Department of Primary Industries

Summer crop management guide 2019

NSW DPI MANAGEMENT GUIDE

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Front cover main photo: 2017 Jade-AU⚘ irrigation experiment at Breeza; insets: Jade-AU⚘ at various growth stages. Photos: Kathi Hertel, NSW DPI.

Plant Breeder's Rights

Throughout this guide, varieties protected under Plant Breeder's Rights (PBR) legislation are signified by the symbol ⚘

Plant Breeder's Rights are exclusive commercial rights to a registered variety. In relation to propagating material of the registered variety, the breeder has exclusive rights to:

- **a** produce or reproduce the material;
- **b** condition the material for the purpose of propagation (conditioning includes cleaning, coating, sorting, packaging and grading);
- **c** offer the material for sale;
- **d** sell the material;
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- **f** export the material; and
- **g** stock the material for any of the purposes described in (a) to (f).

In most instances the breeder will licence these rights to a selected seed company (the licensee).

Exceptions to breeder's rights are the rights of farmers to save seed for sowing future commercial crops. However harvested material derived from farm saved seed will be subject to the End Point Royalty (EPR) applying to that variety.

Where EPRs apply, growers will be required to enter into arrangements with the breeder or licensee whereby royalties are paid on delivery of the grain. Some varieties may have a Seed Royalty (SR) paid on purchase of seed rather than an EPR.

Royalties collected are used to support ongoing research and the breeding of new and improved varieties.

Always read the label

Users of agricultural chemical products must always read the label and any permit before using the product and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from any compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.

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Introduction

Crop rotation is important for spreading the financial risks associated with seasons and markets; summer cropping is playing an increasing role in today's farming systems. Excluding cotton and rice, in 2018–19 sorghum accounted for 75% of the summer crop area planted in NSW.

Mixing summer and winter cropping is recognised for improving cash flow and reducing the overhead costs for small–mid size enterprises. Spreading the workload throughout more of the year achieves greater productivity from machinery and labour resources.

Seasonal variability, such as spring rainfall, means farmers can take advantage of good conditions. An early planting opportunity could mean the difference between being able to plant or not plant a summer crop.

These opportunity-based systems, which include a broader crop selection, are now replacing fixed cropping systems thanks to our improved knowledge about the added agronomic value from rotations.

Research topics and trials have included ways to:

- reduce disease severity
- lower herbicide resistance risks
- control hard-to-kill weeds
- maintain arbuscular mycorrhizae fungi levels – AMF (a symbiotic process allowing plants to capture nutrients)
- use legumes as an alternative source of nitrogen.

Summer crops add flexibility to the summer cropping program, for example:

- sunflower can be planted 4–6 weeks earlier than sorghum
- legumes fix their own nitrogen
- mungbean's relatively short cropping period allows a double crop in a good season
- maize is an excellent source of silage as well as grain; there are hybrids adapted to locations across the state
- maize and soybean have human consumption markets providing an opportunity to diversify farm income.

This publication contains information to help growers make key agronomic decisions for producing grain sorghum, maize, mungbean, soybean and sunflower. Where possible, recommendations for both dryland and irrigated production systems have been included. Each crop covers the following topics:

- paddock selection
- sowing time
- plant population
- row spacing
- hybrid or variety characteristics
- nutrition
- subsoil constraints
- irrigation
- weed management
- diseases and insect pests
- harvest and marketing

A summary at the back of this guide on safe storage requirements for summer grains and receival standards for their delivery into various market segments.

For readers new to summer cropping, descriptions of the growth stages that underpin many of the agronomic recommendations have been included. Sources of further information are also listed at the end of each section.

The *Summer crop management guide* aims to provide the latest commercial information relevant to variety selection, together with agronomic recommendations, in an easy to use format and is available both in hard copy and on the DPI website.

The authors hope you find this publication to be a valuable resource and welcome feedback on opportunities for its improvement in the future.

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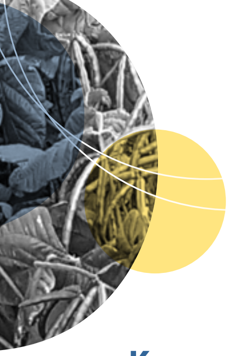

Grain sorghum

Key management issues

- Use no-till farming for dryland crops to increase fallow soil moisture storage and seedbed moisture retention.
- Set a target yield based on moisture availability, seasonal outlook and local yield expectations.
- Match the plant population and row spacing to the target yield. Plant uniformity is critical.
- Use nitrogen fertiliser rates based on target yields, soil tests and/or previous crop yields and protein levels.
- Use effective weed control, especially for grasses.
- Check previous herbicide applications for potential residues or plantback issues to avoid the risk of herbicide damage.
- Select at least two high-yielding hybrids that have the desired characteristics for your conditions to spread production risk.
- To reduce the risk of ergot in northern NSW, plant crops so that they complete flowering by mid March.
- Most areas have wide planting windows. Avoid planting too early (potential exposure to frost) or too late (potential exposure to ergot and frost). Aim to plant so that flowering does not coincide with the extreme heat in late December and January.
- Monitor (and if necessary control) insects, especially wireworms (planting), midge, heliothis and Rutherglen bug (flowering–grain fill).
- Use registered knockdown herbicides at physiological maturity to hasten dry down, improve harvesting and start the fallow recharge.
- Be prepared to dry grain from late-sown crops.

Brief crop description

Grain sorghum is the dominant summer crop grown in New South Wales (NSW), with the bulk of the crop grown in northern NSW (Table 1). The area planted with sorghum in NSW has been 110,000–120,000 ha in the past two seasons; drought conditions have reduced the long-term average. Smaller areas of sorghum are grown in the central west of NSW and the southern irrigation areas. Being a sub-tropical (C4) plant, sorghum is susceptible to frost. Sorghum is well suited to inland farming systems as it responds very well to no-till farming systems on the deep vertosols of the plains and the duplex red soils (often chromosols) of the slopes.

The current range of hybrids ensures robust tolerance to disease and insect pests and makes sorghum an excellent break crop in rotations, particularly from crown rot (*Fusarium pseudograminearum*).

Grain sorghum is used domestically for livestock feed in the beef, dairy, pork and poultry industries as a source of both starch and protein. There is also an increasing human consumption market, and interest in sorghum as a source for ethanol production continues to grow.

Table 1. NSW grain sorghum production.

Region	2016–2017			2017–2018		
	Area (ha)	Average yield (t/ha)	% of NSW production	Area (ha)	Average yield (t/ha)	% of NSW production
North west	101,351	3.3	86.5	84,729	2.7	78.2
Central Tablelands	100	6.5	0.08	95	5.0	0.08
Central west	10,706	2.4	9.1	15,857	2.0	14.6
Murray	124	5.0	0.1	163	4.7	0.15
Riverina	974	7.0	0.83	1,764	2.0	1.63
Northern Tablelands	2,469	4.6	2.1	5,731	2.7	5.3
State total	**117,124**	**3.3**	**–**	**108,340**	**2.6**	**–**

Source: Australian Bureau of Statistics, Agricultural Commodities, State and NRM region –2016–17 and 2017–18.

Paddock selection

The majority of sorghum crops are planted using no-till or minimum-till methods following a long fallow from a winter cereal. Alternatively, sorghum can be sown into a field that had sorghum the previous summer, in which case the fallow period is around seven months. Only in years of above-average rainfall should sorghum be double cropped in northern NSW, where it can be planted directly following harvest of a winter cereal or a pulse crop. Successful sorghum crops have been grown immediately after winter crops provided the soil water profile is full to a depth of one metre.

Be cautious when growing sorghum crops immediately following canola or Indian mustard. These brassica crops do not host arbuscular mycorrhizal (AM) fungi levels and so act like a long fallow. They also leave the soil profile very dry. It has also been discouraged because of the antagonistic effect these crop residues were thought to have on sorghum germination, establishment, growth and yield. However, research conducted within the northern cropping region of NSW failed to validate this claim. Further research is currently underway with the Northern Grower Alliance (NGA) and preliminary results have supported the previous observations of ill thrift, delayed head emergence and reduced yields in sorghum as a result of previous brassica crops. Reduced levels of AM fungi were also measured in the fallow following canola, as opposed to durum wheat. Adding starter fertiliser did not alter these responses.

No-till and minimum-till are well established farming practices in the northern grains region. Grain sorghum grown under no-till farming systems has been shown to consistently yield approximately 0.5–1.0 t/ha more than sorghum grown under conventional tillage systems, because no-till fallows store an extra 30 mm of plant available water (PAW) on average, provided adequate weed control is maintained. Cereal stubble also provides high levels of ground cover and maximises protection against soil erosion in predominantly summer rainfall environments. Using no-till and minimum-till fallows enables crops to be planted for up to seven weeks after rain as moisture retention in the seeding zone is greater. This widens the planting window, increasing the likelihood of planting at an optimum time. It can also mean the difference between planting a crop or not.

Occasional cultivation can sometimes be beneficial without having a negative effect on soil biological activity, organic matter levels or crop yield. Targeted cultivation in a no-till farming system has proven to be effective for:

- controlling herbicide-resistant weeds
- cereal stubble breakdown
- amelioration of soils that have been compacted following wet harvests.

These beneficial effects can be observed, provided the cultivation occurs immediately following the preceding crop's harvest, to maximise the opportunity for soil water storage during the fallow period. Fallow weed control within minimum and no-tillage systems uses knockdown and residual herbicides. It is crucial to ensure that before planting sorghum into fallowed fields appropriate plantback guidelines are followed (the time that has elapsed between spraying and planting), otherwise poor establishment and crop injury will result. Herbicide manufacturers often specify both a specific number of days and a rainfall requirement before the plantback period begins. Sorghum growers need to be aware that there might be a limit to the quantity of a specific herbicide product that can be applied within a year (i.e. atrazine) without causing harm to the sorghum crop. Further, rules for using some products differ according to the presence or absence of irrigation and the application method, be it aerial or ground.

Paddocks with poor grass weed control are not suited to sorghum. Sorghum is a member of the Poaceae family, as are all grasses. This means that in-crop chemical weed control options for grasses are limited. In contrast, broadleaf weed control options are greater.

Sorghum is resistant to the *Pratylenchus thornei* species of root-lesion nematodes. Resistance is defined as reduced levels of *P.thornei,* as well as inhibited reproduction within the soil. No negative symptoms are exhibited by sorghum planted into fields containing high *P. thornei* numbers. Sorghum resistance to *P. thornei* is therefore an effective management strategy to reduce nematode numbers, which can ultimately reduce *P. thornei* effects on intolerant crops in the rotation, such as wheat and chickpea. It should be noted that sorghum is susceptible to *P. neglectus,* meaning the same benefit is not evident where this pathogen is present.

Starting soil water

Knowing the soil moisture status at critical crop growth stages can help producers make appropriate decisions regarding fallow length, crop choice and input investment to optimise production and improve profitability.

Planting sorghum into paddocks with less than 1 m of wet soil reduces the likelihood of high yields, increases crop failure risk and places a greater reliance upon in-crop rain to produce an economic yield. Crop failure risk increases as you move further west where average rainfall is lower and temperatures are higher.

Crops planted in heavy clay soils with 1.5 m of wet soil that receive 100 mm of effective in-crop rainfall should yield about 3.5 t/ha. However, crops starting with 1 m of wet soil that receive 50 mm of effective rain will only yield about 1.3 t/ha. Sorghum can produce grain at an approximate rate of 15 kg/ha/mm of available soil water and in-crop rainfall.

Planting time

Sorghum should be planted when the soil temperature at seed depth (about 3–5 cm) is at least 16 °C (preferably 18 °C) at 8 am AEST and when frost risk has passed. This temperature should be recorded for 3–4 consecutive days. Planting into cold soil (<12 °C) slows germination and emergence, and can reduce establishment depending on the conditions. Cold soils also increase the crop's susceptibility to seedling blight. Recent research has been successfully trialling sorghum establishment at 14 °C, however, additional research is needed to determine the practice's suitability where the young crop is exposed to frosts.

Low soil and air temperatures slow plant growth and reduce nutrient uptake, particularly phosphorus, which can induce purpling in some hybrids. Paddocks that are planted very early in the season are more likely to need replanting. Some hybrids do have better cold tolerance than others; research is under way to better quantify this tolerance.

The preferred planting time for the Moree and Narrabri districts is late August through to early October. For the Gunnedah, Inverell and Tamworth districts, mid October to late November is the preferred planting time (**Table 2**).

Planting at the beginning of these windows often minimises plants being exposed to moisture and heat stress during flowering. Crops that are planted early are more likely to be exposed to cold conditions, particularly during August, where soil temperatures tend to flutuate more.

Growers are advised to complete planting by early January in the north-western slopes and Liverpool Plains so that crops finish flowering by mid to late March, which might reduce the risk of sorghum ergot infection. Midge-resistant hybrids planted in January with good soil moisture and nutrition still have good yield potential, despite being slower to dry down. Planting in January means the crop will need to establish in hot soil temperatures, which can reduce establishment.

Generally, the earlier that sorghum is planted in recommended windows, the better. Planting sorghum at the beginning of the window minimises the probability of moisture and heat stress during the critical flowering and grain-fill periods. In addition, early planting is a recommended strategy to avoid sorghum midge and allows producers the option to double-crop should there be sufficient rainfall. Sorghum midge adults emerge from the overwintering diapause in spring and produce larvae that feed on the developing sorghum grain ovaries. Early planting is a recommended preventative measure for sorghum midge in combination with a midge resistant hybrid.

A compromise must therefore be made between planting sorghum early and avoiding excessively cool soil and air temperatures and planting late when soil temperatures are hotter and crop drydown is slow. Early planting reliability might be improved by using varieties that show cold tolerance, using fungicidal/insecticidal seed dressings and shallow planting with a disc planter.

If ergot avoidance is a major consideration, the planting date should be adjusted to ensure that flowering does not occur while temperatures are <13 °C, as these conditions are most conducive to infection. This can be achieved by having sorghum planted by early January so that flowering will have finished by mid March, before temperatures cool. Some hybrids also have poor pollen viability at these temperatures.

Table 2. Suggested planting times for sorghum in NSW.

Region	Early planting										Late planting													
	Aug		Sept				Oct				Nov				Dec				Jan				Feb	
	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
North-western plains	<	★	★	★	★	★	★	★	★	★	>				<	<	★	★	★	★	>			
North-western slopes, Liverpool Plains							<	★	★	★	★	★	>		<	★	★	★	★	>				
Central west									<	★	★	★	★	★	>									
Southern irrigation areas									<	★	★	★	★	★	>									

< Earlier than ideal, but acceptable
★ Optimum planting time.
> Later than ideal, but acceptable.

Row spacing

Solid plant rows (75 cm or 100 cm) out-yield skip row or wide rows (150 cm) under good growing conditions. Solid plant rows are therefore more appropriate in high-yielding dryland environments and with irrigated crops. While 75 cm is the most common row spacing in high yielding dryland environments, narrow row spacings (50 cm or less) are also used successfully.

Research at Moree in north-western NSW has shown that once yield potential is above 3.5–4.0 t/ha, there are significant advantages of 100 cm solid plant rows over single and double skip configurations. This research showed that solid plant row spacings of 100 cm can yield up to 50% more than double skip configurations in very favourable seasons when yield potential is as high as 6 t/ha.

