are 5°C to 10°C higher than the air temperature. Yield is generally reduced due to a reduction in seed number and increase in small grains. In addition, sunscald can affect heads which are erect or semi erect as the angle of head inclination is directed at the sun, receiving high heat intensity under hot conditions. This causes brownish red seed hulls and undeveloped or non existent seeds.

The effect of temperature on fatty acid composition is most important during early stages of seed fill. Rondanini et al. (2005), found that high alternating day/night temperatures for 4 days or longer with a mean daily grain temperature greater than 35°C produced significant reductions in grain yield and quality. Yield was reduced due to lower seed weights resulting in an increase in the percentage of half full grains in all sections of the head (outside, inter, middle sections). Reductions were highest during early grain fill (10–12 days after anthesis) with reduced yield of 6% per degrees Celcius above a mean grain temperature of 29°C. Later heat stress (18–24 days after anthesis) resulted in yield reductions of 4% per degrees Celcius above 33°C, demonstrating that the timing of heat stress is critical to yield and quality responses.

This experiment also found that heat stress 10–18 days after anthesis resulted in lower final pericarp weight due to thinner cell walls and less cell layers. High temperatures (especially 10–12 days after anthesis) reduce both the rate and duration of oil deposition in the developing seed (Rondanini et al. 2005). Constantly higher temperatures reduce oil content when occurring in the grain fill oil deposition period, when compared to alternating high/low temperatures (Rondanini and Mantese, 2004). Temperatures greater than 35°C also affect other grain properties including fatty acid composition and hull to kernel ratio. [5]

14.1.5 Waterlogging

Waterlogging can have an impact on plant growth and development. Waterlogging involves the rapid reduction in the amount of oxygen available in the soil. This has a direct impact on water and nutrient uptake and also on physiological processes such as photosynthesis, respiration and leaf senescence.

The effects of waterlogging will vary depending on a number of factors including soil type, e.g. slow draining, length of inundation and crop growth stage. [6]

4 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Plant Growth and Development https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

5 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Plant Growth and Development https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

6 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Plant Growth and Development https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=3

MORE INFORMATION

http://www.graintrade.org.au/commodity_standards

https://bettersunflowers.com.au/home.aspx

http://www.australianoilseeds.com/Technical_Info/standards_manual

Marketing

The final step in generating farm income is converting the tonnes produced into dollars at the farm gate. This section provides best in class marketing guidelines for managing price variability to protect income and cash flow.

Figure 1 shows a grain selling flow chart that summarises:

- decisions to be made
- drivers behind the decisions
- guiding principles for each decision point.

The grower will run through a decision-making process each season, because growing and harvesting conditions, and prices for grains, change all the time. For example, over the six years to and including 2014, Newcastle APWI wheat prices varied by A$70–150/t, a variability of 25–60%. For a property producing 1,000 tonnes of wheat this means $70,000–$150,000 difference in income, depending on the timing of sales (Figure 2). The same principle operates in the same way with other crops.

The reference column refers to the section of the GrowNote where you will find the details to help in making decisions. [1]

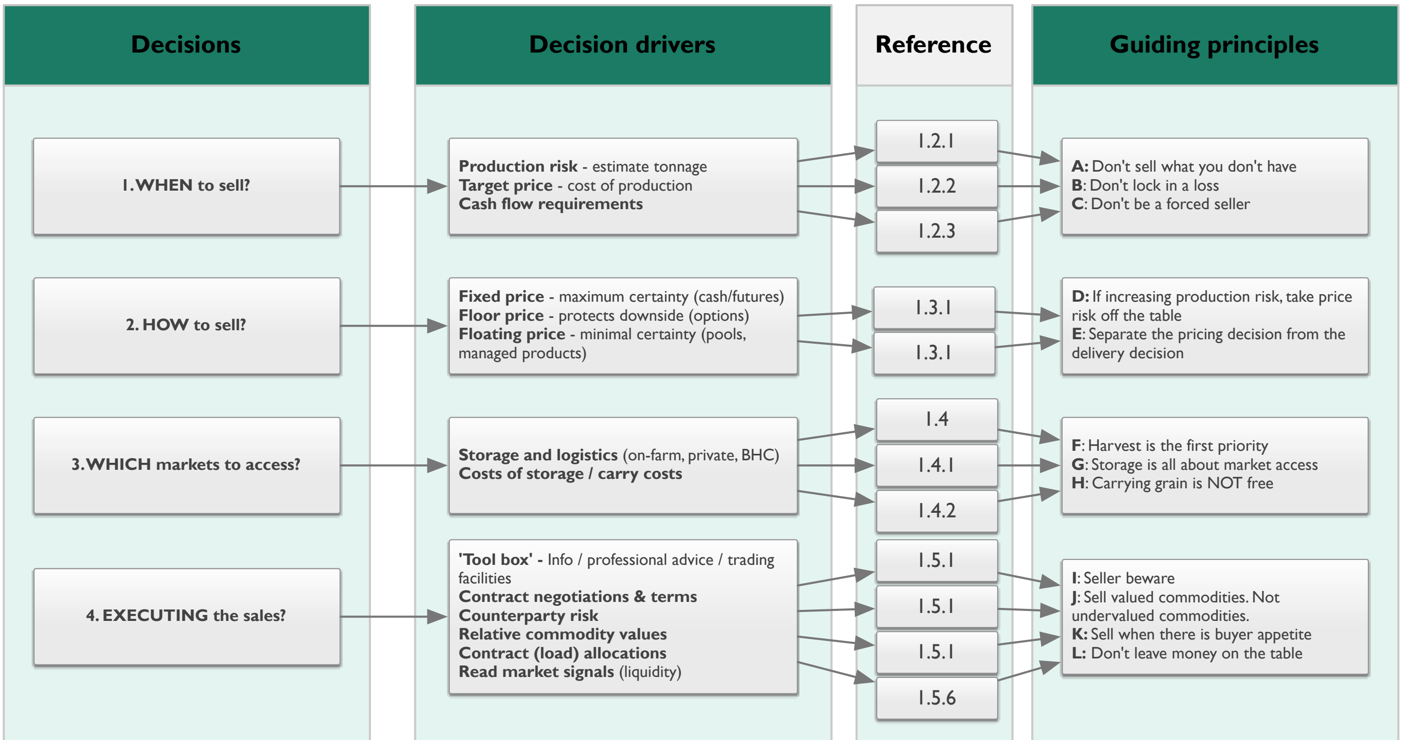
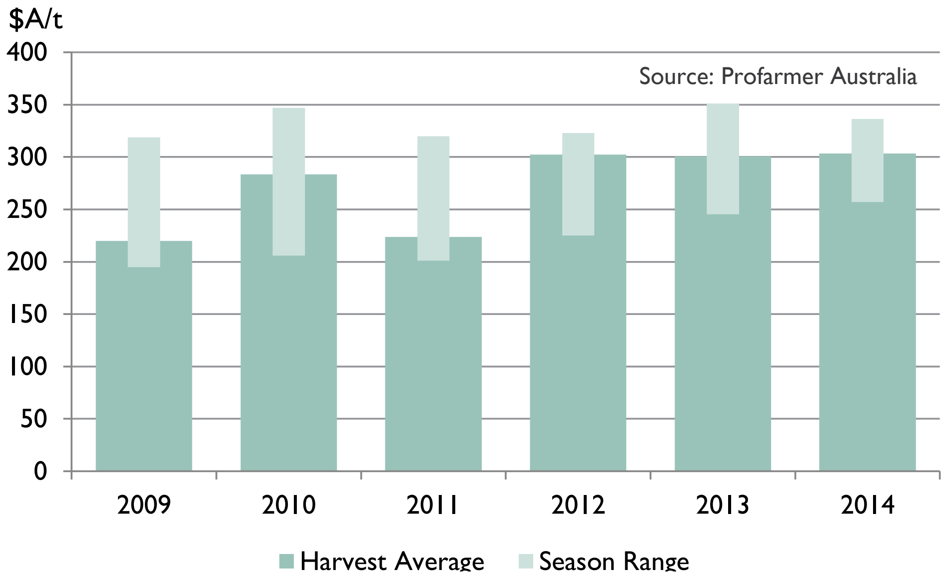


Figure 1: *Grain selling flow chart.*

1 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote



Note to figure:
Newcastle APW1 wheat prices have varied A$70-$150/t over the past 6 years (25-60% variability). For a property producing 1,000 tonne of wheat this means $70,000-$150,000 difference in income depending on price management skill.

Figure 2: *Seasonal variance in Newcastle APWI wheat prices.*

Source: Profarmer Australia

MORE INFORMATION

http://www.australianoilseeds.com/commodity_groups/australian_sunflower_association/sunflower_marketing_guide

https://bettersunflowers.com.au/newsletter/news.ashx?CampaignItemId=82

https://bettersunflowers.com.au/user/marketing.aspx

15.1 Selling principles

The aim of a selling program is to achieve a profitable average price (the target price) across the entire business. This requires managing several unknowns to establish a target price and then work towards achieving the target price.

Unknowns include the amount of grain available to sell (production variability), the final cost of producing the grain, and the future prices that may result. Australian farm-gate prices are subject to volatility caused by a range of global factors that are beyond our control and are difficult to predict.

The skills growers have developed to manage production unknowns can also be used to manage pricing unknowns. This guide will help growers manage and overcome price uncertainty. [2]

15.1.1 Be prepared

Being prepared by having a selling plan is essential for managing uncertainty. The steps involved are forming a selling strategy, and forming a plan for executing sales. The selling strategy consists of when and how to sell.

When to sell

Knowing when to sell requires an understanding of the farm's internal business factors, including:

- production risk
- a target price based on cost of production and a desired profit margin
- business cash flow requirements.