Skip rows are useful for conserving water during the vegetative stage of crop growth, which can be used at flowering and grain fill. The term 'skip row' indicates that the row configuration is changed by skipping, or not planting rows. Alongside sorghum, this skip row management strategy has also been used with peanuts, cotton and maize. Table 3 shows descriptions of row configurations (commonly used) for sorghum and other crops such as cotton.

Table 3. Row configurations used to plant sorghum.

Row configuration	Rows planted
0.75 m or 1.0 m solid plant	All rows planted on 0.75 m or 1.0 m row spacing
1.2 m or 1.5 m solid plant (also referred to as super wide)	All rows planted on 1.2 m or 1.5 m row spacing
Single skip	Two rows planted, one row unplanted (1.0 m)
Double skip	Two rows planted, two rows unplanted (1.0 m)

The advantages of solid row configuration decrease rapidly as planting soil moisture profiles decline, especially in more marginal areas. Table 4 is a useful guide to determine which row spacing is more appropriate for a specific target yield in dryland systems. In more marginal western dryland areas, wider rows or skip rows are preferred to decrease yield variability and greatly reduce the risk of crop failure. Double skip configurations, while being a very safe option, can yield significantly less in seasons where yields are above 3.5 t/ha.

Agronomic management is very important if sorghum is planted on wide or skip row configurations. Plant population should be the same as when solid plant configuration is used – same plants/ha. Uniform plant establishment within rows will maximise the water use between the wide rows; good stubble management (ground cover) is necessary to reduce water and soil loss in the skip areas. Effective weed control before and during the season is critical, otherwise the advantages from the wider rows will be lost. Wide rows can also allow inter-row cultivation or shielded spraying for weed control.

Sorghum planted using wide or skip row spacings might have a lower risk of pest problems (midge), lower herbicide costs (less herbicide is required) and promotes a more uniform flowering and dry-down time. This improves harvestability.

The yields from skip row spacings in wet seasons are less than solid plant configurations. Research shows that in some instances where chickpeas are double cropped following skip row sorghum, the gross margin is higher than where the chickpeas are double cropped out of solid plant sorghum. These results will depend on the summer and winter seasonal conditions as well as the relative crop commodity prices.

Table 4. Row spacing and expected yield.

Expected yield	Optimum row spacing
Above 4 t/ha	≤0.75 m solid plant
3–4 t/ha	≤1.0 m
Below 3 t/ha	≥1.0 m or skip rows

Plant population

A uniformly established plant population is very important. The targeted plant population can vary depending on the depth of soil moisture at planting and the likely growing conditions (Table 5). Under high yielding dryland situations, low tillering hybrids should be planted at slightly higher populations.

Growers should consider re-planting when populations are less than 15,000 plants/ha, especially with quick maturity or low tillering hybrids. There will be significant yield penalties if there are insufficient plants to optimise grain production. High tillering hybrids might be able to compensate for low plant density.

In skip row configurations, aim for plant populations that are the same as the plant populations used for solid plant stands.

When calculating planting rates, it is recommended to increase your rate by up to 20–25% to allow for establishment losses. When planting into good seedbed moisture on a heavy black soil using press wheels, the establishment percentage can be reduced. Extremes in soil temperature and moisture can reduce establishment as can poor seed placement. Ensure you check the number of seeds per kilogram and the germination percentage from the merchant where you purchased the seed.

To determine the planting rate (kg seed/ha) for an airseeder:

$$\frac{\text{Target number of plants/m}^2 \times 10{,}000}{\text{Seeds/kg} \times \text{germination percentage} \times \text{establishment percentage}} = \text{Planting rate (kg seed/ha) for an airseeder}$$

Example calculation:

$$\frac{4 \times 10{,}000}{30{,}000 \times 0.9 \times 0.75} = 1.98 \text{ kg/ha}$$

Table 5. Recommended sorghum plant populations.

Growing conditions	Target population/m²
Dryland	
Good conditions	4–6
Marginal conditions	3–4.5
Irrigation	
Supplementary	5–10
Full	10–15

Crop establishment

Apart from moisture stress, poor crop establishment and weed competition are usually the major factors that significantly reduce yields. The following recommendations will help to improve crop establishment and crop yields.

1. Accurate seed placement and planting depth is critical to ensure uniform establishment; precision planters achieve both. Planters should be able to follow the paddock undulations with tynes or discs mounted on parallelogram planter units. Seed size also needs to be checked to ensure there are no misses or double/triples on the planter seed-plates.
2. Narrow points or discs are better suited to no-till and minimum-till conditions and work very well in free-flowing soils. Excessive planting speeds reduces establishment rates.
3. In moist seedbeds the seed should be placed about 3–5 cm deep or slightly deeper in summer planting or when the seedbed is likely to dry out quickly. In dry seedbeds where moisture seeking is used, create a deep furrow up to 10–12 cm to place the seed into a moist seedbed. However, the seed should still only be covered by 5 cm of soil, and the remaining 5–7 cm will be an open trench.

4. Press wheels are essential; they improve establishment and help control soil insect pests, including true and false wireworms.
   - **Conventional seedbeds:** use press wheel pressures of 4–6 kg/cm (across the press wheel width).
   - **No-till and minimum-till seedbeds**: use press wheel pressures of 6–10 kg/cm (across the press wheel width).
   - **When planting moisture is marginal, seed is planted deep or soil insects are present**: use pressures towards the top of the range.
   - **When soils are hard setting or surface crusting**: use pressures towards the bottom of the range.

Crop establishment is improved when the press wheel shape matches the shape of the seed trench.

Hybrid characteristics

Selecting the right hybrid will depend on the location and the forecast seasonal conditions. Growing two or three hybrids with slightly different characteristics can help spread production risk. Table 6 lists the hybrid characteristics of commercially available varieties in NSW in 2019–20, which might help you choose suitable hybrids for your area.

In recent years, a number of new companies have entered the sorghum market such as Elders and Radicle Seeds. Most have currently available commercial hybrids. However, other companies are still evaluating hybrids at this stage for potential release in 2020–21. S&W Seed Company is assessing a number of grain sorghum lines, both in small plot replicated trials and farmer demonstrations, as well as providing material to the grain sorghum National Variety Trials (NVT) program. S&W indicate that several lines have shown promise; however, these lines have not yet been named or released at the time of publication. Growers are advised to access each company's website or speak to their representative for additional hybrid details and for information on new releases each season.

Hybrid maturity

Select hybrids with a maturity that is suitable for local climatic conditions.
- **North-western slopes and Liverpool Plains**: With good to average dryland conditions, medium to medium–slow maturity hybrids are recommended.
- **North-western plains**: medium to medium–quick hybrids are recommended, depending on subsoil moisture storage.
- **Under irrigation**: hybrids with longer maturity and therefore higher yield potential are best.

In northern NSW, from planting to the start of flowering:
- quick maturity hybrids take about 66 days
- medium maturity hybrids take about 73 days
- slow maturity hybrids take about 80 days.

The time a hybrid takes to flower depends on temperature. At Moree, for example, medium-maturity hybrids planted in early October take about 80 days to flower, but only take about 60 days when planted in mid-November. At Spring Ridge, medium maturity hybrids planted in early November flower in about 80 days compared with 65 days if planted in late November.

Yielding ability

Choose hybrids that have a high yielding ability under a range of seasonal conditions and grow more than one hybrid each season. Trial hybrids over several seasons and grow those that perform best on average. Use the results of hybrid evaluation trials where available as a guide.

Lodging and disease resistance

Lodging can be a problem in all dryland growing areas. Select hybrids with good lodging resistance, especially where moisture stress is likely during the latter stages of grain fill. Crops that remain green and have access to available soil moisture during grain fill are generally less prone to lodging.

Moisture stress is the most common cause of lodging. Moisture stress also predisposes the crop to infection and rapid colonisation by *Fusarium* and charcoal stem rots. These are also associated with lodging, leading to plant death and

Table 6. Sorghum hybrid characteristics 2019–20.

Company	Hybrid	Maturity	Estimated days to 50% flower	Height	Standability	Sorghum midge#	Staygreen (L, M, H)	Head type	Tillering (L, M, H)	Irrigation suitability
Nuseed	Cracka	M	68-78	S-M	5	3	L	SO	M-H	YES
	Rippa	MS	70-80	S-M	4	5	L	SC	H	YES
	Liberty White	MS	70-80	MT	4	4	L	SO	H	YES
Pacific Seeds	MR Bazley	MQ	65-75	S-M	5	4	ML	SO	H	YES- limited
	MR Taurus	MQ	66-74	M	5	6	ML	SO	M	YES
	MR Buster	M	69-77	S-M	5	4	ML	SO	M-H	YES
	Sentinel IG*	M	69-77	MT	4	5	L	SC	H	YES
	Resolute	M	70-80	M	5	8+	ML	O	M	YES
	Halifax	MS	72-82	M	5	7	ML	O	M	YES
Pioneer	A66	M	66-77	M	5	7	L-M	SO	M	YES
	A75	M	70-79	M	5	6	L	SO	H	YES
	85G33	MQ	65-76	S-M	5	6	L-M	SO	M-H	YES
Heritage Seeds	HGS 747	MQ	66-74	S-M	5	5	M	O	M	YES
	HGS 114	M	67-79	M	5	7	M	SO	ML	YES
Radicle Seeds	AGITATOR	MQ	65-75	M	5	4	M	O	L	YES
	BRAZEN	MS	70-80	M	5	5	M	O	VL	NO
Elders	ARCHER	MQ	62-72	M	4	6	M	O	L	YES

\# Midge rating is the factor by which a hybrid's midge resistance exceeds that of a fully susceptible hybrid (rating 1). For example, if it is cost effective to control 2 midges/head in a rating 1 hybrid, then cost effective control in a rating 7 hybrid occurs when there are 14 midges/head.

* Sentinal IG is igrowth. This is Pacific Seeds' world first imidazolinone tolerant train for grain sorghum hybrids.

Maturity
MQ Medium quick
M Medium
MS Medium slow

Height
S Short
M Medium
MT Medium tall

Standability
1 Poor
2 Fair
3 Good
4 Very good
5 Excellent

Midge resistance
1 Susceptible
2 Low
3 Moderate
4 High
5 Very high
6 Excellent
P Preliminary

Staygreen
L Low
M Medium
H High

Head type
O Open
SO Semi open
SC Semi compact
C Compact

Tillering
VL Very low
L Low
M Medium
H High

Irrigation suitability
Company recommendations

The information presented in this table was kindly supplied by seed companies and is not based on DPI data. Only varieties commercially available in NSW are listed. Consult seed companies before final selection of sorghum hybrids for particular markets and for particular localities.

considerable yield loss. Agronomic practices such as no-till, stubble retention and controlled traffic farming all aim to store more fallow and in-crop rainfall. This will help reduce lodging. Using wide or skip rows, especially in the north-western plains, will also help. These practices allow medium-maturity hybrids with higher yield potential to be grown.

Lodging is rarely a problem in fully irrigated crops, but can occur in partially irrigated crops that are stressed during the later stages of grain fill or following desiccation.

Sorghum midge resistance

Most hybrids have some level of resistance to sorghum midge. The industry testing group (comprising DAFF Qld and seed companies) assess newly released hybrids for midge resistance. Midge resistance ratings are listed in Table 6 and control thresholds in **Table 11**. Resistant hybrids have significantly reduced the need to spray for midge. The highest midge rating is 8+.

Organophosphate insecticide reaction

Some hybrids have a phytotoxic reaction to organophosphate (OP) insecticides. This causes a range of symptoms from spotting to intense purpling of leaves and stems. When crops are likely to be sprayed with OP insecticides, growers are advised to grow OP-tolerant hybrids and consult with seed companies for hybrid ratings.

Growth stages

Sorghum is a perennial tropical grass with a growing season between 115 days and 140 days. The rate of growth depends strongly on hybrid genetics, temperature and moisture. Soil fertility, insect and disease damage can also be an influence.

Germination and establishment

Emergence usually occurs within three and 10 days of planting under warm temperatures, adequate soil moisture, good seed vigour and suitable planting depth. Sorghum has hypocotyl emergence, meaning a shoot emerges from the seed and pushes through the soil surface.

Sorghum planted into slightly cooler soil will delay emergence by a couple of days. Under cold soil temperatures, it takes longer for the shoot to emerge and the risk of insect or disease damage is higher. Research has shown that it can take up to 49 days for seedlings to emerge when soil temperatures at planting are <10 °C at 8 am EST due to the high amount of diurnal fluctuation. Emergence did not occur until temperatures increased sufficiently for seedling growth.

Vegetative development

Following shoot emergence, leaves will progressively unfold. The first leaf can be easily identified as it has a rounded tip instead of a pointed tip. The growing point remains below ground until approximately 30 days after emergence, at which point the plant changes from vegetative to reproductive growth. The root system will grow at a rate of around 2.5 cm/day to a maximum depth of about 1.8 m.

Reproductive development

Leaves will continue to unfold until the flag leaf has emerged. At this time, around 80% of the total leaf area has developed. The head will form within the flag leaf sheath and continue to be pushed upwards until it becomes visible. Flowering then starts, beginning at the top of the head and moving downwards over 4–5 days.

Once pollinated, seeds will begin to form, taking around 30 days to reach full development. Visually, the seeds become rounded, up to around 4 mm in diameter before starting to change colour. The final colour varies from white with hybrids such as Liberty White, through to red or brown in most sorghum hybrids.

Physiological maturity to harvest

Sorghum grain is said to be physiologically mature when a black spot appears at the point where the seed attaches to the plant. At this time, the seed is fully mature and will not gain any more nutrients or moisture from the plant. The seed moisture content is usually around 30% at this time. If desiccating a crop, this is the optimum time to apply a registered herbicide to kill the plant, preventing additional soil moisture uptake.

The length of time between physiological maturity and harvest depends on a number of factors including whether desiccation is used and environmental conditions such as temperature.

Nutrition

Nitrogen (N)

Of all the nutrients, sorghum is most responsive to N application; numerous trials across northern NSW have demonstrated the yield benefits. An N response will not occur in soils known to be N deficient, if water or concentrations of other nutrients such as phosphorus (P), potassium (K) and sulfur (S) are limiting. Therefore, it can be uneconomical to apply N without knowing about the PAW or concentrations of other major nutrients in the soil.

Nitrogen is best applied either pre-plant or at the time of planting in the northern cropping region as the opportunity to apply N in crop is risky due to variable in-crop rainfall. Post-emergence N application can still contribute positively to yield if it is applied before the seven-leaf stage. If N application is delayed beyond this, a greater proportion ends up contributing to grain protein. Growers are not paid for higher protein, so it is difficult to justify a return on investment for late N application.

Rates of 100–150 kg/ha of N are commonly applied to crops grown after winter cereals on the Liverpool Plains that have a potentially high yield. Nitrogen is a large proportion of input costs, however, its use is justified.

A balance must be found between sufficient N application to maximise yield and avoiding excess application, which leads to increases in grain protein content but not yield. **Table 7** shows suggested rates of N fertiliser that incorporate the N effect from the previous crop for dryland and irrigated crops respectively. However, soil testing and completing an N budget are the more accurate and preferred methods for determining N application rates.

The contribution that a pulse crop or pasture makes to soil N largely depends on the quantity of dry matter the pulse crop produces and the nodulation levels. Grasses present in the crop or pasture can also use any N that was fixed. As a guide, compared with a previous sorghum crop, cowpea and mungbean crops can leave up to 40 kg/ha of soil N, while soybean and pigeon pea can leave 25–50 kg N/ha.

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Sorghum planted following lucerne pastures can produce higher yields than sorghum planted following cowpea or long fallow, based on the N supplied. This will depend on the soil water profile having re-filled following lucerne.

Table 7. Nitrogen rates (kg N/ha) for sorghum, as influenced by crop rotation on the Liverpool Plains.

Previous crop	Dryland sorghum target yield		Irrigated sorghum
	4 t/ha	6 t/ha	
Sorghum, sunflower, cotton	100	140	180
Cowpea, mungbean	60	120	–
Soybean	–	–	100
Long fallow winter cereal	80	120	150
Long fallow faba bean	30	90	120
Long fallow chickpea	45	100	–
Lucerne (good stand)	0	0	–

Nitrogen budgeting is used to determine a crop's N requirements and can be calculated using the formula below. The quantity of N required to grow the crop is about twice the quantity removed in the grain.

Calculating nitrogen requirement

Target yield (t/ha)		Grain protein %		1.6 (conversion factor)		2 (N use efficiency)		N required for the crop
............5...........	×	........10........	×	..........1.6..........	×	.........2.........	=	...160 kg...

|______ N removed in grain ______| |___ N required for crop ___|

Using the above example, if only 80 kg/ha of nitrate N was available in the soil, a further 80 kg N/ha would be needed.

A crop's N uptake comes from the available soil nitrate N and from fertiliser N. Estimate soil nitrate N by soil testing to 100 cm depth (or deeper) and from the paddock's cropping history, especially the previous crop's grain yield and protein content. More N will be mineralised from organic matter throughout the season and become available to the crop for uptake. The mineralisation rate is determined by several factors such as soil temperature, moisture and type of organic material. The possible mineralised N is not included in these calculations.

Once a crop's N requirement is known, the amount of N that already exists within the soil can then be subtracted to estimate the quantity of N that must be applied to produce a crop with the target grain protein content and target yield.

The grain protein content is a good indicator of how adequate the N supply is to a crop (Table 8).

Maximum yield is thought to be achieved when grain protein content is between 9% and 10%. At lower protein contents, the crop is considered to have been N deficient, while at higher levels, crop N availability is considered excessive.

Table 8. Crop N status as indicated by grain protein % (at a given moisture %).

Indicated N supply	Grain protein %		
	Wheat (12% mc)	Barley (10% mc)	Sorghum (13.5% mc)
Acute N deficiency. Yield will increase with added N.	<11.5%	<11%	<9%
Marginal N deficiency. Probable yield increase with added N.	11.5–12.5%	11–12%	9–10%
N not limiting. Additional N will increase grain protein but not yield.	>12.5%	>12%	>10%

Phosphorus (P)

Sorghum is much more tolerant of low soil P levels than wheat or barley as it extracts P from the soil profile more efficiently. As a guide, sorghum crops in soils with <20–25 mg/kg P in the top 10 cm and less than 10 mg/kg in the subsoil (Colwell-P) are likely to respond to P application. However, this can also vary with soil type. BSES soil test results can also be used.

Trial work is currently underway within the northern grains region to better refine critical soil P values for vertosol soils (Table 9).

Table 9. Critical P values used to determine likely P availability response or drivers in northern vertosols.

	Surface (0–10 cm)		Subsoil (10–30 cm)	
Colwell-P	<20–25 mg/kg	Likely to get a response to starter P. Critical values might be lower in some areas.	<10 mg/kg	Likely to get a response to deep P placement, unless BSES P high.
	25–40 mg/kg	Unlikely to respond to starter P.	10–20 mg/kg	Probably no response to deep P provided soil volume is accessible to roots.
	>60 mg/kg	Ensure good groundcover to limit erosion risk!	>100 mg/kg	Unlikely to see P deficiency in your lifetime.
BSES P	<25 mg/kg	Limited evidence of residual fertiliser accumulation.	<30 mg/kg	Limited reserves of slowly available P. Consider replacement of removed P once every five years.
	25–100 mg/kg	Probably naturally high in native P minerals or accumulating fertiliser residues; limited use for replacing starter P but likely to contribute to later crop uptake if topsoil is moist.	30–100 mg/kg	A large grey area. Availability to plants will depend on solubility of native minerals. Try test strips if Colwell-P <10 mg/kg.
	>100 mg/kg	High residual fertiliser load; slowly available to surface roots.	>100 mg/kg	Potential to slowly replace Colwell-P reserves and support crop growth in large soil volumes.

*Bell et al. 2014 .

Growers are advised to conduct both Colwell-P and BSES-P tests in order to gauge soil P concentration rather than solely relying on the Colwell-P test. The test provides a measure of labile P within soil, while the BSES-P test measures both labile P and Ca-bound P.

Alkaline vertosol soils, the predominant soils within the northern cropping region, are dominated by Ca-phosphate species which are thought to contribute a significant quantity of available P to sorghum crops upon mineral dissolution. The Colwell-P test does not detect this reserve, whereas the BSES-P test does. This means that the Colwell-P test potentially underestimates P availability whilst the BSES-P test potentially overestimates it. Considering results from both tests will help farmers make decisions about P response from fertiliser application.

Sulfur (S)

Sulfur deficiency in the northern grains region soils has attracted greater attention in recent years. Sulfur should be measured to depth, in increments of 30 cm, every five years. This allows for better gypsum layer detection and potential subsoil reserves. Monitoring surface layers more frequently is also recommended. Crops in this region generally do not respond to S fertilisers unless surface soil (0–30 cm) S concentration is less than 3 mg/kg.

Zinc (Zn)

Sorghum frequently responds to Zn on heavy alkaline clay soils. Zinc-deficient soils typically have a pH_{Ca} greater than 7.5, high P levels and low organic matter content.

Good yield responses have been obtained from starter fertilisers containing 2.5 % Zn that are applied at 40–100 kg/ha. For longer term responses lasting 5–6 years, Zn oxide should be applied at approximately 15 kg/ha and incorporated into the seedbed well before planting. Foliar sprays have also become a popular option for applying Zn. Most common starter fertilisers contain some Zn.

Subsoil constraints

Subsoil salinity is reasonably common in the brown, grey and black clay soils in northern NSW. Soil salinity is the amount of dissolved salts in the soil solution.

Past research where sorghum was exposed to additional salt levels has indicated that grain sorghum tolerates salinity, but more recent research in northern NSW indicates that grain sorghum is much more sensitive to salinity than barley. In this research, plant growth and yield rapidly declined as soil salinity increased, i.e. when electrical conductivity (saturated extract – EC) increased from 2 dS/m to 5 dS/m. Anecdotal evidence from growers and agronomists supports these results; they observed reduced root exploration into layers of subsoil salinity. Consequently, PAW is reduced in a saline soil.

Subsoil sodicity is also reasonably common in northern NSW. A sodic soil has an excess of exchangeable sodium ions attached to clay particles. The excess ions affect the physical characteristics of a soil and cause soil to disperse. When a clay soil disperses with water, the clay particles swell as they are no longer bound together, resulting in minimised drainage through the soil pores (spaces). A dispersive soil sets hard, which results in crusting at the surface. Surface crusting should not restrict roots in the subsoil.

Subsoil sodicity restricts rooting depth; it restricts crop access to water and nutrients. Surface sodicity also causes surface sealing, reduced water infiltration and can cause waterlogging on the surface or inhibit emergence.

Irrigation

How much water is needed to fully irrigate a sorghum crop will vary depending on seasonal and soil conditions. However, budget on 1.4 mL/ha (delivered to the field) for one pre-irrigation and three irrigations of 1.2 mL/ha during the growing season. Time the first irrigation, in the absence of rainfall, for mid–late tillering. The second and third irrigations should be at flowering and 10–14 days later (during early grain fill) respectively. Irrigated yield potential is around 10–12 t/ha, but this is not often achieved.

Weed management

Significant yield losses occur if weeds are not controlled after planting. To effectively control most weeds, apply atrazine either before planting, at planting or immediately after planting. Apply Primextra® Gold, Dual® Gold or other S-metolachlor products as a pre-emergent spray to control grasses, especially liverseed grass. Ensure seed is treated with Concep®II seed safener when using Primextra® Gold, Dual® Gold or other S-metolachlor products.

No-till and minimum-till fallows where atrazine and glyphosate have been used should have good weed control at planting and during crop growth. These fallows conserve more soil moisture and should improve the chances of planting crops at the optimum time.

Atrazine residues prevent planting crops other than sorghum or maize for 18 months after an application of 2.5–6.5 L/ha of atrazine (500 g/L active ingredient [a.i.]), 1.4–3.3 kg/ha of atrazine (900 g/kg a.i.) or more than 3.2 L/ha of Primextra® Gold. Check the herbicide label for relevant instructions. Chemical residues can occur on soils with pH_{Ca} >7. A small field test, pot test or an analytical test should be done before planting susceptible crops. Pennisetum forages, white French millet, faba bean, chickpea and cowpea (in order of decreasing tolerance) can tolerate limited residues. Most other crops are highly sensitive.

Herbicide resistance is an emerging problem in most grain producing areas. Producers should apply their weed control accurately so that the correct application rate and timing is achieved, and herbicide groups are rotated. This is particularly important for weeds such as barnyard grass, liverseed grass, fleabane and bindweed.

The introduction of Sentinel IG, an imidazalinone tolerant hybrid, has added another weed control option for growers. This is the only hybrid where Intervix® (Group B chemistry) can be used in-crop to aid summer grass and broadleaf weed control.

Table 10. Herbicides registered for use in sorghum.

	Herbicide active	Example product	Group	Sorghum use pattern			
				Pre-plant	Post-plant/ pre-emergent	Post-emergent	Pre-harvest crop desiccation
Residual activity – check plant backs	2,4-D amine	2,4-D amine 625	I			✓	✓
	atrazine	Atrazine 500 SC	C	✓	✓	✓	
	dicamba + atrazine	Cadence® WG + Gesaprim® 600 SC	I & C	✓	✓	✓	
	Flumioxazin	Valor®	G	✓			
	fluroxypyr	Starane™ Advanced	I			✓	
	Imazamox + imazapyr	Intervix®*	B			✓	
	S-metolachlor#	Dual®Gold	K		✓	✓	
	S-metolachlor# + atrazine	Primextra® Gold	K & C		✓		
	triclopyr	Garlon® 600	I	✓		✓	
	tribenuron-methyl	Express®	B	✓			
Knockdown activity	glyphosate	Roundup® PowerMAX™	M	✓			✓
	amitrole + paraquat	Alliance®	L & Q	✓			
	diquat	Reglone®	L	✓			✓
	paraquat	Gramoxone® 250	L	✓			
	paraquat + diquat	Spray.Seed® 250	L	✓			

Use only on Concep® II treated sorghum.
* Only for use on imidazolinone-tolerant hybrids.
The empty cells indicate that the herbicides cannot be used at these stages.

Diseases

Sorghum ergot (*Claviceps africana*)

Sorghum ergot has been identified in late-flowering commercial grain crops in northern NSW. Sorghum ergot has also been detected in seed production crops in the Macquarie Valley and at Boggabri, as well as in late-flowering forage sorghum crops in the Moree and Gunnedah districts. It is difficult to estimate the effect of sorghum ergot on yields of commercial grain crops.

Symptoms

Sorghum ergot is a fungus whose spores replace pollen in flowering sorghum heads. Ergots produce creamy coloured sclerotia, usually smaller than sorghum seed, that replace the developing seed. It also produces a sticky honeydew.

Conditions favouring development

The fungus infects sorghum heads at flowering. Mild temperatures (15–30 °C), high humidity and overcast conditions are ideal. Ergot spores replace the pollen in unfertilised florets, decreasing grain set and potential yield.

Management

To reduce the risk of ergot in northern NSW, plant crops by early January so that they flower by mid March when the weather is hotter and drier than it is in autumn.

Crops with poor pollination risk the same infections as forage sorghum crops, tillers of late flowering plants, late sown grain crops and those exposed to cold temperatures during flowering.

Sorghum ergot produces sticky honeydew that can delay harvest by clogging machinery. At levels higher than 0.3% by weight, sorghum ergot is toxic to livestock. If ergot levels are less than 0.3% by weight, the grain is within safe usage levels for many end-users.

Leaf rust (*Puccinia purpurea*)

Leaf rust is a serious disease in susceptible hybrids, particularly in humid coastal areas. The incidence of leaf rust in northern NSW has been variable in recent years.

Symptoms

Leaf rust appears as small reddish brown spots on sorghum plant leaves. As these spots develop, the pustules become raised and release a reddish-brown powdery spore.

Conditions favouring development

The spores germinate on wet leaves, penetrating the leaf. Subsequently, it takes approximately 10–14 days for the pustules to appear. The spores are primarily dispersed by wind, which tends to occur in cool wet conditions.

Management

Rust often appears in autumn at the end of grain fill in northern NSW. If severe, leaf rust can reduce yields and contribute to lodging in susceptible hybrids. The highest recorded effect on yield in Australia from leaf rust was a 13% reduction.

Fusarium stalk rot (*Fusarium* spp.)

Fusarium stalk rot in sorghum is known to be caused by a range of *Fusarium* species (19 have currently been identified), however, QDAF research has identified *Fusarium thapsinum* and *Fusarium andiyazi* as the major species that cause stalk rot in Australia.

Symptoms

Typically, the most obvious and damaging symptom of fusarium stalk rot is crop lodging. However, an orange-red discolouration of the pith tissue inside the stalks, often centred on the nodes, also occurs, alongside a typically brown–reddish purple discoloration of the stem.

Conditions favouring development

Periods of physiological stress favour fusarium stalk rot. This could be moisture stress as a result of seasonal conditions or stress caused by applying a desiccant. Additional research is required to differentiate between the main causes of fusarium stalk rot and charcoal rot (*Macrophomina phaseolina*).

Management

Any practices that minimise crop moisture stress should be encouraged. Rotation with non-host crops is recommended. Currently, sorghum species are the only known hosts of *Fusarium thapsinum* and *Fusarium andiyazi.*

Dessicant use is currently thought to increase the possibility of fusarium stalk rot, so when dessicants are applied to sorghum crops, harvest as soon as practical.

Insect pests

Aphids: corn aphid (*Rhopalosiphon maidis*), oat aphid (*Rhopalosiphon padi*) and rusty plum aphid (*Hysteroneura setariae*).

The most common aphid to infest sorghum is the corn aphid, with the oat and rusty plum aphid occurring less frequently.

Damage

Adults and nymphs infest crops, suck sap and produce honeydew. High aphid numbers can cause vegetative plants to turn yellow and appear unthrifty. Aphids frequently infest sorghum heads towards the end of grain fill. When crops are under extremely high aphid pressure, yield and quality can be affected. Aphid honeydew can cause blockages and breakdowns in headers and delay or extend harvest.

Threshold

Aphid control should be implemented when in the:

- vegetative stage – 100% of plants have aphids covering 80% of the leaf
- reproductive stage – 75% of heads with 50% of the head covered with aphids.

Management

Insecticides that target aphids are available and cost effective. Be aware that aphid insecticides can also affect beneficial insect populations. A pre-harvest spray with a knockdown herbicide will help avoid the problems often caused by aphids at harvest. In severe cases, chlorpyrifos is a registered option for corn aphid. Hybrid selection can also help manage aphid populations. Hybrids with an open head type tend to be less heavily infested than hybrids with closed heads.

Heliothis (*Helicoverpa armigera*)

All heliothis caterpillars on sorghum are *Helicoverpa armigera*.