How to sell

Working out how to sell your grain is more dependent on external market factors, including:

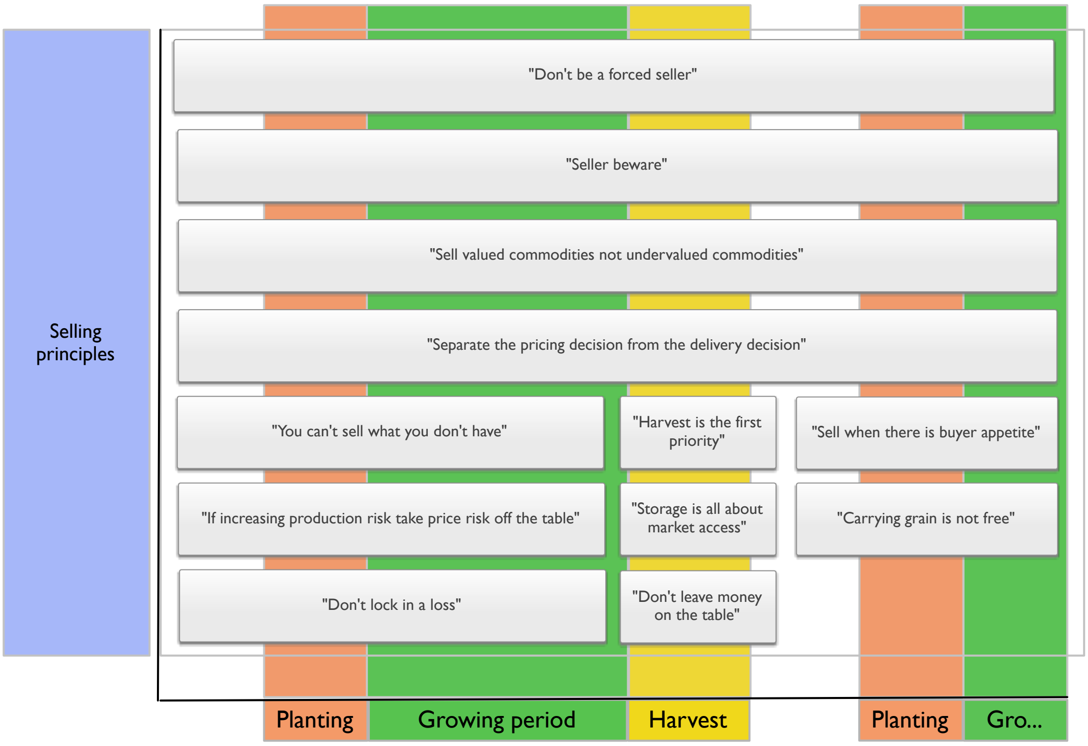
- time of year—determines the pricing method
- market access—determines where to sell

2 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

- relative value—determines what to sell.

The following diagram (Figure 3) lists key selling principles when considering sales during the growing season.

Exactly when each principle comes into play is indicated in the discussion of marketing planning and timing in the rest of section 15. [3]



Note to figure: The illustration demonstrates the key selling principles throughout the production cycle of a crop.

Profarmer AUSTRALIA

Figure 3: *Timeline of grower commodity selling principles.*

Source: Profarmer Australia

15.1.2 Establish the business risk profile

Establishing your business risk profile helps you determine when to sell: it allows you to develop target price ranges for each commodity, and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify those risks during the production cycle are described below (Figure 4).

3 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

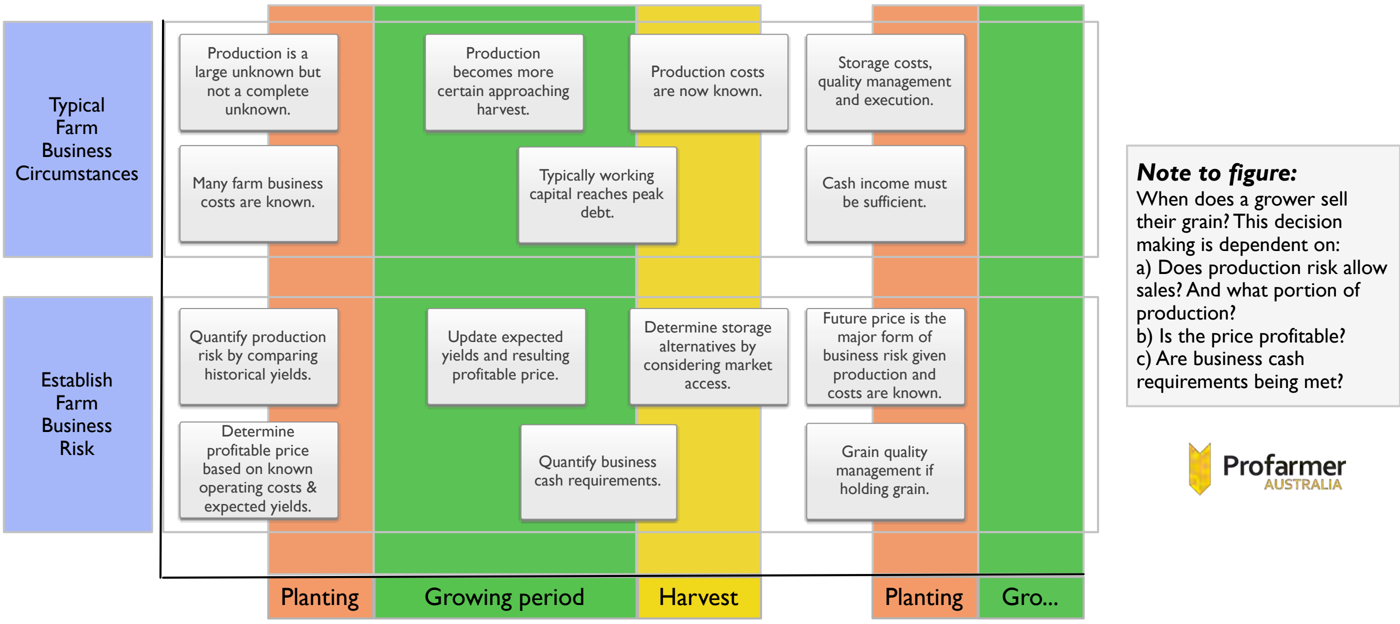


Figure 4: *Typical farm business circumstances and risk.*

Source: Profarmer Australia

Production risk profile of the farm

Production risk is the level of certainty around producing a crop and is influenced by location (climate, season and soil type), crop type, crop management, and the time of the year.

Principle: You can't sell what you don't have.

Therefore, don't increase business risk by over committing production. Establish a production risk profile (Figure 5) by:

1. Collating historical average yields for each crop type and a below-average and above-average range.
2. Assessing the likelihood of achieving the average, based on recent seasonal conditions and the seasonal outlook.
3. Revising production outlooks as the season progresses.

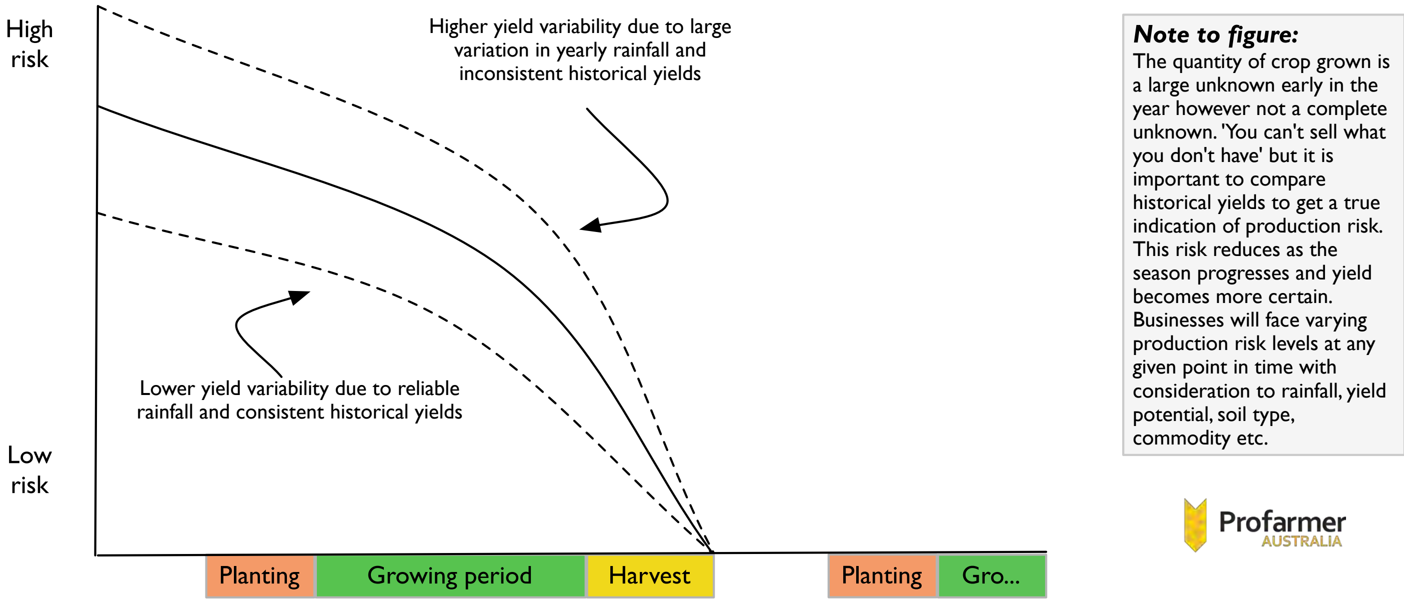


Figure 5: *Typical production risk profile of a farm operation.*

Source: Profarmer Australia

Establishing a target price

A profitable commodity target price is the cost of production per tonne plus a desired profit margin. It is essential to know the cost of production per tonne for the farm business, which means knowing all farming costs, both variable and fixed.

Principle: Don't lock in a loss.

If committing production ahead of harvest, ensure the price will be profitable. The steps needed to calculate an estimated profitable price is based on the total cost of production and a range of yield scenarios, as provided below (Figure 6).

Estimating cost of production - Wheat	
Planted area	1,200 ha
Estimate yield	2.85 t/ha
Estimated production	3,420 t
Fixed costs	
Insurance and general expenses	$100,000
Finance	$80,000
Depreciation/Capital replacement	$70,000
Drawings	$60,000
Other	$30,000
Variable costs	
Seed and sowing	$48,000
Fertiliser and application	$156,000
Herbicide and application	$78,000
Insect/fungicide and application	$36,000
Harvest costs	$48,000
Crop insurance	$18,000
Total fixed and variable costs	$724,000
Per tonne equivalent (total costs + estimated production)	$212 /t
Per tonne costs	
Levies	$3 /t
Cartage	$12 /t
Receival fee	$11 /t
Freight to port	$22 /t
Total per tonne costs	$48 /t
Cost of production port FIS equiv	$259.20
Target profit (ie 20%)	$52.00
Target price (port FIS equiv)	**$311.20**

Step 1: Estimate your production potential. The more uncertain your production is, the more conservative the yield estimate should be. As yield falls, your cost of production per tonne will rise.

Step 2: Attribute your fixed farm business costs. In this instance if 1,200 ha reflects 1/3 of the farm enterprise, we have attributed 1/3 fixed costs. There are a number of methods for doing this (see M Krause “Farming your Business”) but the most important thing is that in the end all costs are accounted for.

Step 3: Calculate all the variable costs attributed to producing that crop. This can also be expressed as $ per ha x planted area.

Step 4: Add together fixed and variable costs and divide by estimated production

Step 5: Add on the 'Per tonne' costs like levies and freight.

Step 6: Add the 'Per tonne' costs to the fixed and variable per tonne costs calculated at step 4.

Step 7: Add a desired profit margin to arrive at the port equivalent target profitable price.

Figure 6: *An example of how to estimate the costs of production.*

Source: Profarmer Australia

GRDC's manual Farming the business also provides a cost of production template and tips grain selling *v.* grain marketing.

Income requirements

Understanding farm business cash flow requirements and peak cash debt enables growers to time grain sales so that cash is available when required. This prevents having to sell grain below the target price to satisfy a need for cash.

Principle: Don’t be a forced seller.

Be ahead of cash requirements to avoid selling in unfavourable markets.