Damage

Heliothis can attack sorghum in both the vegetative and reproductive phases of crop growth. During the vegetative stages the moths feed on foliage only, chewing circular holes in leaves. Eggs are laid on heads immediately before flowering. The eggs then hatch and cause damage by attacking developing grain. Sorghum crops are most at risk of heliothis damage from head emergence through to grain fill.

Threshold

Economic thresholds (i.e. the number of larvae per head where control cost is equal to the value of the grain saved) for sorghum can be calculated by using the following formula. The formula is based on one heliothis larva causing 2.4 g of yield loss.

Economic threshold:

$$\frac{C \times R}{V \times N \times 2.4} = \text{No. of larvae/head}$$

Example calculation:

$$\frac{\$36 \times 100\text{ cm}}{\$180 \times 10 \times 2.4} = 0.83$$

Where:

C = cost of control ($/ha)
R = row spacing (cm)
V = value of crop ($/tonne)
N = number of sorghum heads/metre of row
2.4 = weight of sorghum (grams) lost per larva

Management

Check for heliothis very early in the morning or very late in the evening, twice a week. Aim to control larvae before they reach 7 mm long – larger larvae cause more damage and are harder to control. Eggs are laid between head emergence and flowering. Aim to apply insecticide three days after 50% of the crop has brown anthers to the base of heads.

Helicoverpa armigera is resistant to pyrethroids, organophosphates and carbamates. The effectiveness of these products depends on what percentage of the heliothis population is resistant.

GemStar® or Vivus MAX *Nuclear polyhedrosis virus* (NPV) are regarded as highly effective control options, when used under suitable conditions. Using NPV reduces the chances of *H. armigera* developing chemical resistance and is therefore the preferred control option. NPV works more slowly than conventional chemistry in killing larvae, however, the larvae cease feeding for a few days before dying.

Rutherglen bug (*Nysius vinitor*) and grey cluster bug (*Nysius clevelandensis*)

Rutherglen bug is an insect pest of grain sorghum, especially in hot and dry weather.

Damage

Rutherglen bug can cause significant damage when present in high numbers. The bugs suck the sap from the plant leaves, stems and heads, reducing yield and/or quality. Seed that the bugs have damaged is small and shrivelled. Damaged seed can also be more prone to fungal and bacterial attack.

Threshold

Rutherglen bug populations within a head of sorghum can increase rapidly. Preliminary studies suggest that at flowering, a threshold of 20–25 bugs/head indicates when control measures should be implemented. This threshold increases to 30–35 bugs/head at the soft dough stage. They cause no damage from the hard dough stage through to harvest.

While these specific numbers of adults/head cause little economic damage, the subsequent generations of nymphs can cause severe grain pinching.

QDAF preliminary research has shown that adult Rutherglen bug will reduce seed set by around 20% when populations are 50–100 bugs/head. Therefore, newly proposed thresholds suggest that control is needed when there are more than 30 bugs/head during flowering and the milky dough seed stage, and more than 80 bugs/head during the soft dough stage.

Management

Controlling Rutherglen bug adults is generally recommended because of their ability to lay a significant number of eggs, rapidly increasing the population. Further, it is more difficult to control nymphs, which are hidden within the sorghum head. Carbaryl and maldison are registered pesticides for controlling the bug. Unfortunately, there are no soft chemical options for control. Repeated influxes of adults can make repeat applications necessary.

Sorghum midge (*Stenodiplosis sorghicola*)

Sorghum midge was a major issue until the 1990s when midge-resistant hybrids became commercially available.

Damage

Sorghum midge can severely reduce yields, especially in crops that are planted late. Translucent larvae hatch from midge eggs and feed on immature seed. Sorghum midge can be detected by the white pupal cases that stick out of the glumes of flowering plants. The life cycle is 2–4 weeks, depending on temperature. This short life cycle allows for many generations in one season. It also accounts for the extremely high midge densities that rapidly build-up where the sorghum flowering is extended by successive plantings.

Signs of damage include a depression in the developing seed, which then prevents seed kernel development.

High midge populations can completely destroy the crop. The progeny of each egg-laying adult can destroy 1.4 g of grain.

Threshold

Midge thresholds for a crop can be calculated using the following formula. For more detailed information, seek advice from your agronomist.

Control measures should be taken when:

$$\frac{\text{No. of midge/row}}{\text{R}} > \frac{\text{C}}{1.4} \times \frac{\text{W}}{\text{V}} \times \frac{\text{CB}}{\text{RD}}$$

Example calculation:

$$\frac{4}{3} = 1.33$$

Is 1.33 greater than..

$$\frac{\$17}{1.4} \times \frac{100\text{ cm}}{\$155} \times \frac{2}{4} = 3.92$$

As 1.33 is <3.92, do not spray at this stage

Where:

R = midge rating of hybrid used
C = cost of control ($/ha)
W = row spacing width (cm)
CB = cost benefit ratio
1.4 = weight of sorghum (grams) lost per midge
V = value of crop ($/t)
RD = residual life of chemical used (days)

Management

During head emergence and flowering, crops should be checked daily, about 3–4 hours after sunrise. Midges are very mobile so crop re-infestation is common. A range of synthetic pyrethroids is available to control midge. Crops should be sprayed when the economic thresholds in Table 11 are reached (based on $17/ha spray cost, grain at $120/t and a benefit cost ratio of 2:1). Because insecticides are only 60–80% effective, a cost benefit ratio of 2:1 is appropriate in most situations.

Table 11. Sorghum midge/head levels that warrant control in hybrids with different levels of midge resistance.

Hybrid midge resistance (Tested rating)	Flowering heads/ha		
	20,000	40,000	60,000
Susceptible (1)	2.5	1.2	0.8
Low (2)	5.0	2.5	1.7
Moderate (4)	10.0	5.0	3.3
High (6)	15.0	7.5	5.0

Avoid sorghum midge by planting during the preferred window. Plant the slowest maturing hybrid first and ensure an even establishment. Damage to crops, especially late planted crops, can be significantly reduced by planting a hybrid with a resistance rating of at least 4.

Using synthetic pyrethroids for midge control can lead to increased aphid populations, which can then cause harvest issues.

Wireworms (*Orondina* spp.)

Damage

Soil insects such as true and false wireworms can severely reduce crop establishment. True wireworms feed on seed as well as seedling stems. False wireworms feed on seed, roots and underground stems.

Threshold

Control measures should be taken if three or more larvae are detected per metre of row.

Management

Use seed treated with an insecticide. Using press wheels at 4–6 kg/cm pressure across the width of wheel reduces the soil insects’ mobility near the seed and can improve establishment. Chlorpyrifos and terbufos are other registered options for wireworm control.

Desiccation

Desiccating sorghum is used to reduce the time between physiological maturity and harvest.

Control late season weeds in the fallow after a sorghum crop to store more soil moisture, if possible. Fallowing is an effective way to reduce late season transpiration losses so that the subsequent crop or earlier fallow start can use conserved soil moisture. Research in the northern grains region demonstrated that appropriately timed dessication can conserve up to 24 mm of moisture within the deeper (below 30 cm) layers of the soil profile.

Spray either glyphosate or Reglone®(knockdown herbicides) pre-harvest immediately after physiological maturity has been reached to hasten grain dry-down. Desiccation allows crops to be harvested earlier and more efficiently than unsprayed crops.

Timing the pre-harvest spray is critical. Crops should be sprayed preferably before the end of March when temperatures are still warm and the crops are still green. It is important that desiccants are applied to plants with actively growing leaf tissue for optimum uptake. Spraying desiccant onto a severely drought-stressed crop, or following a frost, is likely to be ineffective. In general, desiccant effectiveness can be improved by:

- applying in the morning when the stomata are most open
- using good quality water
- using appropriate water volumes.

Be sure to adhere to specified withholding periods of desiccant products.

Sprayed crops should be harvested as soon as they have dried down and the with-holding period for the herbicide has been met, as they are more prone to lodging.

Spraying early
Research by NSW DPI and Northern Grower Alliance has shown that when crops are sprayed before physiological maturity, yield and quality are significantly reduced. A 50%, 20% and 10% reduction in yield can result when desiccation occurs three, two and one week earlier than ideal, respectively. Premature desiccation also leads to small grain, low test weight and increased lodging.

Spraying late
Delaying desiccation beyond the ideal timing also has significant consequences. When spraying is delayed past physiological maturity, the amount of water stored in the profile is reduced, limiting future planting options. It is also a poor return on the spray operation.

Deciding when to spray
Aim to maximise yield through carbohydrate assimilation in the seed, and balance moisture use with efficient soil water storage for the next crop.

Senescent varieties
In general, maturity is when 95–100% of the grains have formed a black layer (i.e. are physiologically mature), the crop is ready to be desiccated. This black layer is the abscission layer at the base of the seed.

The grain located two-thirds of the way down the southern side of the head should be inspected since the southern side of the head is last to mature. If the black abscission layer is found at this location, 90% physiological maturity is assumed and desiccation is recommended. Negligible losses in yield or grain quality will result by desiccating at this time. Waiting until all of the grains in the bottom third of the sorghum head are physiologically mature is considered to be too conservative.

Stay-green sorghum hybrids
Stay-green sorghum hybrids have more green leaf area during grain fill and at physiological maturity than traditional senescent varieties. In order to fully exploit the advantages the stay-green trait provides during grain-fill, delaying desiccation until 100% physiological maturity is recommended.

Lodging
Expect to harvest the crop 10–14 days following desiccant application. However, environmental conditions often determine when desiccants can be applied. It is crucial to ensure that sorghum crops are not standing for a prolonged time after desiccation to avoid lodging before harvest. When disease pathogens are present before desiccation, the likelihood of lodging is increased since desiccation commonly promotes the rapid pathogen development. In such cases, the acceptable timeframe between desiccation and harvest can be reduced so that the crop can be harvested before lodging.

Harvest
Harvest should start once grain has dried to a level where it can be safely stored or transported to an accumulation site (<13.5% moisture). On-farm storage can speed up harvest and allow growers to pay better attention to the post harvest marketing. Both aeration and drying facilities can help speed the harvest. Keeping storage facilities clean and free from grain insect pests is extremely important. (see **Grain storage on page 121**)

Consider trafficability, particularly on the heavier clay soils. Soil can become compacted when soils are too wet, resulting in long-term soil damage that reduces subsequent crop performance.

Marketing
Grain sorghum is marketed by private contract to grain merchants, intensive livestock end users in the chicken, pork, dairy and beef industries, and by major grain accumulators such as GrainCorp.

Marketing grain is a particular skill. Spending time tracking markets and using the financial mechanisms available, such as forward selling and hedging, can make a substantial difference to farm profits.

International demand for grain sorghum has been increasing. China, in particular, is currently sourcing Australian sorghum for spirit production in the human consumption market.

Further information

NSW DPI website (www.dpi.nsw.gov.au/agriculture/broadacre-crops).

Sorghum northern region – Grownotes™ (https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/sorghumgrownotes).

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GO TO PAGES

NSW DPI website

Sorghum northern region

ABS 2016–2017

ABS 2017–2018

Bell et al. (GRDC)

Dang et al. (GRDC)

Guppy (GRDC)

McMullen et al. (GRDC)

Robertson et al. Canola residues

Wylie (GRDC)

Maize

Key management issues

- Organise marketing contracts before planting. Discuss specific quality requirements with end users when negotiating contracts – human consumption market sectors have strict specifications.
- Plant hybrids that have the desired characteristics for your conditions and targeted end use market. Use insecticide-treated seed.
- Plant at the optimum time to avoid effects from early frosts on establishment, extreme heat at tasselling, and cool, slow dry down for late-planted crops.
- Set a target yield based on moisture availability and match inputs to the target. Maize is less tolerant of moisture stress than other summer crops such as grain sorghum.
- Plant inland dryland crops where there is wet soil to at least one metre deep.
- For irrigated crops, calculate water budgets matching the crop area to water allocation. Do not plan to stretch irrigation intervals in order to increase crop area, in particular from just before tasselling to the start of the milk line stage.
- Adjust plant population and row spacing according to the target yield and always use press wheels at planting.
- Apply nitrogen (N), phosphorus (P) and potassium (K) fertiliser based on target yields, soil tests and/or previous crop yields.
- Use controlled traffic farming with no-till to reduce soil compaction (maize is relatively susceptible to compaction) and improve moisture storage.

Brief crop description

Maize is a summer-growing, multipurpose cereal crop that needs warm (but not hot) daytime temperatures, mild nights and moist, well-drained soil to maximise yield. The growing season is usually 130–150 days from planting to harvest. Maize is primarily grown as an irrigated crop, but is also suited to favourable dryland areas. A high yielding crop uses up to 850 mm of water during the growing season. Crops can usually be grown successfully without irrigation along the coastal belt, on the tablelands, and in high yielding dryland environments.

Maize can be grown to produce grain for a range of human food and stock feed markets, or the whole plant can be harvested green for fodder or silage. Dryland yield potential tends to be slightly less than sorghum, but higher under irrigation. Generally, most maize production in NSW is in the Murray and Riverina regions, with a smaller portion in north-western NSW (Table 12). NSW maize production in 2017–18 was estimated to be just over 20,000 ha producing an average yield of 9.4 t/ha. This area is slightly reduced based on estimates since 2010–11.

Table 12. NSW maize production.

	2016–17			2017–18		
Region	Area (ha)	Average yield (t/ha)	% of NSW production	Area (ha)	Average yield (t/ha)	% of NSW production
North-western	4,221	6.2	18.6	3,416	3.4	16.9
Murray	7,036	10.3	31.1	7,889	11.9	39.1
Riverina	8,317	10.3	36.7	7,643	10.2	37.9
Northern Tablelands	1,248	6.4	5.5	450	2.5	2.2
North Coast	1,348	3.5	6.0	48	8.4	0.2
Central West	373	8.4	1.6	168	10.1	0.8
State total	22,655	8.9	–	20,163	9.4	–

Source: Australian Bureau of Statistics, Agricultural Commodities, State and NRM region: 2016–17 and 2017–2018.

Paddock selection

Maize grows well on a range of soils, but does best on deep, well-drained, fertile soils that are slightly acid to neutral, pH_{Ca} 5.5–7.0. Maize does not grow well on poorly drained soils, therefore, the majority of irrigated crops are grown in a minimum tillage system on permanent raised beds or under pivot or lateral irrigation.

When maize follows maize, stubble residue from the previous crop has traditionally been burnt in southern irrigation areas. Burning has been practiced to reduce disease risk and make seeding operations easier. However, research has indicated that stubble retention does not automatically increase disease incidence. Before burning stubble, also consider the effects on N and K management. The operation of mulching stubble and ensuring good soil–stubble contact, soon after harvest, will allow time for decomposition and reduce problems with N tie-up. Large quantities of K are leached from the retained residues back into the soil in a plant-available form.

Many of the Group B herbicides have plantback periods of 6–26 months that need to be observed before planting maize.

Planting time

Planting time is governed by:

- soil temperature
- soil moisture
- targeted tasselling date.

Start planting when the 9.00 am AEST soil temperature at planting depth reaches 12 °C and is rising for 3–4 days. For irrigated crops, the water temperature for pre-irrigation or watering-up can influence planting time. If watering-up, allow for a 3–4 °C drop in soil temperature after watering. Applying cold irrigation water can damage or reduce seedling emergence. The rate of seedling emergence increases with increasing soil temperature. At 12 °C soil temperature, emergence will occur in 14 days, whereas at 25 °C, emergence occurs in 4–5 days.

Planting time and hybrid selection determine whether the crop will be exposed to hot conditions during pollination, which can significantly reduce yield. Tasselling and silking occurs ~10–12 weeks after planting for mid maturity hybrids for a spring planting and less for a later planting. Temperatures above 35 °C at this time can lead to pollen blasting, resulting in poor kernel set and yield loss. Moisture stress is also more likely to occur on hot days. In the inland areas, temperatures above 35 °C are most likely between mid December and mid February. Planting time should aim to avoid tasselling and silking during this period. Staggered planting times across maize paddocks mitigates the risk of large yield penalties due to pollen blast across the entire crop.

Early planting balances the risks of frost soon after emergence and excessive heat at tasselling. Cold conditions after emergence will slow seedling growth and foliage might turn purple as P is less available at low soil temperatures, however, crops recover as conditions warm up. Young crops can generally survive one or more frosts because the growing point does not appear above the soil surface for 3–4 weeks after emergence at the 6–8 leaf stage. Generally a frost of lower than −2 °C is considered to be a killing frost during the early vegetative stage.

Late planting avoids excessive heat at tasselling, but increases the risk of insect attack by heliothis and mites, disease in late summer, and slow dry down periods in cool autumn temperatures. For these reasons, quick-maturing hybrids are favoured for late plantings.

The north and central coast regions have the longest growing season for maize. However, early planting opportunities tend to be limited to irrigated situations as spring is typically dry. Maize planting is usually delayed until mid November through December.

Coastal rain-grown crops should be planted when there is a high probability of good rain in the critical period from two weeks before silking through to four weeks after silking.

On the south coast and on the tablelands, the safest planting time is October and November. This is due to the risk of late frosts at the beginning of the season and/or early frosts towards the end of the season (Table 13).

Table 13. Suggested planting times for maize in NSW production areas.

Region	Early plant												Late plant													
	Aug				Sept				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
Northern inland		<	<	★	★	★	★	★	★	★	>	>					<	<	★	★	★	>	>			
Central irrigated					<	<	★	★	★	★	★	★	>	>												
Southern irrigated							<	<	★	★	★	★	★	★	>	>										
Tablelands							<	<	★	★	★	★	★	★	>	>										
North and central coast				<	<	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	>	>				
South coast								<	★	★	★	★	★	★	★	★	>	>								

< Earlier than ideal.
★ Optimum planting time.
> Later than ideal.

Plant population

Many factors, including soil moisture, climatic conditions, soil fertility, hybrid and end use determine the best plant population for a crop. Dryland crops in drier areas should have lower plant populations than irrigated or high rainfall area crops.

Within any maturity group, hybrids have different tolerances to high plant populations with the more tolerant having better resistance to lodging, a low percentage of barren plants and good silking synchronisation with pollen shedding. **Table 15** details the hybrid maize characteristics.

If the only available planting window will expose the crop to high temperatures during tasselling, silking and early cob formation, reducing the plant density or altering the row spacing can reduce moisture stress and mycotoxin risk.

Maize is highly responsive to plant population and plant uniformity, which makes the planting operation critical for high yields. Care must be taken. Precision planting equipment such as vacuum seed metering systems are essential. Sow at a uniform depth to ensure uniform emergence and achievement of the target plant stand. Increasing speed at planting should only be used where the operation's precision is not compromised. Carefully check seed placement and seed size to ensure doubles and triples on seed discs are minimised.

Calculating planting rate and seed spacing within the row

When calculating the planting rate, allow an extra 5–10% for establishment losses, depending on seedbed and moisture conditions. Obtain the number of seeds/kg and the germination percentage from the bag label.

To determine the planting rate (kg/ha):

$$\frac{\text{Target plant population/m}^2 \times 10{,}000}{\text{Seeds/kg} \times \text{germination percentage} \times \text{establishment percentage}} = \text{Planting rate (kg seed/ha)}$$

Example calculation:

$$\frac{7 \times 10{,}000}{3{,}000 \times 0.95 \times 0.9} = 27.3 \text{ kg/ha}$$

Row spacing

Maize is commonly planted on 75–100 cm row spacing. Width is ultimately determined by the available planter, tractor, harvester and other equipment. Narrow rows are an advantage when there is good in-crop rainfall or irrigation, high fertility and high plant populations. In such conditions, narrower spacing will usually produce slightly higher yields. For dryland production in drier areas such as the north-western plains, single skip on 100 cm rows are suggested so that soil moisture is conserved for grain fill. Research on the Liverpool Plains in a low yielding season and at Moree in a good dryland season both show that there is no yield penalty from using a single skip configuration (**Table 14**). However, wider row spacings such as double skip or super wide are likely to suffer a yield penalty due to lateral roots being unable to extract moisture from the centre of the row. With skip or wide row configurations, use the same target plant population as for solid planting. This means, for example, that in-row plant population in double skip rows will be twice that in solid planting.

Table 14. Effect of row configuration on grain yield at Spring Ridge 2014–15 and Gurley 2015–16.

Row configuration	Spring Ridge	Gurley
Solid 75 cm	1.91 a	–
Solid 100 cm	1.74 b	2.83 b
Single skip (100 cm)	1.84 ab	4.48 a
Super wide (150 cm)	–	3.27 b

* letters following the grain yields indicate significant differences at the P=0.05 level.

Hybrid characteristics

Hybrid selection

Select two or three hybrids to spread your risk. Growing hybrids of different corn relative maturity (CRM) and varying planting times will reduce exposure to risks associated with adverse climatic conditions, especially during tasselling and grain fill. Table 15 details the characteristics of maize hybrids commercially available in 2019–20. It is recommended to speak with the seed company representative to discuss individual hybrid traits, including the likelihood of tillering, multi cobbing and cob flex.

End use

The desired end use of a maize crop should be considered when selecting a hybrid. Different markets can require different hybrids.

Grain for processing

The processing varieties include those grown for grits, starch (waxy and white) and special products such as corn chips. Select varieties that the processor buying your maize recommends. Grit manufacturers, for example, require hard endosperm hybrids to make breakfast cereals and confectionary products. In Table 15, hybrids with 'Grits' listed as an end use are used by at least one of the grit manufacturers. Waxy maize hybrids produce starch consisting entirely of amylopectin rather than 72% amylopectin and 28% amylose. Starch from waxy maize has properties which make it particularly suited for food processing.

Waxy, high amylose, white and popcorn hybrids should only be grown under contract as the Australian market is very small. Some special purpose hybrids might be less vigorous than yellow maize hybrids and yield less, especially high amylose and popcorn hybrids. However, recently released waxy, white and popcorn hybrids have improved performance and have good lodging resistance.

Seed companies supplied the information in Table 15; it is not based on DPI data. Only varieties commercially available in NSW are listed. Consult seed companies before selecting maize hybrids for particular markets and for particular localities.

Grain for stockfeed

If the crop is to be used as stockfeed, select varieties adapted to your area that produce a high grain yield. Grit hybrids will also fit this market.

Silage

Maize is a premium silage crop, producing a large bulk of high-energy forage without the need for wilting before ensiling or adding silage additives. It is best suited for chopped silage stored in a pit or bunker. The economics of maize silage is very dependent on yields and energy values. The major limiting factors are inadequate nutrition and low plant populations. Mid maturity hybrids are usually preferred. A maize crop intended for silage can be harvested for grain if circumstances change.

Select varieties adapted to your area that:

- continue to grow over the full season (to ensure the maximum dry matter per hectare)
- produce a high grain and biomass yield
- produce a high starch content grain
- retain a high proportion of green leaf through to harvest
- tolerate relatively high density planting.

Table 15. Maize hybrid characteristics 2019–20.

Hybrid	CRM [2]		NSW area of adaptation	End use [1]	Husk cover [5]	Disease reactions [7]			Lodging [6]		Company recommendations Target plant population/ha × 1000			Seed company
						Turcicum leaf blight	Rust	Cob rot	Root	Stalk	Irrigation/ coastal [3]	Tablelands/ dryland >650 mm	Inland/ dryland <650 mm	
Titus	82		All	Feed, silage	M	8	7	9	9	9	75–100	40–75	35–45	HSR Seeds
Asterix	85		All	Feed, silage	M	7	7	9	8	9	75–100	40–75	35–45	HSR Seeds
Obelix	93		All	Feed, silage	M	8	9	7	8	8	75-100	40–75	35–45	HSR Seeds
P9400	94		Southern coastal	Feed, silage	M	7	6	6	8	8	80–100	–	–	Pioneer
P9911	99		Southern irrigated, southern coastal	Feed, silage	M	5	7	5	7	7	85 –100	46–60	20–35	Pioneer
Maximus	102	Quick 80–104	All	Feed, silage	M	8	9	7	9	9	75–100	40–75	35–45	HSR Seeds
Brutus	105		All	Feed, silage	M	8	9	8	9	9	75–100	40–75	35–45	HSR Seeds
P0725	107		All	Feed, silage	M	6	6	8	8	8	85–100	45–65	20–35	Pioneer
PAC 440	108		All	Feed, silage	MT	8	8	7	8	9	60–100	45–60	20–45	Pacific
NeroIT	112	Medium– quick 105–112	All	Feed, silage	M	7	8	7	9	9	75–100	40–75	35–45	HSR Seeds
P1315IT [4]	113		All	Feed, silage, grit	MT	6	–	8	7	9	85–100	45–65	20–35	Pioneer
P1467	114		All	Feed, silage	M	5	5	7	8	9	70–90	45–65	20–35	Pioneer
P1477W (white corn)	114		All	White corn, feed, silage, grit	MT	7	6	7	8	8	75–95	40–60	20–35	Pioneer
PAC 606IT [4]	114		All	Feed, silage	MT	8	7	7	7	8	60–110	40–60	20–40	Pacific Seeds
HM-114	114		All	Feed, silage	MT	7	6	7	–	9	60–85	30–45	20–30	Heritage Seeds
HM-330	114		All	Feed, silage	M	4	6	7	–	9	60–85	30–45	20–30	Heritage Seeds
PAC 725IT [4]	115		All	Feed, grit, chips	T	8	7	9	8	8	60–100	30–45	20–35	Pacific Seeds
PAC 624	117		All	Feed, silage	MT	7	7	7	8	7	60–90	40–50	20–35	Pacific Seeds
P1756	117		All	Feed, silage, grit	M	6	7	7	8	9	75–90	30–45	20–35	Pioneer
P1888	118		All	Feed, silage, grit	T	7	7	8	8	8	75–90	30–45	20–35	Pioneer
PAC 804	118		All	Grit, feed, silage	T	8	9	8	9	8	60–100	30–50	20–30	Pacific Seeds
Apollo	118		All	Feed. grit, chips, silage	M	9	9	8	8	8	60–85	30–60	20–35	HSR Seeds
P1813IT [4]	118		All	Feed, grit, chips	T	7	6	7	8	9	60–75	30–45	20–35	Pioneer
Amadeus IT [4]	118	Medium 113–120	All	Feed, grit, chips, silage	M	9	9	8	8	8	75–100	40–75	35–45	HSR Seeds
P2307	123	Long season >121	North coast, southern central irrigated	Silage, grit	VT	9	–	7	–	7	50–65	30–45	20–25	Pioneer
Specialty hybrids														
Dolphin 12	110		All	Butterfly	M	8	8	9	8	8	78–85	NR	NR	Dolphin Seeds
Dolphin 18	104		All	Butterfly	M	7	8	9	7	7	78–85	NR	NR	Dolphin Seeds
Dolphin 38	110		All	Butterfly	M	7	8	9	8	8	78–85	NR	NR	Dolphin Seeds
Dolphin 42	108		All	Butterfly	M	8	8	9	8	8	78–85	NR	NR	Dolphin Seeds
Dolphin 37M	106		All	Mushroom	M	7	8	9	7	7	78–85	NR	NR	Dolphin Seeds
Dolphin 46M	111	Medium–quick	All	Mushroom	M	8	8	9	8	8	78–85	NR	NR	Dolphin Seeds

[1] End use is listed in order of the most common use for that hybrid.
NR Not recommended.
– No Information.
[2] Corn relative maturity.
[3] Coastal dryland populations will vary from 60,000/ha up to 100,000/ha.
[4] IT (imidazoline tolerant).

[5] **Husk cover**
M moderate
MT moderate to tight
T tight
VT very tight

[6] **Lodging resistance**
1 Poor
5 Average
9 Excellent

[7] **Disease reactions**
1 Highly susceptible
5 Intermediate
9 Highly resistant

Yielding ability

Select hybrids that perform well over a range of seasonal conditions. Some quicker maturing hybrids can yield as much grain as slower hybrids and have a more rapid dry down. Use hybrid trials as a guide, but always test hybrids on your farm and grow those best suited to the conditions. The slower maturing hybrids usually produce more silage than quicker maturing hybrids.

Corn relative maturity (CRM)

Maize maturity is based on the time from planting to silking; planting to physiological maturity; and planting to harvest maturity. Temperature is the most important environmental factor influencing the rate of maize development. Later plantings (when weather is warmer) influence maturity by reducing the days from planting to silking, but can increase the time between physiological maturity and harvest maturity where seasons are short.

Commercially available hybrids in NSW range in maturity from 82–123 days CRM. CRM is an American system, also known as the Minnesota RM system and the Comparative RM system, which has been used since 1939. The system indicates the rate of maturity relative to a 'standard' hybrid, but 'relative maturity' should not be confused with 'days to maturity'. For example a hybrid with a CRM of 110 days might take 150+ days to reach 'maturity', which in the CRM system is more closely aligned with physiological maturity (black layer formation) than harvest maturity.

The system incorporates how day length influences the rate of crop maturity. In Australia, CRM is of greatest relevance in southern latitudes (Tasmania, Victoria), equivalent to Minnesota (US), where the growing season is shorter (fewer warm days) and day length has the greatest variation over the growing season. The CRM indicates where a hybrid should be grown.

For grain production in NSW that is using irrigation or that has adequate rainfall, medium maturity hybrids generally perform best. These hybrids usually grow taller and leafier than shorter, quicker maturing hybrids and need lower plant populations. In the North West Slopes and Plains, the medium–quick to medium maturity hybrids with drought tolerance are usually superior. In the southern irrigation areas, highest yields are generally from hybrids with medium–slow maturity (the 'late maturing' varieties).

In the inland production areas, select hybrids to fit the local climatic conditions so they reach tasselling and silking before mid December, or physiological maturity before temperatures are too cool (10 °C) to complete grain fill. Hybrids selected for silage production might have later maturity than those selected for grain.

Lodging resistance

Preventing lodging is essential to avoid harvest difficulties and significant yield losses. Hybrid selection can play an important role. Hybrids with high stalk and root strength ratings are preferable, however, agronomic factors also need to be managed to reduce lodging risk. Major causes of lodging include:

- seedling diseases
- plant nutrient imbalance
- stalk and root rots during grain-fill
- moisture stress and very high plant populations.

Good irrigation management to prevent waterlogging, especially from tasselling onwards, will significantly reduce stalk and root rots, and hence reduce lodging. Deep planting is not an effective technique for reducing lodging as it leads to slower seedling emergence and does not enhance plant standability or lead to deeper root development.