Typical cash flow to grow a crop are illustrated below (Figures 7 and 8). Costs are incurred up front and during the growing season, with peak working capital debt incurred at or before harvest. Patterns will vary depending on circumstance and enterprise mix. Figure 8 demonstrates how managing sales can change the farm’s cash balance.

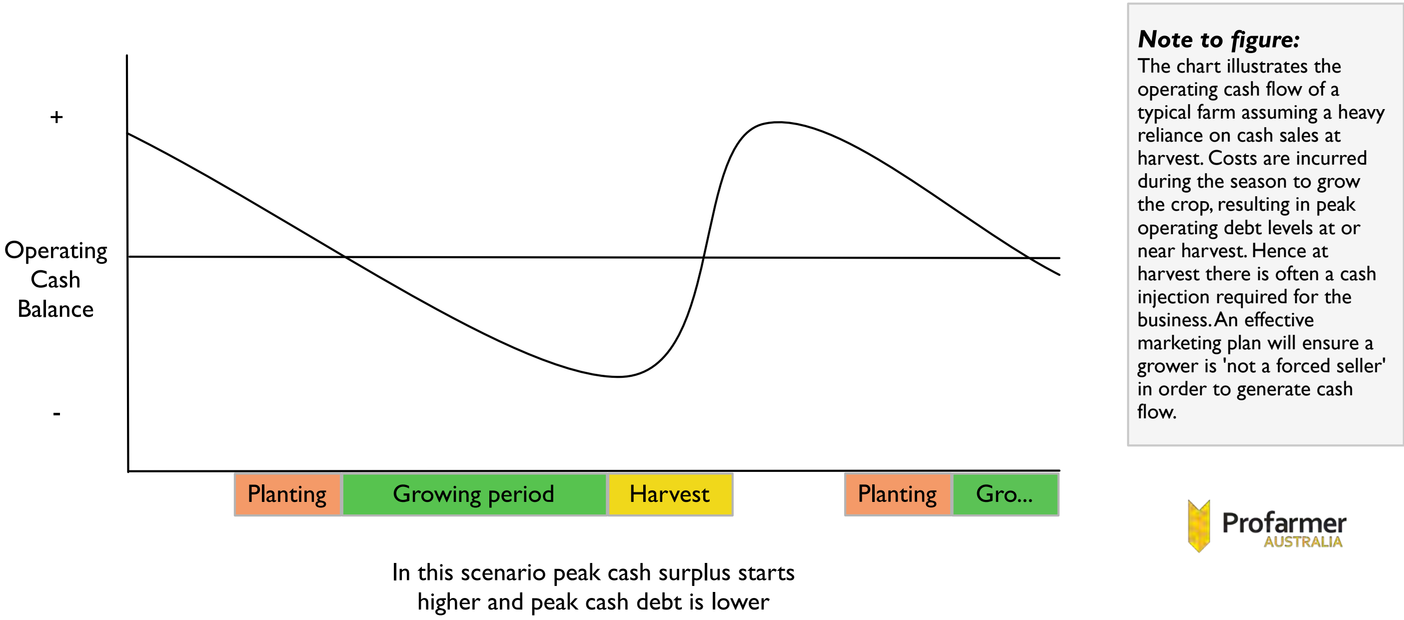


Figure 7: *A typical operating cash balance when relying on cash sales at harvest.*

Source: Profarmer Australia

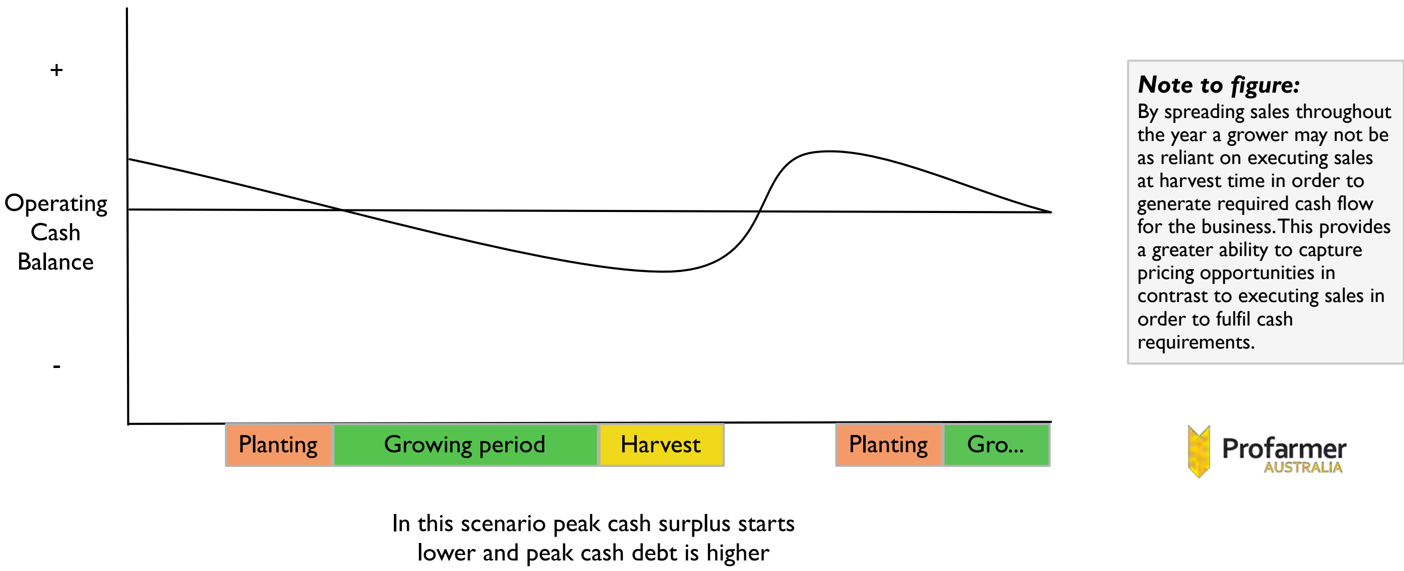


Figure 8: *Typical operating cash balance when crop sales are spread over the year.*

Source: Profarmer Australia

The 'when to sell' steps above result in an estimated production tonnage and the risk associated with that tonnage, a target price range for each commodity, and the time of year when cash is most needed. [4]

4 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

15.1.3 Managing your price

The first part of the selling strategy answers the question when to sell and establishes comfort around selling a portion of the harvest.

The second part of the strategy, managing your price, addresses how to sell your crop.

Methods of price management

Pricing products provide varying levels of price risk coverage, but not all products are available for all crops (Table 1).

Table 1: *Pricing methods and how they are used for different crops.*

	Description	Wheat	Barley	Canola	Oats	Lupins	Field peas	Chick peas
Fixed price products	Provides the most price certainty	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash	Cash	Cash	Cash
Floor price products	Limits price downside but provides exposure to future price upside	Options on futures, floor price pools	Options on futures	Options on futures	none	none	none	none
Floating price products	Subject to both price upside and downside	Pools	Pools	Pools	Pools	Pools	Pools	Pools

Figure 9 summarises how the different methods of price management are suited to the majority of farm businesses.

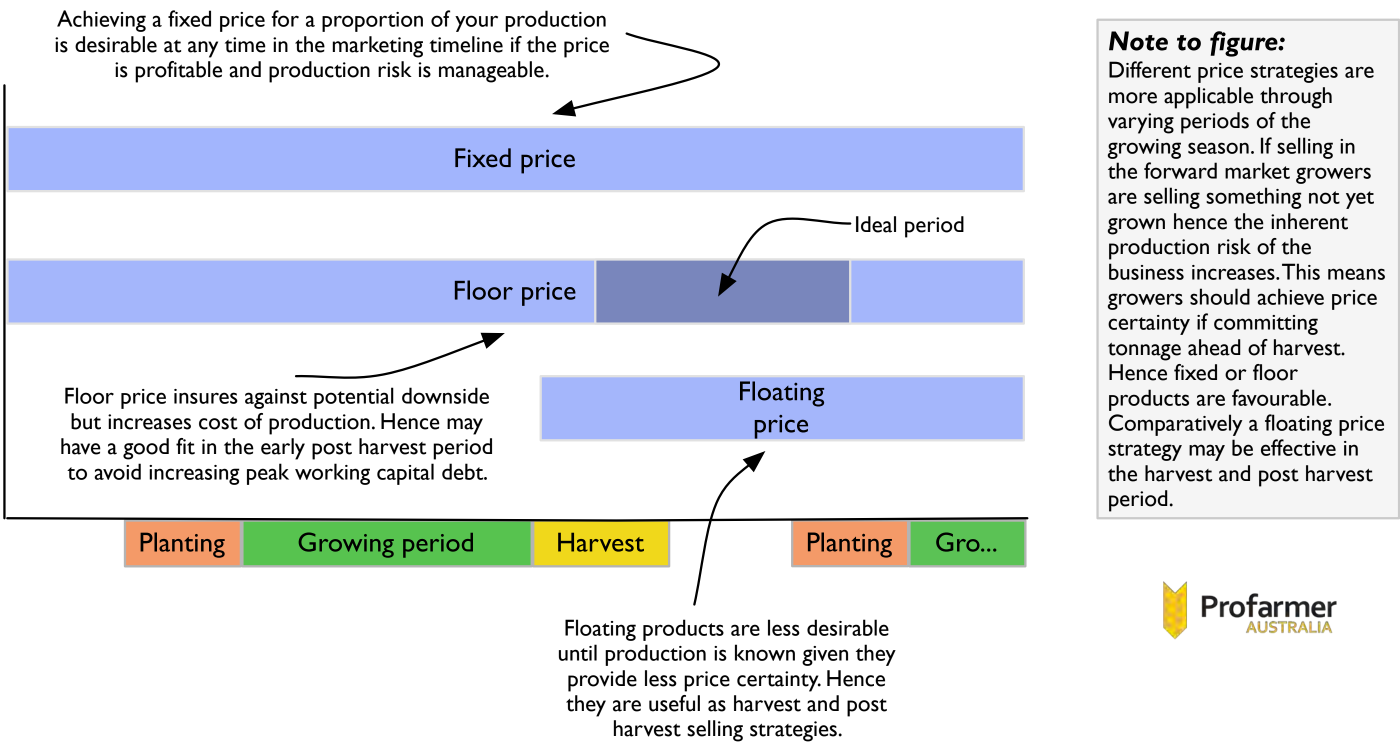


Figure 9: *Price strategy timeline, summarising the suitability for most farm businesses of different methods of price management for different phases of production.*

Source: Profarmer Australia

Principle: If increasing production risk, take price risk off the table.

When committing to unknown production, price certainty should be achieved to avoid increasing overall business risk.

Principle: Separate the pricing decision from the delivery decision.

Most commodities can be sold at any time with delivery timeframes being negotiable, hence price management is not determined by delivery.

1. *Fixed price*

A fixed price is achieved via cash sales and/or selling a futures position (swaps) (Figure 10). It provides some certainty around expected revenue from a sale as the price is largely a known factor, except when there is a floating component in the price, e.g. a multi-grade cash contract with floating spreads or a floating-basis component on futures positions.

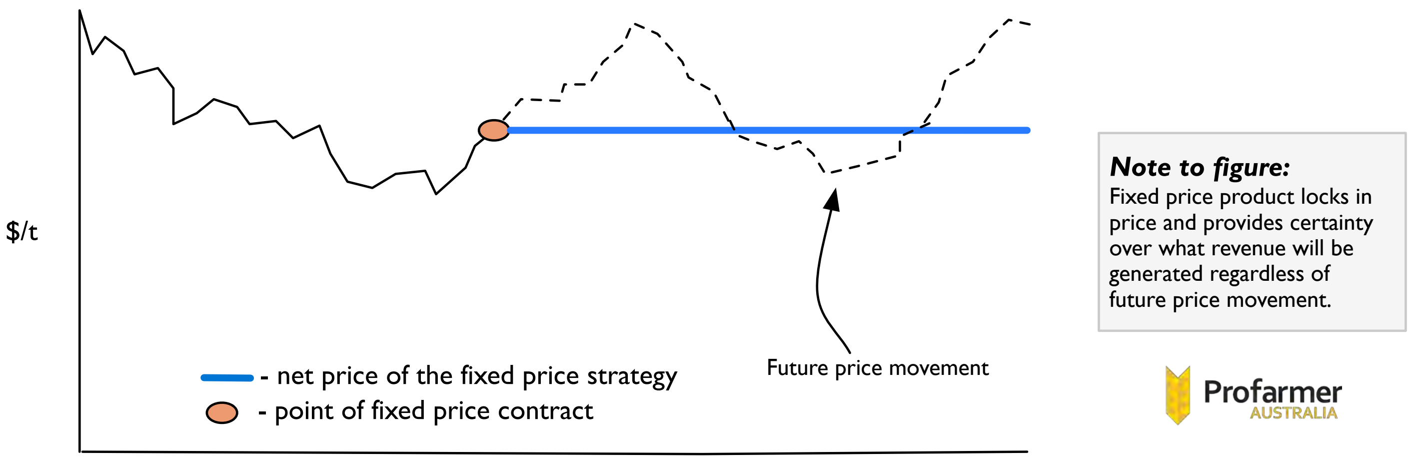
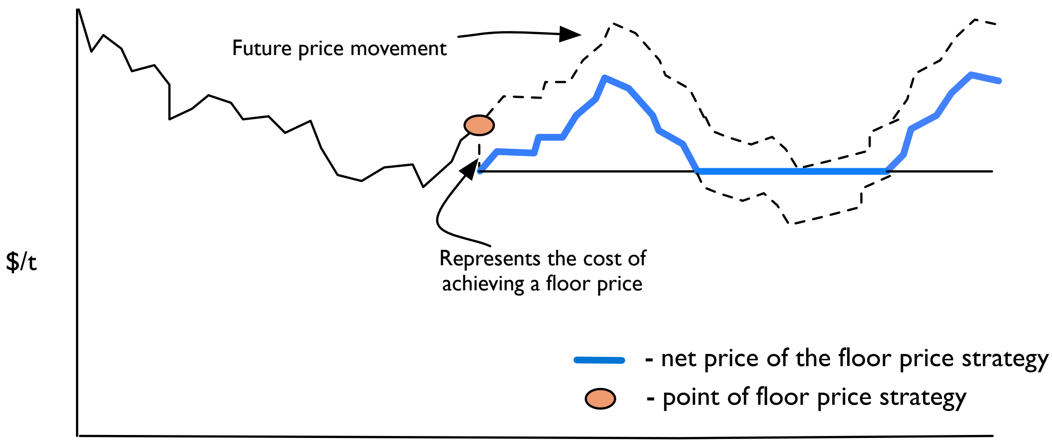


Figure 10: *Fixed price strategy.*

Source: Profarmer Australia

2. *Floor price*

Floor price strategies (Figure 11) can be achieved by utilising options on a relevant futures exchange (if one exists), or via a managed-sales program (i.e. a pool with a defined floor price strategy) offered by a third party. This pricing method protects against potential future price decrease while capturing any price increase. The disadvantage is that this kind of price 'insurance' has a cost, which adds to the farm's cost of production.



Note to figure:
A floor price strategy insures against potential future downside in price while allowing price gains in the event of future price rallies.

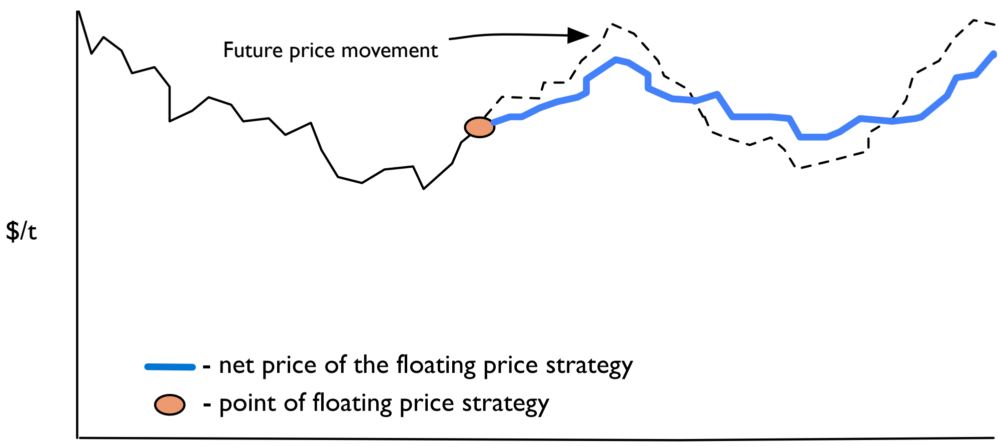
Profarmer AUSTRALIA

Figure 11: *Floor price strategy.*

Source: Profarmer Australia

3. *Floating price*

Many of the pools or managed-sales programs are a floating price, where the net price received will move up and down with the future movement in price (Figure 12). Floating price products provide the least price certainty and are best suited for use at or after harvest rather than before harvest.



Note to figure:
A floating price will move to some extent with future price movements.

Profarmer AUSTRALIA

Figure 12: *Floating price strategy.*

Source: Profarmer Australia

Having considered the variables of production for the crop to be sold, and how these fit against the different pricing mechanisms, the farmer may revise their selling strategy, taking the risks associated with each mechanism into account.

Fixed price strategies include physical cash sales or futures products and provide the most price certainty, but production risk must be considered.

Floor price strategies include options or floor price pools. They provide a minimum price with upside potential and rely less on production certainty, but cost more.

Floating price strategies provide minimal price certainty and so are best used after harvest. [5]

15.1.4 Ensuring access to markets

Once the questions of when and how to sell are sorted out, planning moves to the storage and delivery of commodities to ensure timely access to markets and execution of sales. Planning where to store the commodity is an important component of ensuring the type of access to the market that is likely to yield the highest return (Figure 13).

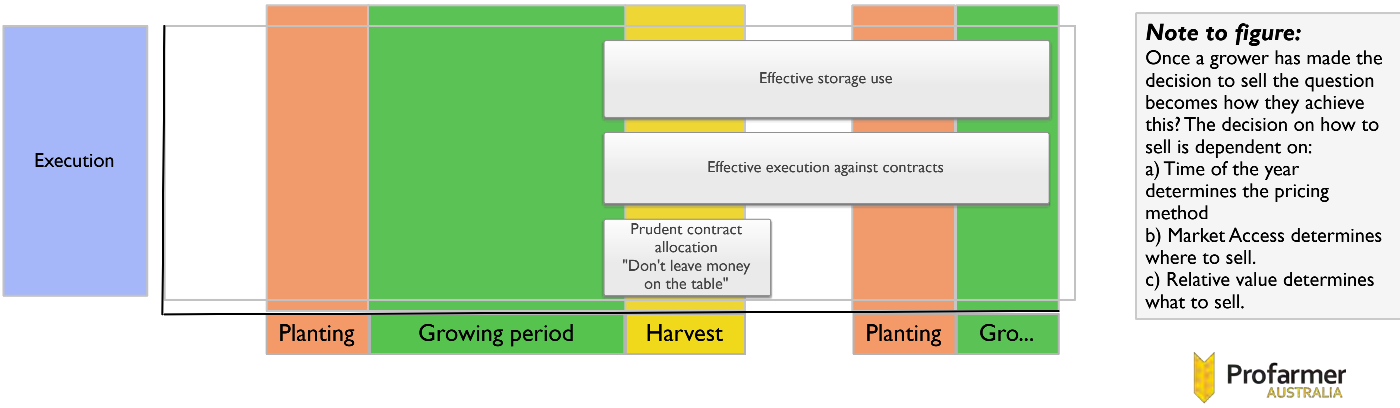


Figure 13: *Storage decisions are influenced by selling decisions and the timing of all farming activities.*

Source: Profarmer Australia

Storage and logistics

The return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access so as to maximise returns as well as harvest logistics.

Storage alternatives include variations of bulk handling, private off-farm storage, and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity (Figure 14).

Principle: Harvest is the first priority.

During harvest, getting the crop into the bin is the most critical aspect of business success; hence storage, sale and delivery of grain should be planned well ahead of harvest to allow the grower to focus on the harvest itself.

Bulk export commodities requiring significant quality management are best suited to the bulk handling system. Commodities destined for the domestic end user market, (e.g. feedlot, processor, or container packer), may be more suited to on-farm or private storage to increase delivery flexibility.

Storing commodities on the farm requires prudent quality management to ensure that the grain is delivered to the agreed specifications. If not well planned and carried out, it can expose the business to high risk. Penalties for out-of-specification grain arriving at a buyer's weighbridge can be expensive, as the buyer has no obligation to accept it. This means the grower may have to incur the cost of taking the load elsewhere, and may also have to find a new buyer.

On-farm storage also requires that delivery is managed to ensure that the buyer receives the commodities on time and with appropriate weighbridge and sampling tickets.

Principle: Storage is all about market access.

5 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

Storage decisions depend on quality management and expected markets.

For more information on on-farm storage alternatives and economics, see Section 13: Grain Storage.