Disease resistance

Select hybrids with resistance to diseases prevalent in your area. On the north coast, hybrids need good resistance to turcicum leaf blight (also known as northern leaf blight) and *Maize dwarf mosaic virus* (MDM). In many areas, fusarium kernel rot has caused significant yield losses and quality issues in grain samples. Commercial hybrids are relatively tolerant to boil smut and, to date, the disease has not caused significant yield losses, except where crops have been moisture-stressed just before silking.

In coastal districts select hybrids with tight husk cover to help prevent weevil and heliothis damage, and also to reduce cob rots and weather damage. In inland regions, loose husk cover is often considered an advantage as it encourages rapid dry down.

Isolation requirements

All waxy, white maize and popcorn varieties must be grown in isolation as pollen from an external source will affect grain quality. Guidelines for isolation requirements include:

- maize crops sown at a similar time should be separated by a minimum of 800 m
- where there is less than an 800 m isolation zone, maize crops should be separated by six weeks between plantings to avoid cross pollination.

Growth stages

Germination and establishment

The developing seedling uses energy reserves in the seed. The primary roots develop and the stem's first internode elongates until the tip emerges from the soil. The rate at which this process occurs depends on temperature and moisture.

Vegetative development

Three weeks after emergence, the plant is about 40 cm tall and has five fully emerged leaves. At this point the tassel and cob are initiated and begin development. Rapid leaf growth continues. The growing point, which will become the tassel, remains below the soil surface until about four weeks after emergence. By five weeks after emergence the crop is 80–90 cm tall, has eight fully expanded leaves and the developing tassel is 15 cm above the soil. Over the next two weeks the stem continues to elongate, leaves expand to their maximum size and the cob begins rapid development. After ~nine weeks the tassel reaches full size, marking the end of vegetative development.

Tasselling and silking

Silks emerge from the top of the uppermost cob and sometimes the second cob a day or two after the tassel completes its development. Air movement through the crop causes clouds of pollen to be dispensed from the tassel, fertilising the cobs. This occurs over 3–8 days. Moisture stress in the weeks before tasselling can delay silk emergence, causing the pollen to be shed and wasted in their absence, thus resulting in poor kernel set. It is critical that the stages of tasselling and silking are synchronised to ensure the maximum number of kernels are set. If these growth stages are not synchronised the resulting cobs will have empty grain sites.

Grain fill and denting

The husks, cob and cob shank are fully developed, about 12 days after the silks emerge. This point is referred to as 'blister' as the kernels are white and are blister-shaped. By this stage, K uptake is almost complete.

The crop continues to rapidly take up N and P as the embryos develop within the kernels. Embryo development is complete when the kernels display a yellow colour on the outside and are filled with whitish liquid (referred to as milk). This is usually 3–4 weeks after the silks first emerge and signifies the start of 'denting'.

Denting refers to the changing shape of the kernel and signifies that starch is being laid down in the grain. Early dent is when 95% of kernels have a visible dent. At full dent, all kernels are dented.

The major activity during grain fill is nutrient transfer from the stems and leaves (stover) to the kernels for storage as starch. The 'milk line' seen on the surface of the developing kernel is the boundary between the liquid phase and the progressing starch phase. The line moves from the top of the kernel towards the core as laying down the starch proceeds. During grain fill, yield gains can still be made from the photosynthesis and carbohydrate accumulation that occurs during this time, however, these are often offset by senescence or nutrient leaching from the lower leaves. The milk line position is closely related to the dry matter content of the crop, indicating the crop's progress towards harvest maturity.

A scoring system is used to track the milk line movement. The milk line score (MLS) begins at zero (0) when the kernels are fully expanded, but there is no visible line at the top of the kernel where starch deposition has begun. It finishes at five when the milk line reaches the base of the kernel and a black layer forms, indicating physiological maturity. Under most circumstances, MLS progresses at the rate of one unit approximately every four days. It can be faster in hot, dry conditions.

Physiological maturity

At physiological maturity the grain is solid and nutrient translocation to the grain is complete. At this time, a black line forms at the base of the kernel where it joins the core. Moisture content of grain at black layer is 28–34%.

Severe moisture stress, hot temperatures or early frost during grain fill can cause the black layer to set prematurely. Even if conditions improve, nutrients will no longer be transferred.

Nutrition

Good yields of grain or silage require high levels of soil fertility. The amount of N, P and K required in fertiliser applications depends on previous cropping and fertiliser history, cultivation age, fallow conditions and yield targets. The overall nutrient removal is greater in silage compared with grain crops, particularly for K. Table 16 shows the expected nutrient removal by maize grain and silage crops of varying yields. Continuous nutrient removal without replacement leads to declining soil fertility. Defining a target yield and its expected nutrient removal is the basis of building a nutrition program for maize.

Maize takes up only small amounts of nutrients until four weeks after planting after which nutrient uptake rapidly accelerates. More than 90% of K uptake occurs between four and seven weeks after planting, when less than half of the final above-ground dry matter has been produced. Nitrogen uptake also increases rapidly with 55% occurring in the short window from seven weeks after planting until the end of silking. Nitrogen uptake is virtually complete two weeks after tasselling. Phosphorus uptake is complete four weeks after tasselling.

Timing fertiliser application is extremely important. Crop accumulation of N, P and K is rapid in the early growth stages. Banding fertiliser at planting ensures that the crop can access nutrients from the very early stages of root development. Referred to as the 'pop-up effect', seedlings are observed to develop faster when sown with banded fertiliser. An added advantage of band-applied fertiliser over broadcast fertiliser is that the nutrients remain in available forms for longer.

Banding fertiliser at planting is possible with most modern precision planters. Apply mixed fertilisers (N, P and K) in a band 5 cm to the side of the seed and 5 cm below it. This placement prevents the fertiliser burning the seedling, which is a risk if the seed and fertiliser are in direct contact.

Table 16. Nitrogen, phosphorus and potassium removal by maize.

Yield potential (tonnes/ha)	Dryland						Irrigation					
	Grain			Silage			Grain			Silage		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
	2.5	5	7.5	22	37	52	10	12.5	15	65	75	86
Nutrient removal (kg/ha)												
Nitrogen	40	80	120	68	136	204	160	200	240	272	340	408
Phosphorus	9	17	25	13	26	36	32	39	46	46	55	65
Potassium	11	22	32	65	112	157	41	51	60	207	245	284

Source: Pacific Seeds Yearbook 2006/2007

Nitrogen (N)

Nitrogen is the main nutritional limitation to yield in all maize-producing regions. The challenge is to manage N fertilisers for maximum use efficiency. Nitrogen supply must be adequate to meet daily uptake demands while minimising losses through, for example, runoff, leaching, denitrification and volatilisation.

The quantity of N required to grow the crop is about 1.6 times the quantity that will be removed in the grain. About 25 kg N/tonne of dry matter is removed when a maize crop is cut for silage, of which 12–16 kg is in the grain.

Crops take up N from the available soil nitrate N and from fertiliser N. Soil nitrate N is estimated by testing soil (preferably to 90 cm depth) and by considering the cropping history, especially the previous crop's grain yield and protein content. Legume rotations and long fallows increase the availability of soil nitrate N, reducing the fertiliser requirement. Table 17 shows the indicative N requirements for a range of target yields following various rotations.

High yielding irrigated and coastal-grown crops can need 250–350 kg N/ha, depending on the yield target and cropping history. Dryland crops in inland regions need about the same quantity of N as grain sorghum.

Irrespective of the form of N applied, the N fertiliser efficiency use, and thus its cost effectiveness, can be enhanced by adopting a split application program. Fertiliser can be applied before planting, at planting and during crop development. In the southern inland region, several approaches to split N application are being used successfully.

Approach 1: Half the N requirement is applied before planting and the remainder is applied as 50 kg N/ha in each irrigation starting with the third irrigation.

Approach 2: Apply a third of the N pre-planting, a third as a side dressing before the first irrigation and the final third through irrigation water.

Urea is commonly used for water-run applications. It is convenient to handle and meter. Anhydrous ammonia can also be used for water-run applications however, it is less efficient than using urea. This is due to the large ammonia volatilisation losses that can occur and the uneven distribution of dissolved ammonia gas in the water.

Nitrogen budgeting can also be used to determine a crop's N requirements by using the following calculations.

Calculating nitrogen requirement

Target yield (t/ha)		Grain protein %		1.6 (conversion factor)		1.6 (N use efficiency)		N required for the crop
...........10..........	×	........10........	×	..........1.6..........	×	........1.6.........	=	...256 kg...

|_____ N removed in grain _____| |__ N required for crop __|

If, in the example calculation, 86 kg/ha of nitrate N was available in the soil, then a further 170 kg N/ha would need to be supplied through fertiliser applications.

Table 17. Nitrogen rates (kg N/ha) for maize yield targets 4–12 t/ha, as influenced by crop rotation.

	Dryland* yield target (t/ha)		Irrigated yield target (t/ha)		
Previous crop	**4**	**6**	**8**	**10**	**12**
Sorghum, cotton, sunflower, maize	100	150	200	250	300
Soybean	–	–	180	230	280
Cowpea, mungbean	70	120	–	–	–
Long fallow wheat	80	120	160	210	260
Long fallow faba bean	30	80	140	190	240
Long fallow chickpea	50	100	–	–	–
Lucerne	0	0	–	–	–

* Dryland maize N estimates are based on the Liverpool Plains climate and soils with a cultivation age older than 25 years.

Phosphorus (P)

About 5 kg P/tonne of dry matter is removed in maize crops cut for silage, of which about 3 kg is in the grain. Fertiliser rates can be as high as 30–50 kg P/ha on high yielding irrigated crops. The soil type, test strips and arbuscular mycorrhizal fungi (AMF) levels (in northern NSW) are guides to a crop's P requirement. However, a soil test is the only reliable method to determine the amount of P in the soil. In grey vertosols common in the inland areas, Colwell P values below 25 ppm indicate maize will respond to P application.

Phosphorus fertiliser can be broadcast and incorporated before planting, or banded at planting. Early in the crop's development, maize has a relatively high requirement for P, but is inefficient at extracting it from the soil. Therefore, P should be banded at planting at 5 cm below and to the side of the seed. The commonly used P fertilisers are DAP, MAP and single superphosphate.

Potassium (K)

Commonly 10 kg K/tonne of dry matter is contained in the above-ground biomass of a maize crop, of which only 3–4 kg is contained in the grain. When the crop is harvested for silage (or when the grain is harvested and the stubble burnt) up to 300 kg of K is being removed (Table 16). This K will eventually need to be replaced to maintain a high yield potential. Potassium remaining in the roots and retained stubble is rapidly returned to the soil, as K is readily leached from plant material.

The amount of fertiliser K required depends on the level of available K in the soil. Plants absorb K directly from the soil solution, which is far smaller than the exchangeable and fixed pools of K in the soil. In clay soils with shrink–swell properties, K added as fertiliser might be fixed in the soil and not immediately available for plant uptake. Soil testing indicates the likely response on some soil types, but is not totally reliable. The test measures the size of the exchangeable pool rather than the immediately plant-available K in the soil solution. Test strips are worthwhile to validate results where the paddock history shows large volumes of K have been removed. Prolonged K removal can reduce supplies of K in the fixed pool and thus lead to a requirement for large applications of K to overcome deficiencies if they occur.

Deficiencies are common in the lighter soils of the tablelands and coastal areas (high rainfall zones). Treat deficient areas or apply test strips with 60–125 kg/ha of muriate of potash.

Zinc (Zn)

Zinc fertilisers are needed for maize grown on heavy alkaline soils where deficiencies commonly occur. Zinc can be broadcast at 10–20 kg Zn/ha and incorporated at least three months before planting. This application rate should last for five to six years as Zn is relatively immobile in the soil. Lower rates are adequate for lighter-textured soils.

Applying Zn with the seed at planting as either a blended fertiliser product, or as a water-injected solution, are effective ways to apply the nutrient. In-crop foliar applications can also be used. When the maize is 20–30 cm high, apply two foliar sprays of Zn sulfate heptahydrate solution (1 kg per 100 L of water) at 300–400 L/ha, 7–10 days apart.

Molybdenum (Mo)

Molybdenum deficiency usually occurs in acid coastal soils. The deficiency can be overcome by a single application of molybdenised superphosphate every five years. More frequent applications can raise Mo to toxic levels. An Mo trioxide seed dressing or a foliar spray of sodium molybdate or ammonium molybdate are alternative ways to prevent Mo deficiency.

Subsoil constraints

Maize is only moderately tolerant of saline soils or saline irrigation water. Table 18 shows the critical limits for yield reductions and the likely effect from salinity on maize production.

Soil texture dictates the quality of irrigation water that can be used on a crop. As clay content increases, tolerance to salinity decreases. A leaching fraction (irrigation water moving below the root zone) is needed when irrigating with saline water. When assessing paddock suitability for maize, the depth to the water table and its salt content should also be considered. Water tables could rise during the season in response to rainfall or irrigation.

Table 18. The likely effect from salt on maize production.

Average salt concentration	Likely effect on maize production
1.1 dS/m in irrigation water	above this critical limit, yield starts to decline
1.7 dS/m in the root zone	above this critical limit, yield starts to decline
2.5 dS/m in the root zone	up to 10% yield loss
3.8 dS/m in the root zone	at least 25% yield loss

Soil moisture

It is essential to know the soil water holding capacity and starting moisture for setting yield targets in all production systems, and for identifying refill points for effective irrigation scheduling. Consider impediments to moisture availability such as salinity and compaction, which will also affect yield.

Inland dryland crops require moisture to a minimum of one metre soil depth at planting. Maize is less tolerant of moisture stress than other summer crops such as grain sorghum. It is particularly sensitive to moisture stress just before tasselling and through to three weeks after silking finishes.

Plant crops into fields which are no-till with retained stubble where possible as this helps to conserve soil moisture. While the ideal planting depth is 4–5 cm, seed can be moisture-seeked down to 9 cm.

For irrigation, the choice between pre-planting and post-planting irrigation depends on soil characteristics, especially soil crusting and soil temperatures. Crops grown in southern NSW are commonly sown into a dry seedbed and then irrigated post-planting. This works best when crops are sown on hills or raised beds.

Maize is sensitive to soil compaction, which limits root development, water and nutrient extraction.

Irrigation

Well-irrigated maize crops use water very efficiently, commonly yielding 16–18 kg grain/ha/mm of water. Research has recorded efficiencies above 20 kg of grain/ha/mm of water. Irrigation water use efficiency is affected by crop agronomy, irrigation system efficiency and seasonal conditions – primarily evaporation and in-crop rainfall. In generating yield responses to applied water, it is as critical to avoid waterlogging stress as it is to avoid stress from moisture deficits.

Water budgeting

When planning a maize crop it is important to consider the area that can be fully watered. At Gunnedah, budgeting 7 ML/ha of irrigation water applied to the field will satisfy crop water requirements in four out of five years. In the Murrumbidgee Valley, irrigation water use ranges from 6 ML/ha to 10 ML/ha applied to the field. The average budget is 8–9 ML/ha.

Maize is typically irrigated using furrow or flood irrigation. Sprinkler (lateral move and centre pivot) and drip irrigation methods are well suited to high-yielding maize production, due in part to the lower potential for waterlogging. These more efficient systems (Table 19), are another significant advantage in maize production.

Table 19. Indicative efficiency of irrigation methods.

Irrigation method	Indicative system efficiency
Flood or furrow	60–70%
Sprinkler – centre pivot, lateral move	85–90%
Drip	90–95%

Peak water use

Maize has a high water use from tassel appearance through to early dent grain maturity. Approximately 70% of the crop's total water use will be in this window, 5–12 weeks after planting during cob initiation, tasselling, pollination and kernel set.