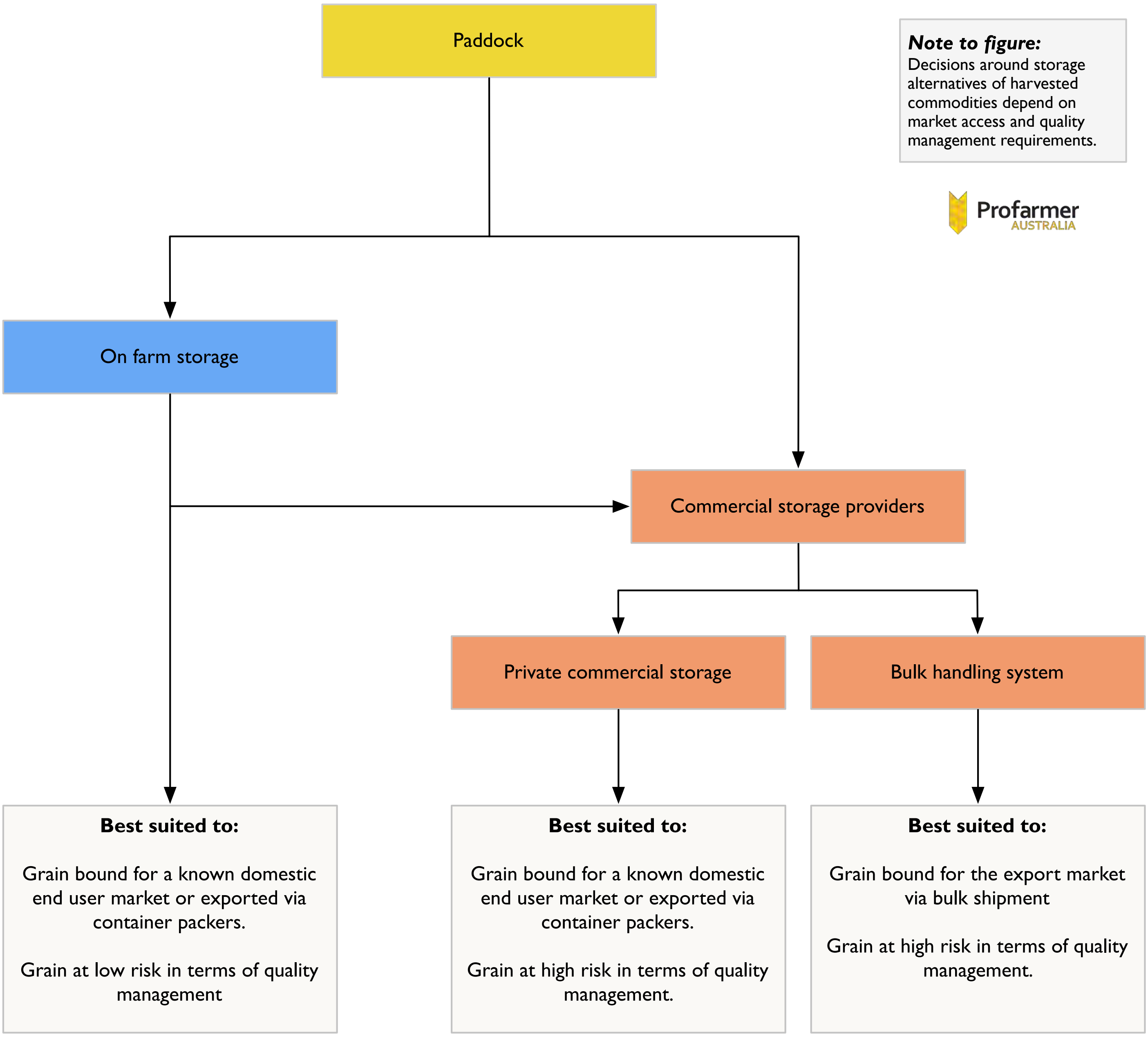


Figure 14: *Grain storage decision-making.*

Source: Profarmer Australia

Cost of holding grain

Storing grain to access sales opportunities post-harvest invokes a cost to ‘carry’, or hold, the grain (Figure 15). Price targets for carried grain need to account for the cost of carrying it.

Carrying costs are typically $3–4/t per month and consist of:

- monthly storage fee charged by a commercial provider (typically ~$1.50–2.00/t per month)
- monthly interest associated with having wealth tied up in grain rather than available as cash or for paying off debt (~$1.50–$2.00/t, depending on the price of the commodity and interest rates).

The price of carried grain therefore needs to be $3–4/t per month higher than the price offered at harvest.

The cost of carrying also applies to grain stored on the farm, as there is the cost of the capital invested in the farm storage plus the interest component. A reasonable assumption is a cost of $3–4/t per month for on-farm storage.

Principle: Carrying grain is not free.

The cost of carrying grain needs to be accounted for if holding it for sale after harvest is part of the selling strategy.

If selling a cash contract with deferred delivery, a carrying charge can be negotiated into the contract. For example, a March sale of wheat for March–June delivery on the buyer's call at a price of $300/t + $3/t carrying per month would generate revenue of $309/t for grain delivered in June. The price negotiated will depend on the market the grower is selling into (Figures 15 and 16). [6]

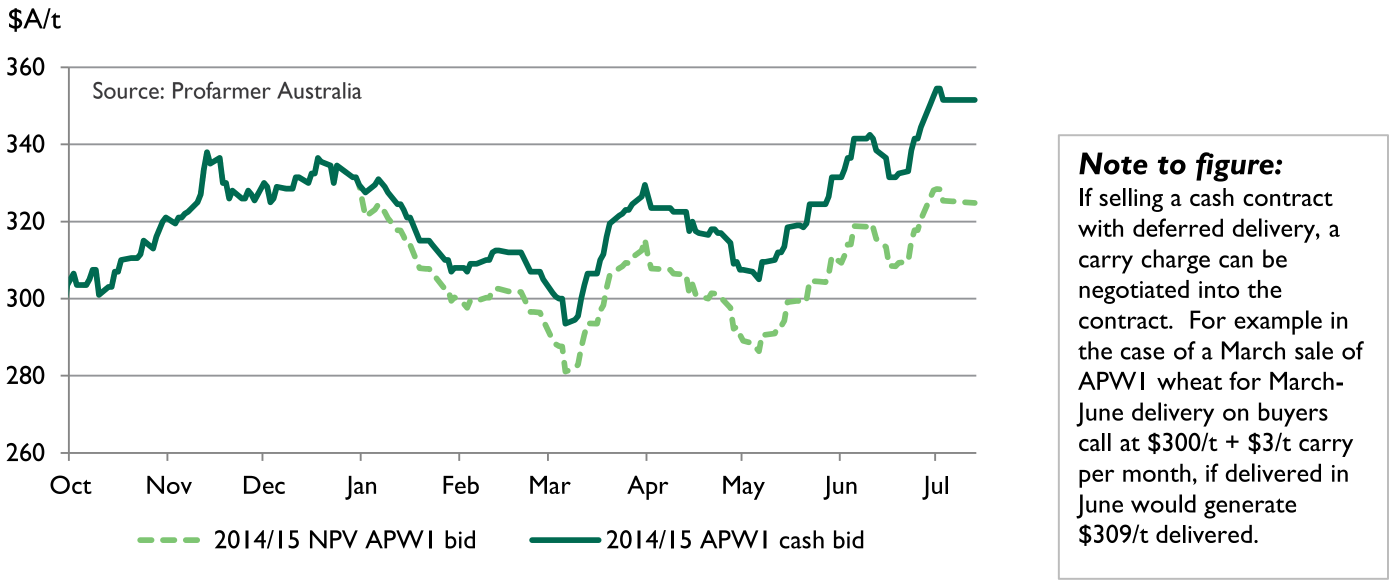
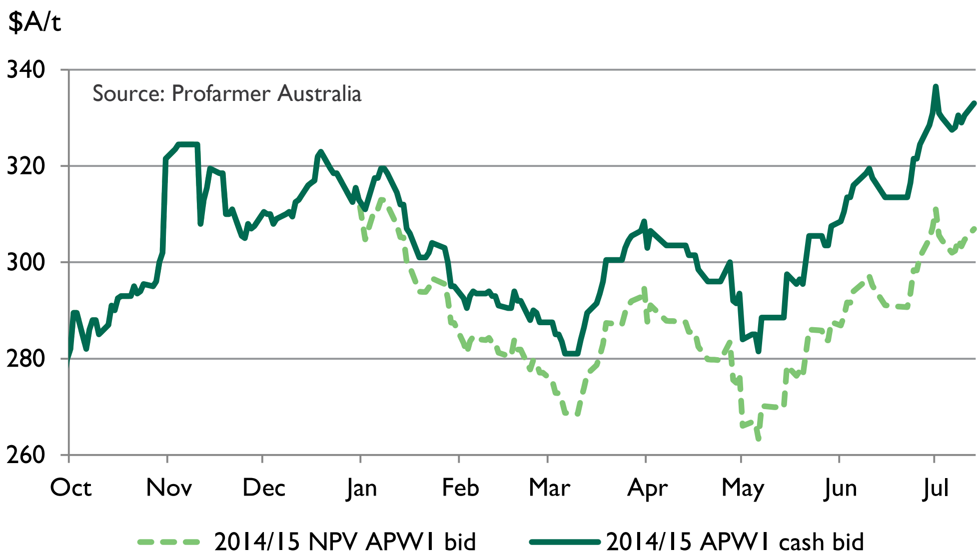


Figure 15: *How adding a carrying charge changes the total paid in the Brisbane APW2 cash market.*

Source: Profarmer Australia

6 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote



Note to figure:
If selling a cash contract with deferred delivery, a carry charge can be negotiated into the contract. For example in the case of a March sale of APW1 wheat for March-June delivery on buyers call at $300/t + $3/t carry per month, if delivered in June would generate $309/t delivered.

Figure 16: *How adding a carrying charge changes the total paid in the Newcastle APWI cash market. Note differences between this market and that in Figure 15.*

Source: Profarmer Australia

Optimising farm gate returns involves planning the appropriate storage strategy for each commodity so as to improve market access and ensure that carrying costs are covered in the price received. [7]

15.1.5 Converting tonnes into cash

This section provides guidelines for converting the selling and storage strategy into cash by effective execution of sales.

Set up the toolbox

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox for converting tonnes of grain into cash includes the following:

1. Timely information—this is critical for awareness of selling opportunities and includes:
   - market information provided by independent parties
   - effective price discovery including indicative bids, firm bids, and trade prices
   - other market information pertinent to the particular commodity.
2. Professional services—grain selling professional 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. A better return on investment for the farm business is achieved through higher farm-gate prices, which are obtained by accessing timely information, and being able to exploit the seller's greater market knowledge and greater market access.
3. Futures account and bank swap facility—these accounts provide access to global futures markets. Hedging futures markets is not for everyone; however, strategies which utilise exchanges such as the Chicago Board of Trade (CBOT) can add significant value.

For a list of current financial members of Grain Trade Australia including buyers, independent information providers, brokers, agents, and banks providing over-

7 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

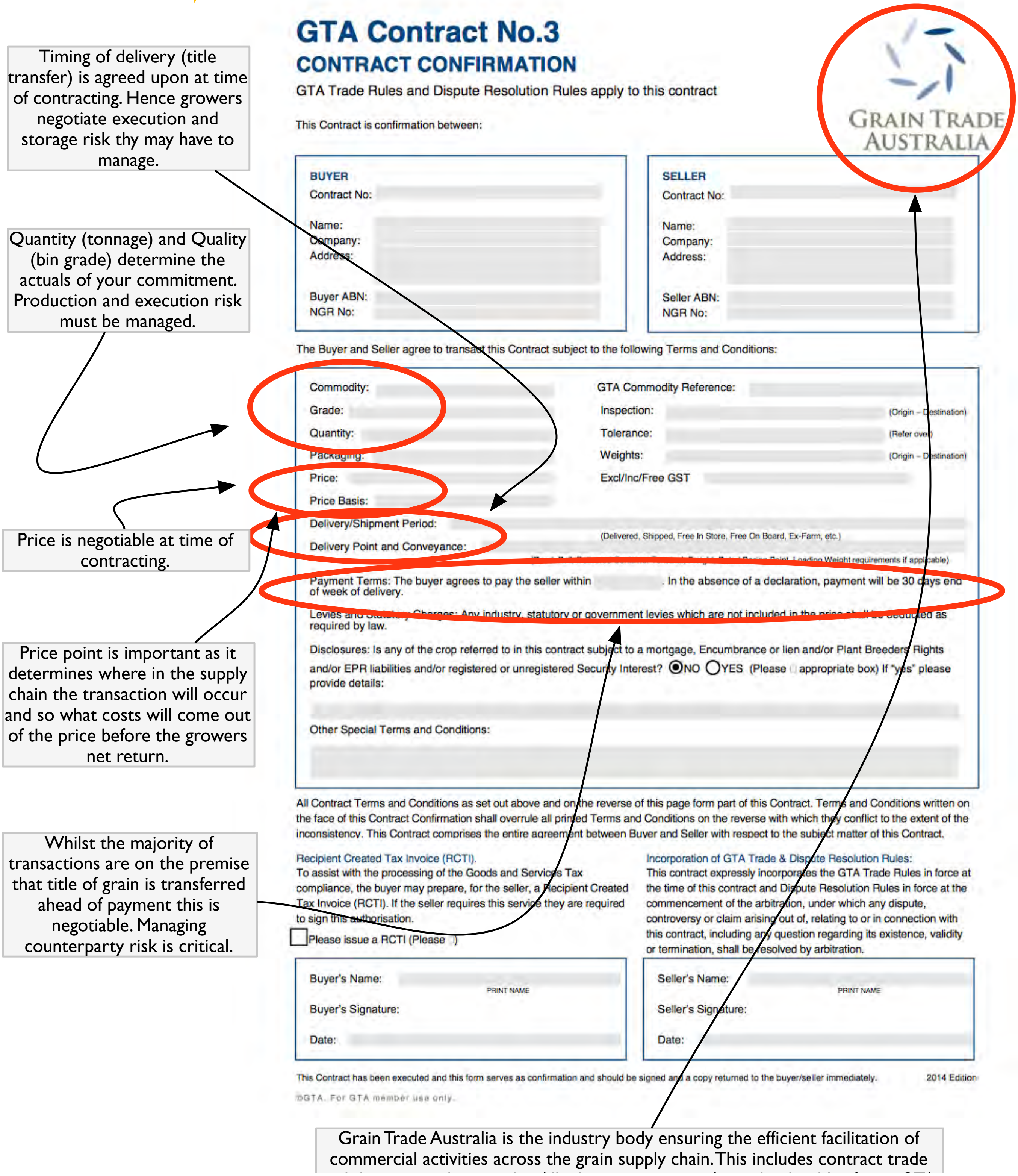
the-counter grain derivative products (swaps), see http://www.graintrade.org.au/membership

For a list of commodity futures brokers, see http://www.asx.com.au/prices/find-a-futures-broker.htm

How to sell for cash

Like any market transaction, a cash grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components with each component requiring a level of risk management (Figure 17):

- Price—future price is largely unpredictable, so devising a selling plan to put current prices into the context of the farm business is critical to managing price risk.
- Quantity and quality—when entering a cash contract, you are committing to deliver the nominated amount of grain at the quality specified, so production and quality risks must be managed.
- Delivery terms—the timing of title transfer from the grower to the buyer is agreed at time of contracting. If this requires delivery direct to end users, it relies on prudent execution management to ensure delivery within the contracted period.
- Payment terms—in Australia, the traditional method of contracting requires title on the grain to be transferred ahead of payment, so counterparty risk must be managed.



GTA Contract No.3

CONTRACT CONFIRMATION

GTA Trade Rules and Dispute Resolution Rules apply to this contract

This Contract is confirmation between:

BUYER
Contract No:
Name:
Company:
Address:
Buyer ABN:
NGR No:

SELLER
Contract No:
Name:
Company:
Address:
Seller ABN:
NGR No:

The Buyer and Seller agree to transact this Contract subject to the following Terms and Conditions:

Commodity:
Grade:
Quantity:
Packaging:
Price:
Price Basis:
Delivery/Shipment Period:
Delivery Point and Conveyance:

GTA Commodity Reference:
Inspection: (Origin – Destination)
Tolerance: (Refer over)
Weights: (Origin – Destination)
Excl/Inc/Free GST

(Delivered, Shipped, Free In Store, Free On Board, Ex-Farm, etc.)

Payment Terms: The buyer agrees to pay the seller within . In the absence of a declaration, payment will be 30 days end of week of delivery.

Levies and Statutory Charges: Any industry, statutory or government levies which are not included in the price shall be deducted as required by law.

Disclosures: Is any of the crop referred to in this contract subject to a mortgage, Encumbrance or lien and/or Plant Breeders Rights and/or EPR liabilities and/or registered or unregistered Security Interest? NO YES (Please appropriate box) If "yes" please provide details:

Other Special Terms and Conditions:

All Contract Terms and Conditions as set out above and on the reverse of this page form part of this Contract. Terms and Conditions written on the face of this Contract Confirmation shall overrule all printed Terms and Conditions on the reverse with which they conflict to the extent of the inconsistency. This Contract comprises the entire agreement between Buyer and Seller with respect to the subject matter of this Contract.

Recipient Created Tax Invoice (RCTI).
To assist with the processing of the Goods and Services Tax compliance, the buyer may prepare, for the seller, a Recipient Created Tax Invoice (RCTI). If the seller requires this service they are required to sign this authorisation.
Please issue a RCTI (Please)

Incorporation of GTA Trade & Dispute Resolution Rules:
This contract expressly incorporates the GTA Trade Rules in force at the time of this contract and Dispute Resolution Rules in force at the commencement of the arbitration, under which any dispute, controversy or claim arising out of, relating to or in connection with this contract, including any question regarding its existence, validity or termination, shall be resolved by arbitration.

Buyer's Name: PRINT NAME
Buyer's Signature:
Date:

Seller's Name: PRINT NAME
Seller's Signature:
Date:

This Contract has been executed and this form serves as confirmation and should be signed and a copy returned to the buyer/seller immediately. 2014 Edition

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Figure 17: *Typical terms of a cash contract.*

Source: Grain Trade Australia

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. Figure 18 shows the terminology used to describe pricing points along the grain supply chain and the associated costs to come out of each price before growers receive their net return.

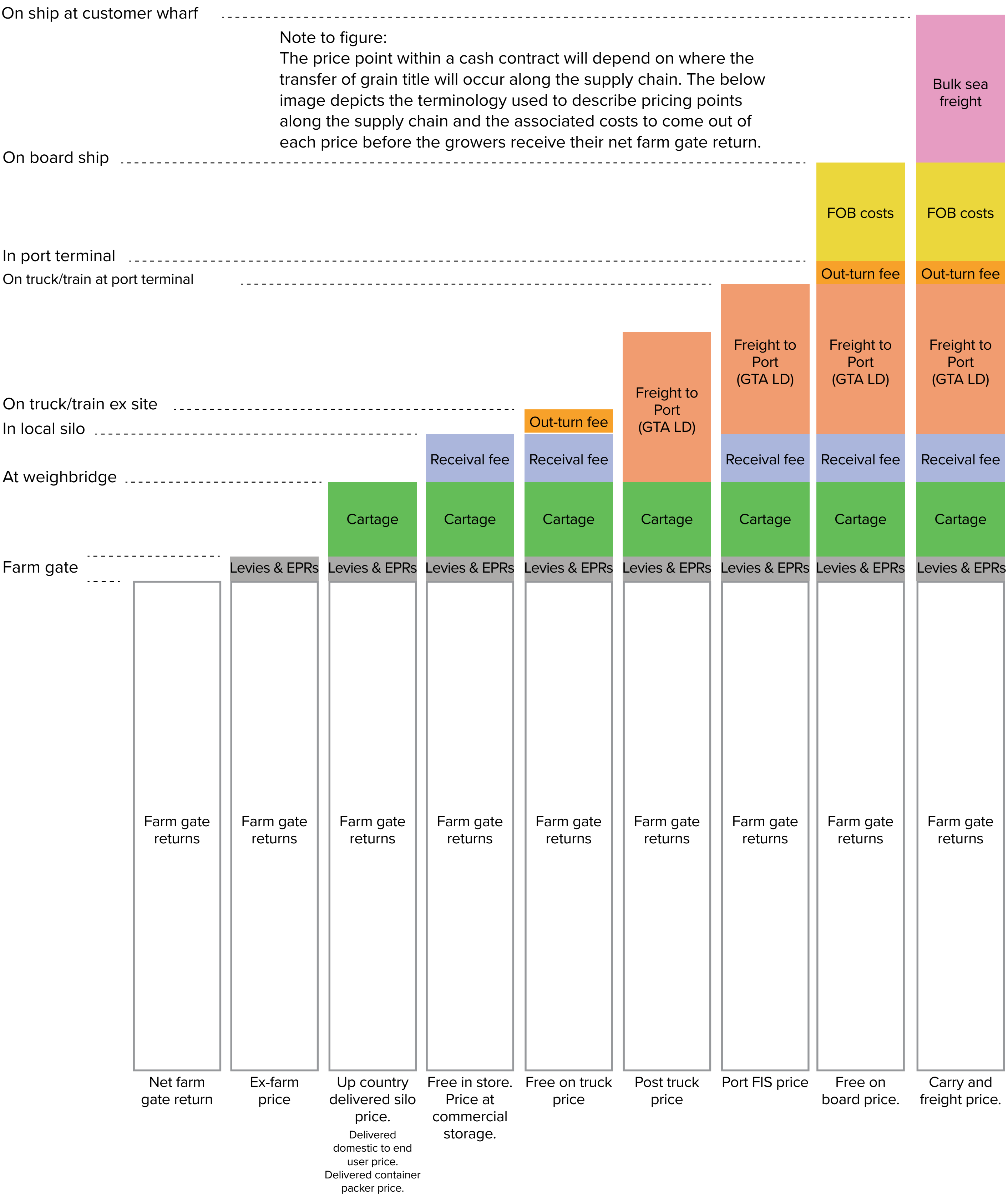


Figure 18: *Cost and pricing points throughout the supply chain.*

Source: Profarmer Australia

MORE INFORMATION

http://www.graintrade.org.au/contracts

http://www.graintrade.org.au/commodity_standards

http://www.graintransact.com.au

http://www.grainflow.com.au

http://emeraldgrain.com

https://www.cleargrain.com.au

MORE INFORMATION

GTA managing counterparty risk 14/7/2014

Clear Grain Exchange title transfer model

GrainGrowers guide to managing contract risk

Counterparty risk: A producer perspective, Leo Delahunty

Cash sales generally occur through three methods:

- Negotiation via personal contact—traditionally prices are posted as a public indicative bid. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and is available for all commodities.
- Accepting a 'public firm bid'—cash prices in the form of public firm bids are posted during harvest and for warehoused grain by merchants on a site basis. Growers can sell their parcel of grain immediately by accepting the price on offer via an online facility and then transfer the grain online to the buyer. The availability of this depends on location and commodity.
- Placing an 'anonymous firm offer'—growers can place a firm offer price on a parcel of grain anonymously and expose it to the entire market of buyers, who then bid on it anonymously using the Clear Grain Exchange, which is an independent online exchange. If the offer and bid match, the particulars of the transaction are sent to a secure settlement facility, although the title on the grain does not transfer from the grower until they receive funds from the buyer. The availability of this option depends on location and commodity. Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

Counterparty risk

Most sales involve transferring the title on the grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

Principle: Seller beware.