Peak water use occurs during the three weeks following silking (weeks 10–12). The greater the canopy, the greater the water use. Taller, denser crops will use more water as they intercept more light and are exposed to more wind, increasing transpiration.

Scheduling irrigations

Irrigation frequency depends on the interaction between crop growth, soil type (stored soil moisture) and the climatic conditions – temperature, rainfall, wind and humidity. Early in the season, when the root system is developing, irrigations are recommended when 40% of the available water is depleted. Beyond tasselling, the deficit can increase to 50%, except when conditions of extreme evaporative demand prevail. The deficit can increase to 75% once grain has reached early dent.

Using the recommended deficits, crops in the southern inland region are likely to require 10–12 irrigations through the season. During peak water use, the deficit will be reached every 7–10 days, depending on climate. In the northern inland region the irrigation requirement is similar to cotton with 6–8 irrigations usually being required.

Daily water use demands can be estimated where daily evaporation information is available. Table 20 details the crop's daily water use at key stages of growth, relative to both pan evaporation and a standard crop's evapotranspiration. A large proportion of the soil water is taken up by the roots from the top 30 cm of the profile.

Table 20. Daily water use of maize at key growth stages.

Maize growth stage	Daily crop water use relative to:	
	Pan evaporation	ET of a standard crop
5 leaf	25%	30%
Silking	95%	120%
Late grain fill	50%	60%

ET evapotranspiration.

Maize

Moisture stress in maize is expressed through the leaf margins curling upwards. However, this is not a useful visual cue for scheduling irrigations. On hot summer days, the evaporative demand can be greater than maize's capacity to take up water. This leads to stress symptoms even when there is ample soil moisture. However, plants should recover at night time.

Timing the first irrigation

Planting the crop into a full soil moisture profile encourages rapid root growth and avoids waterlogging. This might require a pre-planting irrigation. When starting with a full moisture profile, the first in-crop irrigation should occur before there are any visible signs of moisture stress. There is a rapid increase in demand for nutrients in the 5–8 weeks after emergence. The first irrigation should be timed to ensure that access to nutrients is not limited by water at this time.

Timing the last irrigation

As grain matures, maize becomes less sensitive to moisture stress, allowing the last irrigation to be timed to dry down the soil profile in preparation for harvest. Timing the last irrigation will also depend on whether the crop is destined for a silage or grain market.

For grain crops, time the last irrigation to ensure moisture is available until the grain is physiologically mature, as indicated by black layer formation on grain (milk line score of 5). In the Liverpool Plains region, daily water use declines from 6 mm/day to 3 mm/day between early February and early March. To achieve a typical 90 mm deficit by black layer formation, the last furrow irrigation can be scheduled 3–4 weeks earlier, when the milk line score is 2.

Silage crops should be harvested 10–14 days earlier than grain crops when the milk line score is 2.5. Because of the higher daily water use in early February, timing the last irrigation only a few days earlier at early denting (about three weeks after silking) will result in a ~90 mm deficit by the time a 2.5 milk line score is reached.

Stress effects

- Moisture stress in the first four weeks of growth can reduce leaf expansion and crop height, but is less detrimental to yield than later stresses.
- Stress at tassel initiation results in smaller cobs, while stress at tasselling and silking can result in unset kernels.
- Moisture stress following silking can lead to reduced kernel size and increased risk of mycotoxin contamination in the grain.
- Four consecutive days of moisture stress between tasselling and silking can reduce yields by 30%.
- Grain yield declines by 6–8%/day of moisture stress during peak water use.

After a period of moisture stress, the crop can take several days to recover regardless of soil moisture. If irrigating after a stress period, increase the flow rate to minimise the inundation time. Prolonged saturation increases lodging risk if conditions become windy. Ideally watering periods should not be more than 12 hours.

Maize does not tolerate waterlogging. Root activity is restricted due to a lack of oxygen and N losses through denitrification, and leaching can be significant. There are two stages of growth during which waterlogging is most damaging:

1. **Seedling stage before secondary root development**. At this stage, crop water use is low resulting in the soil drying slowly. Any marginal nutritional deficiencies are exacerbated; in particular Zn deficiency becomes much worse. Crop recovery is slow and quite commonly, crops never catch up from early waterlogging setbacks.
2. **Period from tasselling to silking**. At this time the crop is highly sensitive to both reduced water uptake and interruption to nutrient flow. When furrow irrigating, an irrigation is usually timed just before tasselling so that there is time for the field to return to ideal conditions for this critical period.

Scheduling supplementary irrigation

Tasselling generally occurs 7–10 days before silking. When maize plants are moisture stressed leading into tasselling, silks developing lower down the plant can be slower than normal. This can result in pollen being shed and wasted before the silks emerge leading to very poor kernel set. If only one in-crop irrigation is possible, its application just before tasselling (~8 weeks after planting) will usually give the greatest return. If two irrigations are possible, the second should follow the first, avoiding stress in between. Remember that high water use efficiencies are only obtained when crops are fully watered. Maize uses 250–300 mm of water before any yield is produced.

Weed management

Maize is most susceptible to weed competition in the early growth stages until the crop reaches 0.8 m in height, about eight weeks after planting. Effective weed control at this time is essential for high yields. Maintaining weed control beyond this stage is also important for harvestability, preventing grain sample contamination and ensuring that weeds do not set seed.

An integrated approach to weed management is recommended. Herbicide resistance is an increasing problem in most grain-producing areas. Producers should target their weed control carefully so that the correct rate and application time is achieved. This is particularly important for harder-to-kill weeds such as barnyard grass, liverseed grass, fleabane, bindweed and wild oats.

Herbicides

Due to the effects from early competition, the weed control program should include pre-plant or post-plant pre-emergent herbicides targeting both grass and broadleaf weeds. Efficient and economical herbicides are available for the common weeds of maize; however some residual herbicides might have plantback restrictions that limit their suitability. Table 21 summarises the herbicides with registrations for use in maize. Always read and follow the label directions before using any agricultural chemicals.

Cultivation

Inter-row cultivation is occasionally used for weed control. The operation must be shallow to avoid damaging the crop's root system. Straight beds with straight plant lines allow effective cultivation without losing maize plants. Before crop emergence, harrows can be useful for removing young weed seedlings and for breaking up crusted soil after heavy rain. After emergence, hilling up the soil around the base of young maize plants promotes secondary root growth. However, weeds in the plant line will not be controlled so cultivation at this time should be coupled with band spraying herbicide. Later, inter-row cultivation can be used in conjunction with side-dressing fertiliser or clearing water furrows for the first in-crop irrigation.

Note: Previously applied soil-active herbicides such as atrazine and S–metolachlor can be dispersed by inter-row cultivation allowing weeds to emerge through the band of treated soil. This can occur despite the herbicide having been previously incorporated.

Clearfield® hybrids

The available herbicide options can be expanded by choosing to grow a Clearfield® hybrid. These hybrids have tolerance to the imidazolinone (IT) family of herbicides. The herbicide registered for use on IT hybrids is Lightning®. The Lightning® label has a range of broadleaf and grass weeds listed for post-emergence control. This herbicide has residual soil activity so plantback periods for other crops must be observed. There is no yield penalty associated with hybrids carrying the IT trait.

Table 21. Herbicides registered in NSW for use in maize.

Herbicide		Example product	Group	Maize use pattern		
				pre-plant	post-plant pre-emergent	post-emergent
Residual activity – check plant backs	flumioxazin	Valor®	G	✓		
	atrazine	Atrazine 500 SC®	C	✓	✓	✓
	flumetsulam	Broadstrike™	B		✓	✓
	dicamba	Kamba® 500	I	✓		
	EPTC	Eptam®	E	✓		
	fluroxypyr	Starane™ Advanced	I			✓
	imazethapyr + imazapyr ❶	Lightning® ❶	B			✓
	linuron	Linuron®	C		✓	✓
	pendimethalin	Rifle®440	D		✓	
	S–metolachlor + atrazine	Primextra® Gold	C, K	✓	✓	
	propachlor	Ramrod®	K		✓	
	S-metolachlor	Dual® Gold	K	✓	✓	
	2,4-D amine + picloram	Tordon 75–D®	I			✓
	tribenuron methyl	Express®	B	✓		
	triclopyr	Garlon™ 600	I	✓		
Knockdown activity	dicamba	Banvel® 200	I			✓
	fluroxypyr	Starane™ Advanced™	I			✓
	glyphosate	Roundup®PowerMAX™	M	✓		
	paraquat + diquat	Spray Seed®250	L	✓		

❶ Registered for Clearfield® hybrids with the IT trait only.

Maize

Diseases

Many diseases in maize can be overcome by selecting resistant hybrids. Additionally, good farm hygiene, including washing down equipment and controlling weeds and volunteers, can minimise disease spread from crop-to-crop and season-to-season. While diseases are important because of their potential to reduce yield, grain marketing can be severely restricted by the presence of disease, adding further to the need to choose hybrids carefully. Refer to **Table 15** for details of disease reactions in current hybrids and to **Table 22** for more detailed information on diseases.

Boil smut or common smut (*Ustilago maydis*)

Symptoms

Young seedlings become swollen and distorted. Infections during the vegetative growth stage are expressed as galls (boils) on the stems, leaf axils and leaves, which are initially pale green. The galls become white and full of black powdery spores at maturity. In more mature plants, galls form in kernels causing them to enlarge and deform, distorting the cob.

Conditions favouring development

The fungus develops at temperatures over 25 °C and in dry conditions, but spreads with rain or high humidity. High soil N also favours fungus development and physical damage to plants from mechanical disturbance, for example, can also increase infection. Spores are wind dispersed and through contact sources. Inoculum can remain viable in the soil for many years. While losses are not usually significant, occasionally yield loss is severe.

Management

Varietal selection can help to reduce infection risk, however, an integrated management program is necessary for greater effectiveness which involves:

- cleaning machinery and boots to reduce contamination
- regularly inspecting crops
- removing infected plants
- minimising plant injuries
- careful rotations and applying seed treatments.

Vitavax®200FF is currently the only registered chemical seed treatment. Burning stubble might also help to reduce inoculum carryover.

Many countries that import Australian maize require grain certified free of boil smut.

Maize dwarf mosaic virus

Symptoms

Maize dwarf mosaic virus appears as striping and mottling on leaves, which can be confused with Zn deficiency symptoms. Sometimes there are dark green 'islands' surrounded by lighter coloured rings. An overall yellowing of plants is common and some can become stunted. The virus could cause husks to gape, which can result in a higher incidence of grain rot.

Conditions favouring development

The virus is spread from diseased plants to healthy plants by several species of aphids. Sorghum and grasses such as Johnson grass are also hosts, which contribute to the virus over-wintering and increase the risk of infection in late-planted crops. If infection occurs at an early stage, stunting and subsequent reductions in yield and grain quality can result.

Management

There are moderately resistant varieties available to reduce the risk of infection. However, it is also important to manage the disease agronomically through controlling weeds and volunteer maize plants, and regularly monitoring crops.

Cob and stalk rots

Cob and stalk rots are a particularly important group of diseases in maize. There is a number of fungal pathogens involved (*Aspergillus*, *Fusarium* and *Gibberella* spp.). Stalk rots are frequently responsible for crop lodging. Such fungal diseases reduce yield and can contaminate grain with mycotoxins released during the fungal life cycle. These mycotoxins are toxic to pigs and horses, and are also linked to human conditions.

Symptoms

Table 22 outlines a variety of symptoms that can present according to various types of fungi. Fungal species can often be found within a plant, without causing symptoms, hence small amounts exist in crops unnoticed every season. White streaks or lines on grain can indicate fungal presence.

Conditions favouring development

Cob and stalk rots are commonly associated with high humidity or moisture, and some rots also require high temperatures for development. Physical varietal characteristics can influence infection prevalence, specifically pericarp thickness and the cob's husk coverage extent to reduce moisture infiltration. Similarly, insect damage and kernel splitting can also increase infection incidence.

Management

To manage these diseases, aim to reduce the opportunity for disease infections and the likelihood that mycotoxins will be produced when infections occur. Strategies such as careful varietal selection, crop rotation, pest management and promoting stubble breakdown are effective. Also maintaining good soil moisture from silking through to harvest will reduce infection.

Rust (*Puccinia sorghi*)

While rust occurs across NSW and is present in most seasons, severe outbreaks are uncommon.

Symptoms

Rust appears on leaves initially as small reddish brown pustules to 2 mm long in scattered groups, usually from tasselling onwards. Pustules will lighten with maturity as surrounding leaf tissue dies. With severe infection, leaves will wither and die. Seedling infection can lead to stunting and defoliation.

Conditions favouring development

Humid conditions coupled with mild temperatures (16–23 °C) favour disease development in susceptible hybrids. Late plantings tend to be at greatest risk. Maize volunteers host rust; however, spores are also wind dispersed.

Management

Appropriate varietal selection, correct planting time, crop rotations and controlling hosts assist in preventative rust management.

Northern leaf blight or turcicum leaf blight (*Exserohilum turcicum*)

Leaf blight can have a deleterious effect on crop yield. Where significant leaf tissue is destroyed, only small cobs are produced.

Symptoms

Leaf blight is readily recognised by the long, elliptical (cigar-shaped) greyish-green to tan-coloured lesions on the leaves. As the lesions dry out they become black in the centre as the fungus produces masses of spores. Leaf veins do not confine the leaf veins. As the disease progresses the lesions can coalesce, causing large areas of leaf to wither and die.

Conditions favouring development

Leaf blight is a particular concern in areas experiencing heavy dews, humidity and temperatures ranging from 18 °C to 27 °C, such as coastal NSW where the disease is present most seasons. The infection process needs 6–18 hours of leaf wetness and suitable temperatures to develop. Inoculum over-winters on stubble and maize volunteers, as well as sorghum. Inoculum is dispersed by wind and rain splash.

Management

Resistant varieties, correct planting time, crop rotation, regular monitoring and removing stubble and hosts will reduce disease risk. Chemical control options are also available; leaf coverage is essential as untreated leaf area is susceptible to blight.

Wallaby ear

The condition is the plant's reaction to a toxin injected by the jassid (leafhopper), *Cicadulina bimaculata*, when feeding. This jassid species mostly occurs in the northern coastal areas of NSW, where damage has occurred in the past, however, it is not a problem in most years.

Symptoms

Wallaby ear expresses as shortened leaves held very upright with veins on the lower leaf surface markedly thickened and often coloured dark green or blue–green.

Conditions favouring development

Seasonal conditions that promote jassid population proliferation will probably cause a greater incidence.

Management

There are no insecticides registered to control jassids in maize in NSW.

Table 22. Cob and stalk rots associated with mycotoxins of concern in NSW maize crops.