There is not much point selling for an extra $5/t if you don't get paid.

Counterparty risk management includes:

- Dealing only with known and trusted counterparties.
- Conducting a credit check (banks will do this) before dealing with a buyer they are unsure of.
- Selling only a small amount of grain to unknown counterparties.
- Considering credit insurance or letter of credit from the buyer.
- Never delivering a second load of grain if payment has not been received for the first.
- Not parting with the title before payment, or requesting and receiving a cash deposit of part of the value ahead of delivery. Payment terms are negotiated at time of contracting. Alternatively, the Clear Grain Exchange provides secure settlement whereby the grower maintains title on the grain until they receive payment, and then title and payment are settled simultaneously.

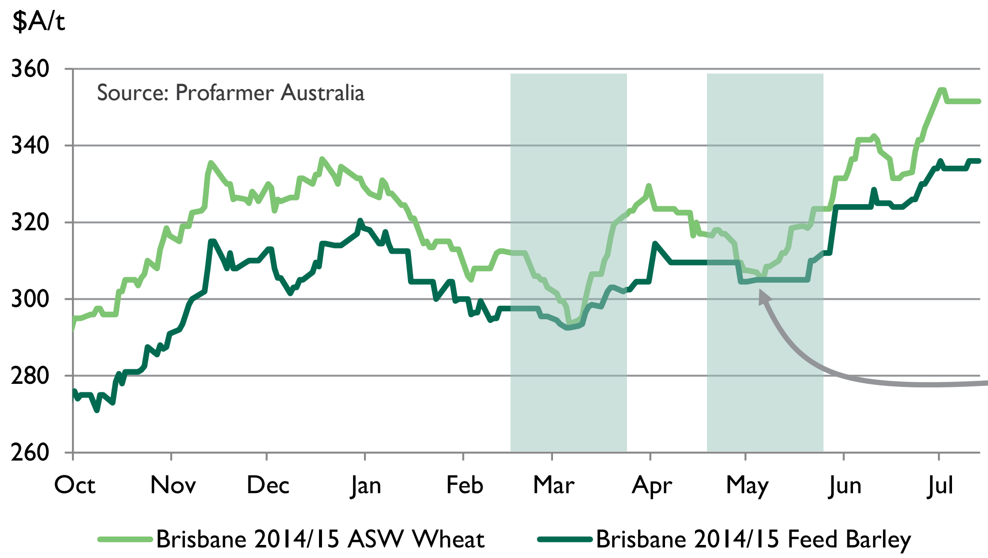
Above all, act commercially to ensure the time invested in implementing a selling strategy is not wasted by poor management of counterparty risk.

Relative values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well, and to hold commodities that are not well priced at any given time. That is, give preference to the commodities with the highest relative value. This achieves price protection for the overall revenue of the farm business and enables more flexibility to a grower's selling program while achieving the business goal of reducing overall risk.

Principle: Sell valued commodities, not undervalued commodities.

If one commodity is priced strongly relative to another, focus sales there. Don't sell the cheaper commodity for a discount. For example, a farmer with wheat and barley to sell would sell the one that is getting good prices relative to the other, and hold the other for the meantime (see Figure 19).



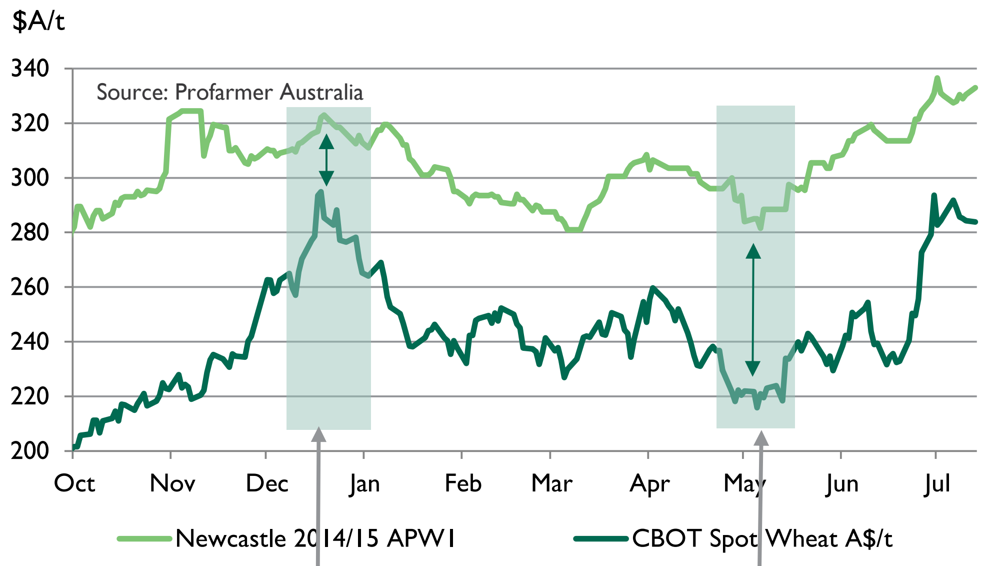
Note to figure:
Price relativities between commodities is one method of assessing which grain types 'hold the greatest value' in the current market.

Example:
Feed barley prices were performing strongly relative to ASW wheat values (normally ~15% discount) hence selling feed barley was more favourable than ASW wheat during this period.

Figure 19: *Brisbane ASW wheat v. feed barley are compared, and the barley held until it is favourable to sell it.*

Source: Profarmer Australia

If the decision has been made to sell wheat, CBOT wheat may be the better choice if the futures market is showing better value than the cash market (Figure 20).



Note to figure:
Once the decision to take price protection has been made, choosing which pricing method to use is determined by which selling methods 'hold the greatest value' in the current market.

Example:
Sales via CBOT wheat were preferred over cash.

Example:
Cash sales were preferred over CBOT wheat.

Figure 20: *By comparing prices for Newcastle APWI vs CBOT wheat, the grower can see which market to sell into.*

Source: Profarmer Australia

Contract allocation

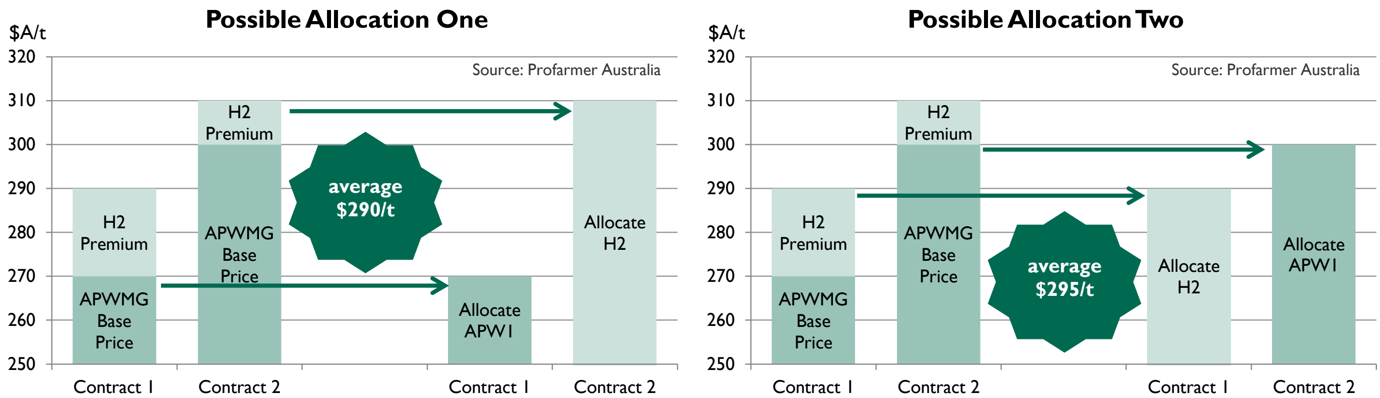
Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (e.g. price, premiums-discounts, oil bonuses), and optimising your allocation reflects immediately on your bottom line.

Principle: Don't leave money on the table.

Contract allocation decisions don't take long, and can be worth thousands of dollars to your bottom line.

To achieve the best average price for their crop growers should:

- allocate lower grades of wheat to contracts with the lowest discounts
- allocate higher grades of wheat to contracts with the highest premiums (Figure 21).



Note to figure:
In these two examples the only difference between acheiving an average price of $290/t and $295/t is which contracts each parcel was allocated to. Over 400/t that equates to $2,000 which could be lost just in how parcels are allocated to contracts.

Figure 21: *How the crop is allocated across contracts can have an impact of earnings from the crop. Although this example uses wheat, the same principle applies for sunflowers.*

Source: Profarmer Australia

Read market signals

The appetite of buyers to buy a particular commodity will differ over time depending on market circumstances. Ideally growers should aim to sell their commodity when buyer appetite is strong, and stand aside from the market when buyers are not very interested.

Principle: Sell when there is buyer appetite.

When buyers are chasing grain, growers have more market power to demand the price they want.

Buyer appetite can be monitored by:

- The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate that buyer appetite is strong. However, if one buyer is offering $5/t above the next best bid, it may mean that cash prices are susceptible to falling $5/t as soon as that buyer satisfies their appetite.
- Monitoring actual trades against public indicative bids. When trades are occurring above indicative public bids it may indicate strong appetite from merchants and the ability for growers to offer their grain at price premiums to public bids.

The selling strategy is converted to maximum business revenue by:

- ensuring timely access to information, advice and trading facilities
- using different cash market mechanisms when appropriate
- minimising counterparty risk by conducting effective due diligence
- understanding relative value and selling commodities when they are priced well
- thoughtful contract allocation
- reading market signals to extract value from the market or to prevent selling at a discount. [8]

15.2 Northern sunflower: market dynamics and execution

15.2.1 Price determinants for northern sunflower

Australian production of sunflower seed is very small relative to global production, accounting for 0.1–0.2% of the global crop in any given year (Figure 22). The largest producers are the Black Sea (Russia and Ukraine), the European Union, and Argentina. The majority of the Australian crop is produced in Queensland and NSW with less than 5% produced outside these two states.

Most of the seed produced in Australia is crushed to produce monounsaturated sunflower oil. Hence values are heavily influenced by the values for competing edible oils, particularly soy oil.

The value of domestic seed and oil is also influenced by overseas prices. This is because Australian production accounts for approximately 50% of domestic consumption, so the country is a net importer of sunflowers and sunflower oil. The value of the Australian dollar therefore heavily affects local values, as it influences the relative competitiveness of imported product. An Australian dollar that is stronger against the US dollar will make imported product more competitive compared to local product.

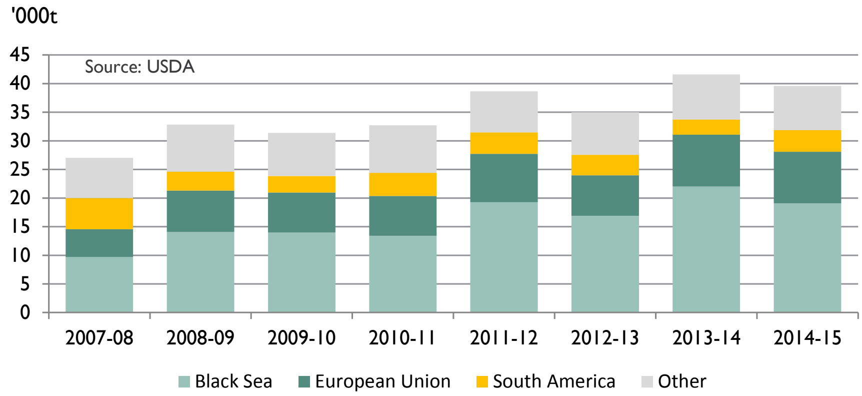


Figure 22: *World sunflower seed production.*

Source: USDA

The by-product of sunflower oil production is the production of sunflower meal, which can be sold as livestock feed. The price of sunflower meal can influence the price of the seed itself. In Australia sunflower meal competes against other domestic and imported meals including those of cottonseed, canola and soybean.

Other markets for sunflower seeds include birdseed, confectionary, horse feed, organic sunflowers, and polyunsaturated sunflower oil. (However, the market has moved nearly 100% away from polyunsaturated oils in favour of monounsaturated oils, so virtually no market remains for this product). [9]

8 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

9 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

MORE INFORMATION

[Better Sunflowers, sunflower marketing guide for growers]

[GRDC, Safe storage of sunflower seed]

[Better Sunflowers]

[Sunflower production in Queensland]

[Better Sunflowers, Marketing]

[Australian Oilseeds Federation, oilseed standards]

[Queensland Agricultural Merchants, birdseed standards]

15.2.2 Ensuring market access for northern sunflowers

Each market for sunflower seeds has specific requirements, and often result in strict varietal and quality specifications (and production methods). Hence, the first step in ensuring market access for sunflowers produced in northern Australia begins before planting, when varieties are chosen.

Buyers who require the utmost consistency of quality and supply usually secure their requirements by using forward contracts. Hence, in order to ensure market access contracts may also need to be secured before planting.

For those producing sunflower seeds for the edible-oil market, the following facilities crush sunflower seeds:

- Newcastle, NSW—Cargill
- Narrabri, NSW—Cargill
- Footscray, Victoria—Cargill
- Cootamundra, NSW—Cootamundra Oilseeds
- Manildra, NSW—MSM Milling

Other oilseed-crushing facilities may also crush sunflower seeds. [10]

15.2.3 Converting tonnes into cash for northern sunflowers

In the forward market, an area program allows producers to commit to planting a certain area of sunflowers, and the buyer may take on some or all of the production risk. These contracts are normally offered directly by domestic users or by their agents. Area contracts can take different forms, so it is important when comparing contracts that the seller considers the following risks in particular:

- Production risk—is the buyer taking on all of the production risk or does the contract include minimum and/or maximum volume commitments?
- Quality risk—what premiums and discounts are being offered for quality parameters?

Fixed-tonnage forward contracts are also available. These tend to price at premiums above an area contract as the grower carries all of the production risk.

Some buyers may also offer ‘guaranteed minimum price’ contracts, where the final price is not locked in but a minimum price is established in order to provide downside price protection. Alternatively, some buyers also provide a ‘no price established’ (NPE) contract, which allows the seller to lock in the volume and the delivery period, and leave the price floating for a period.

Delivery periods are an important consideration when contracting sunflowers, as the processing facility’s schedule of commodity crushing and the plant’s processing capacity are likely to dictate the schedule for receivals. They may not line up with the timing of harvest.

The main buyers of sunflower seeds in Australia are:

- AWB (for Cargill Australia)
- Adams Australia
- Paradise Farms
- Energreen Nutrition (for Cootamundra Oilseeds)

There are also quite a number of smaller buyers in the market. A complete list of all buyers of sunflowers and their specifications is available from the Better Sunflowers website. [11]

10 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

11 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

Current and past research

Project Summaries
www.grdc.com.au/ProjectSummaries

As part of a continuous investment cycle each year the Grains Research and Development Corporation (GRDC) invests in several hundred research, development and extension and capacity building projects. To raise awareness of these investments the GRDC has made available summaries of these projects.

These project summaries have been compiled by GRDC's research partners with the aim of raising awareness of the research activities each project investment.

The GRDC's project summaries portfolio is dynamic: presenting information on current projects, projects that have concluded and new projects which have commenced. It is updated on a regular basis.

The search function allows project summaries to be searched by keywords, project title, project number, theme or by GRDC region (ie Northern, Southern or Western Region).

Where a project has been completed and a final report has been submitted and approved a link to a summary of the project's final report appears at the top of the page.

The link to Project Summaries is www.grdc.com.au/ProjectSummaries

Final Report Summaries
http://finalreports.grdc.com.au/final_reports

In the interests of raising awareness of GRDC's investments among growers, advisers and other stakeholders, the GRDC has available final reports summaries of projects.

These reports are written by GRDC research partners and are intended to communicate a useful summary as well as present findings of the research activities from each project investment.

The GRDC's project portfolio is dynamic with projects concluding on a regular basis.

In the final report summaries there is a search function that allows the summaries to be searched by keywords, project title, project number, theme or GRDC Regions. The advanced options also enables a report to be searched by recently added, most popular, map or just browse by agro-ecological zones

The link to the Final Report Summaries is http://finalreports.grdc.com.au/final_reports

Online Farm Trials
http://www.farmtrials.com.au/

The Online Farm Trials project brings national grains research data and information directly to the grower, agronomist, researcher and grain industry community through innovative online technology. Online Farm Trials is designed to provide growers with the information they need to improve the productivity and sustainability of their farming enterprises.

Using specifically developed research applications, users are able to search the Online Farm Trials database to find a wide range of individual trial reports, project summary reports and other relevant trial research documents produced and supplied by Online Farm Trials contributors.

The Online Farm Trials website collaborates closely with grower groups, regional farming networks, research organisations and industry to bring a wide range of crop research datasets and literature into a fully accessible and open online digital repository.

Individual trial reports can also be accessed in the trial project information via the Trial Explorer.

The link to the Online Farm Trials is http://www.farmtrials.com.au/

Key contacts

GRDC Panel

John Minogue, Chair

John Minogue runs a mixed broadacre farming business and an agricultural consultancy, Agriculture and General Consulting, at Barmedman in south-west NSW. John is chair of the local branch of the NSW Farmers' Association, has formerly sat on the grains committee of the NSW Farmers' Association and is a winner of the Central West Conservation Farmer of the Year award. John has also been involved in the biodiversity area as a board member of the Lachlan Catchment Management Authority. His vast agricultural experience in central west NSW has given him a valuable insight into the long-term grains industry challenges.

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Penny Heuston, Deputy Chair

Penny Heuston is an agronomist based in Warren, NSW. She is passionate about the survival of the family farm and its role in the health of local economies. Penny is dedicated to ensuring research is practical, farm-ready and based on sound science and rigour. She sees 'two-way communication' as one of the panellists' primary roles and is committed to bringing issues from the paddock to 'the lab' and conversely, the science to the paddock.

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Loretta Serafin

Loretta Serafin has extensive experience as an agronomist in north-west NSW and works with the NSW Department of Primary Industries in Tamworth. As the leader northern dryland cropping systems, she provides expertise and support to growers, industry and agronomists in the production of summer crops. Loretta is a member of numerous industry bodies and has a passion for helping growers improve farm efficiency. She sees her role as a conduit between advisers, growers and the GRDC to ensure growers' research needs are being met.

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Jules Dixon

Jules Dixon has an extensive background in agronomy and an established network spanning eastern Australia and WA including researchers, leading growers and agronomy consultants through to the multinational private sector. Based in Sydney, Jules operates a private consultancy specialising in agronomy, strategy development and business review.

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Dr Neil Fettell

Neil Fettell is a part-time senior research adviser with Central West Farming Systems and runs a small irrigation farm near Condobolin, NSW. Neil has a research agronomy background, conducting field research in variety improvement, crop physiology and nutrition, Water Use Efficiency and farming systems. He is a passionate supporter of research that delivers productivity gains to growers, and of grower participation in setting research goals.

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Andrew McFadyen

Andrew McFadyen is an agronomist and manager with Paspaley Pastoral Company near Coolah, NSW, with more than 15 years' agronomy and practical farm management experience. He is an active member of the grains industry with former roles on the Central East Research Advisory Committee, NSW Farmers Coolah branch and planning committees for GRDC Updates. He is also a board member and the chair of Grain Orana Alliance.

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Jack Williamson

Jack Williamson is a private agricultural consultant and helps run a family broadacre farm near Goondiwindi, Queensland. Six years of retail agronomy and three years of chemical sales management have given Jack extensive farming systems knowledge, and diverse crop management and field work experience. He is a member of the Northern Grower Alliance local consultative committee and Crop Consultants Australia.

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Arthur Gearon

Arthur Gearon is a grain, cotton and beef producer located near Chinchilla, Queensland. He has a business degree from the Queensland University of Technology in international business and management and has completed the Australian Institute of Company Directors course. He is vice-president of AgForce Grains and has an extensive industry network throughout Queensland. Arthur believes technology and the ability to apply it across industry will be the key driver for economic growth in the grains industry.

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Dr Tony Hamilton

Tony Hamilton is a grower from Forbes, NSW, and managing director of an integrated cropping and livestock business. He is a director of the Rural Industries Research and Development Corporation. He has worked as an agricultural consultant in WA and southern NSW. With a Bachelor of Agricultural Science and a PhD in agronomy, Tony advocates agricultural RD&E and evidence-based agriculture.

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Brondwen MacLean

Brondwen MacLean was appointed to the Northern Panel in August 2015 and is the GRDC executive manager for research programs. She has primary accountability for managing all aspects of the GRDC's nationally coordinated R&D investment portfolio and aims to ensure that these investments generate the best possible return for Australian grain growers. Prior to her current appointment, Brondwen was senior manager, breeding programs, and theme coordinator for Theme 6, Building Skills and Capacity.

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David Lord, Panel Support

David Lord operates Lord Ag Consulting, an agricultural consultancy service. Previously, David worked as a project officer for Independent Consultants Australia Network, which gave him a good understanding of the issues growers are facing in the northern grains region. David is the Northern Panel and Regional Grower Services support officer.

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