	Disease symptoms	Disease infection and spread	Mycotoxin characteristics	Conditions favouring mycotoxin development	Good agricultural practice to prevent grain contamination
Aspergillus cob rot	Greenish–grey mould affecting a small proportion of kernels in a small number of cobs. Infections tend to be limited to a small section of the field, e.g. an area of shallower soil with moisture stress between irrigations.	*Aspergillus* spp. (most commonly *A. flavus*) enter the crop as wind-blown spores that are highly resistant to desiccation. Fungi access the developing kernels via the silks and where insects or birds have physically damaged the ear. Once fungal growth has begun it continues until grain moisture content (MC) falls below 14%. *Aspergillus* spp. tolerate hotter conditions than many other fungal diseases (*A. lavus* 12–43 °C, optimum is 30 °C). *A. flavus* is also known as a 'storage fungus' as it grows at low moisture contents. Temperature fluctuations in grain stored slightly above 14% MC will cause small amounts of available moisture to migrate into pockets, creating opportunities for the fungi to grow. Initially it will grow in just the few infected kernels, but as the fungal growth releases moisture from the grain the rate of new infection increases. Storage insects accelerate the process.	**Aflatoxins** *A. parasiticus* produces aflatoxins B1 and B2 while *A. flavus* produces B1, B2, G1 and G2. Aflatoxin B1 is one of the most potent known liver carcinogens. Aflatoxins can also cause acute effects when humans or animals injest high doses. No natural cases of human disease caused by aflatoxin have been recorded in Australia, but livestock have occasionally been poisoned. **Ochratoxin A** Produced by *A. ochraceus* and *A. niger*. Causes kidney damage and immunosuppression in animals and is classified as a possible human carcinogen.	The critical period for aflatoxin production begins 20 days after anthesis. At this time, aflatoxin development is favoured if average day/night temperatures exceed 27 °C and approach 32 °C, there is persistent high humidity through grain maturation, and ears dry prematurely. In stored grain, very high concentrations can quickly develop with 16–20% moisture content. Little is known about the factors that promote ochratoxin A. Its occurrence is much less common in Australia than aflatoxins. Until more is known, it is assumed that managing aflatoxins will also minimise the risk of ocharatoxin A.	**Pre–plant** Select hybrids that are adapted for the local conditions. Before planting, calculate water budgets to match the crop area to the available water allocation. Avoid crop moisture stress where possible. **Planting** Choose planting times that minimise exposure to hot temperatures during kernel formation. **Growing** Where hot conditions cannot be avoided during grain fill, monitor crop water use, reducing irrigation intervals as required. Adjust irrigation across the field to counter areas of soil with lower water holding capacity. Closely monitor heliothis and armyworm. **Harvest** Avoid harvest delays. Consider harvesting at higher moisture contents and artificially drying grain to below 14% for storage. At harvest, minimise light weight material in the sample. Damaged kernels or poorly filled kernels are more likely to carry *Aspergillus* spp. and *Fusarium* spp. Harvest areas of the field affected by moisture stress separately. **Storage** Store grain at 12% MC, maintain constant storage temperature and control insect pests.
Fusarium cob and stalk rots	Powdery or cottony whitish–pink fungal growth on stalk nodes, in internal stalk tissue and on kernel clusters scattered randomly over the ear. Kernels turn tan or brown and often appear with a 'starbust' pattern of fine cracks – produced by the grain pericarp (skin) suddenly contracting and expanding.	*Fusarium* spp. (commonly *F. verticilliodes*) over-winters in crop residues and spreads by wind-blown spores and seed transmission. Infections are systemic. Infection becomes pathogenic when drought stress before and during silking is followed by warm, wet conditions during grain fill (causing sudden changes in the grain pericarp). Infection tends to be more severe in dense plant stands and crops damaged by insects. Higher stalk infection risk is associated with maize following a pasture phase in the rotation. *Fusarium* spp. requires moisture contents above 18.4% for growth in kernels.	**Fumonisins** *F. verticilliodes* is presumed to be the main source of fumonisin in Australia, however, several other *Fusarium* spp. are capable of fumonisin production in maize. Fumonisins are particularly toxic to horses causing liquefaction of the brain. In pigs they cause pulmonary oedema. Cattle, sheep and poultry are fairly resistant. The fumonisin role in human diseases is still being investigated, but they have been associated with oesophageal cancer.	Fumonisins are produced when the plant's defences and the activity of a beneficial fungus, *Acremonium zeae*, are impaired by moisture stress or physical damage. Fumonisin is more likely to be produced where grain endosperm has been exposed. Due to *Fusarium* spp.'s requirement for high moisture and humidity, fumonisin development in stored grain is highly unlikely.	
Gibberella cob and stalk rots	Rotting stalks exhibit reddish–pink discolouration in internal tissues. Hard, black, globular fruiting bodies (perithecia) might be found on the outside of the stalks and husks of infected cobs. Infected cobs fill with reddish–pink to dark purple fungal rot from the tip of the ear towards the base. Husks tend to bind to the kernels.	*Fusarium graminearum* (formerly *Gibberella zeae*) survives in many field crop residues – wheat, maize, rice, sorghum and pasture grasses. From silking through grain maturation, cool, wet, humid conditions can trigger ascospore release, initiating infection. Favourable conditions are more common in the north and central coast, and tableland regions. The disease is not easily distinguished from fusarium stalk rot.	**Zearalenone** Produced by *F. graminearum*, this mycotoxin is implicated in some forms of infertility in pigs, cattle and sheep. It has not been proven to affect human health. **Trichothecenes** Primarily produced by *F. graminearum*, but other *Fusarium* spp. might be involved. Of the 150 related toxins, DON (deoxynivalenol) is the most important to NSW maize production. It is known to survive processing and be present in human food products. Acute exposure can suppress appetite, induce vomiting and affect the immune system of humans and animals.	Rainfall at silking and the relative cob rot resistance and maize hybrid husk covering influences zearalenone incidence. In NSW, the DON occurrence has, to date, been limited to regions where there were abnormally cool and persistently moist conditions during grain maturation.	

Insect pests of maize

Successfully managing insect pests is important for achieving high grain or silage yields. Growers who maintain awareness of pest activity through regular crop inspections will be better able to decide if, and when, insect control measures are needed. Insect pest infestations can occur at any time, but crops are most susceptible to damage during establishment and from tasselling until harvest.

African black beetle (*Heteronychus arator*)

Adult beetles are stout-bodied, shiny black, 10–13 mm long with toothed front legs. The larvae are coloured white or cream with a hard brown head and are a common lawn and turf pest. They are often referred to as curl grubs as they rest in a C-shaped curl. Populations thrive in warm, dry spring conditions. Coastal crops and those rotated with pasture are at highest risk. The most severe outbreaks have been observed in drought conditions.

Damage

Adults chew large, ragged holes in the stems of young plants just below ground level. Similar to wireworm damage, the growing point is often destroyed and plants are felled or become dead-hearted. Damaged younger plants might produce suckers, while older plants remain weak and will lodge.

Threshold

Spraying is effective on populations up to five beetles/m^2. If numbers exceed 10/m^2, damage will result despite spraying.

Management

Grass weed control on headlands, farm hygiene and careful crop rotation to avoid following recently cultivated pasture are effective preventative strategies. In clay soils, sampling the seedbed before planting is difficult, but warranted, if the risk is high. To estimate the soil population, dig and sieve soil from 10 randomly located quadrats (20 cm × 20 cm × 30 cm deep). The only insecticide option is to apply chlorpyrifos in-furrow during planting. However, this treatment is not effective when beetle numbers are high (≥10/m^2) or when swarms of beetles fly into the crop after planting.

Armyworm (*Spodoptera* spp.)

Larvae colour and size varies, but their bodies are usually distinctly striped, hairless and tapered at both ends. Armyworms hide during the day in the soil or funnels of well grown plants and feed during overcast conditions, or in the late afternoon and at night. Outbreaks often occur following heavy rain or flooding. Moths can lay their eggs in the crop or partly grown larvae might move from nearby infested areas. Armyworms are a sporadic pest in maize.

Damage

Armyworms feed on leaves and in the funnels of growing points in maize plants. Young plants can be seriously defoliated leading to plant death or stunting. Older plants can outgrow the attack, however, armyworms will feed on the tassels, husks, silks and cobs as well as the foliage. Silks might be severed before pollination. Severe defoliation at silking can reduce cob size and yield potential. Once larvae reach the later instars, damage can occur very quickly.

Threshold

Armyworms are usually present in large populations, so growth stage and potential damage should be considered when determining spray thresholds.

Management

Regularly monitor crops from emergence until early grain fill, as early detection will allow control decisions to be made when larvae are small, before most damage occurs. Natural armyworm predators might regulate the population below damaging levels. Predators include glossy shield bugs, predatory shield bugs, tachinid flies, braconid wasps and spiders. There is a range of insecticides registered for armyworm control in maize, which should be applied during the evening when larvae are feeding. Larvae entrenched in the funnel of younger plants or the cobs of older plants will not be controlled.

Black field earwig (*Nala lividipes*)

Adults have a flattened, shiny black body with a pair of pincers at one end and are 15 mm long. Nymphs resemble adults in shape, but are paler and wingless.

Earwigs are more common in clay soils where moisture is retained near the surface for longer. Rainfall or irrigation in spring/summer stimulates breeding.

Damage

Both nymphs and adults feed on the germinating seeds, but cause most damage when they attack the young plants' roots and older plants' (up to 60 cm high) tap roots. Damage is usually first noticed when plants are blown down by wind or fall over during inter-row cultivation.

Threshold

Examine soil before planting. Earwigs are usually present in large populations and prefer moist soils.

Management

Earwigs have a wide host range, so can be present irrespective of crop rotation or weed control. Planting conditions that favour rapid germination and vigorous seedling establishment will minimise the severity of earwig damage. Sampling the seedbed before planting is recommended. This is achieved by digging and sieving topsoil in test areas and observing earwig presence. A grain bait (cracked wheat or sorghum treated with sunflower oil and chlorpyrifos) can be broadcast before planting as a monitoring tool, or immediately after planting, to attract earwigs away from the germinating crop. Crops can be protected by using a seed treatment and band spraying in-crop.

Corn aphid *(Rhopalosiphum maidis)*

Adults are soft-bodied, 2 mm long and coloured light green to dark olive green or brown with two purple spots at the rear. Adults might have wings. Immature aphids are smaller and wingless. Colonies form on the undersides of leaves, in the plant funnel and later on the tassels, silks and husks. Aphid infestations tend to have patchy distribution within the field.

Damage

Aphids suck sap causing leaves to turn yellow and appear wilted. In heavy or prolonged infestations, leaves become red and shrivelled. When infestations start early in crop development, kernel set can be reduced. Aphid feeding can also transmit *Maize dwarf mosaic virus*.

Management

Currently there are no insecticides registered to control aphids in maize. When conditions are only moderately favourable for aphids, natural enemies tend to regulate populations below damaging levels. These include ladybirds (adults and larvae), parasitic wasps, hover fly larvae, lacewing larvae and two introduced parasitoids: *Lysiphlebus testaceipes* and *Aphelinus varipes*. Heavy rainfall can suppress aphid activity.

Cutworm (*Agrostis* spp.)

These are hairless larvae, which can vary greatly in colour and size, from green to pale yellow or almost black and 25–50 mm long when fully grown. Cutworms hide in the soil during the day, and feed only in overcast conditions, late afternoon or at night.

Damage

Cutworms eat entire leaves and chew through stems at or below ground level, killing plants. Damage can be distributed throughout the field or confined to patches or strips along field edges.

Threshold

Spray at the first sign of damage as populations are usually large.

Management

Weed control and farm hygiene are effective preventative measures, as severe outbreaks are usually associated with weedy conditions before seedbed preparation. Cutworms are also known to move into crops from fence lines and adjoining pastures or weedy fallows. Control weeds at least four weeks before planting. In the first four weeks after planting, monitor for damaged seedlings. Where there is damage, inspect seedlings in the late afternoon and examine the soil around damaged plants to 10 cm deep to confirm cutworm presence.

Insecticides should be applied when cutworms are exposed during feeding. Band spraying over the row or spot spraying affected patches in the field might be all that is necessary, however, heavy infestations could require re-treatment.

Heliothis or corn earworm (*Helicoverpa armigera*)

Larvae colour ranges from yellow–green to red–brown. They are hairy and develop a saddle of darker pigment on the fourth segment instar back from their head. Fully grown larvae are 40–50 mm long. Infestations usually occur during silking/tasselling, when crops are at their most attractive to moths laying eggs.

Damage

Larvae chew on the leaves, tassels, silks and the tops of cobs. Damage to silks can prevent pollination and kernel set resulting in cobs that tend to develop with poorly filled tops and are susceptible to cob rots. Larvae can also bore through the husks and enter the middle and lower parts of the developing cobs. In some seasons, crops might be infested well before tasselling. The larvae will eat holes in the funnel and leaves, arranged in transverse parallel rows, allowing other pests and diseases to enter. Damaged plants can look weakened, but yield will be unaffected unless the infestation is very severe.

Threshold

Damage before tasselling does not warrant control, and spraying is unlikely to be economically viable. Gritting maize crops are more likely to require 1–2 sprays at tasselling and silking, and processing maize, one spray during silking.

Management

Early-planted crops usually have lower infestations than those planted later. Regular monitoring is required; early detection allows control during egg lay or small larval stages when they are most susceptible to insecticides and before damage occurs. Natural enemies of heliothis such as *Trichogramma*, ladybirds and *Micropilitis*, can regulate the population below damaging levels. There is a range of insecticides registered for heliothis control in maize; the biological controls *Bacillus thuringiensis* and NPV (nucleopolyhedrovirus) are safe to use with beneficial insects. Insecticides targeting larvae should be applied using a high clearance, self-propelled sprayer where available as they are more likely to give better control than aerial application. Alternatively, target egg lays before canopy closure. Large larvae and larvae entrenched in the funnel of younger plants or the cobs of older plants will not be controlled.

Red shouldered leaf beetle (*Monolepta australis*)

Adults are 6 mm long and pale yellow with bright cherry-red markings in a band across the base, and a spot near the middle of each wing cover. They most commonly occur in the north coast region, arriving in swarms in tasselling or silking crops.

Damage

Beetles eat leaves, tassels, silks and husks at the top of the cobs. Injury to silks can impair kernel set and leave the tops of cobs exposed to secondary attack by other insects and cob rots. They are usually present in large numbers, creating hot spots.

Threshold

No thresholds are available.

Management

Currently there are no insecticides registered to control red shouldered leaf beetles in maize and little is known about their natural enemies.

True wireworm (*Agrynus variabilis*) and false wireworms (*Pterohelaeus darlingensis, P. alternatus, Gonocephalum macleayi*)

Wireworms have segmented, cylindrical bodies, which are coloured cream, yellow or tan with three pairs of legs located behind the head. True wireworms are soft bodied with a darker, flattened head, growing up to 20 mm long, while false wireworms have hard bodies with darker, rounded heads and can reach 30 mm. Adult beetles are dark; the true wireworm is the larvae of the click beetle, distinguished by the clicking noise it makes when flipped on its back.

Damage

A wireworm larva consumes plant roots and shoots below ground, and bores up into the stem, killing the growing point causing wilting and plant death, known as 'dead-heartening'. Slower seedling growth will expose plants to greater wireworm damage. False wireworm adults are also known to ringbark or completely cut stems at or just above ground level.

Threshold

Wireworms are difficult to sample for as they dig down into the soil as it dries out. they only venture near the surface when the soil is moist. Check under loose clods of soil before planting, and treat seed or soil at three or more false wireworm larvae per metre, and at >1 true wireworm larvae/m.

Management

Wireworms have a very wide host range. They can be present irrespective of crop rotation or weed control. Early plantings into retained stubble tend to be at the greatest risk of attack. Control measures must be applied before, or at, planting. Testing the seed for germination and vigour before planting is recommended by planting seed at the normal depth in a section of the intended seedbed 2–3 weeks before planting to observe seedling mortality. Baited seed – soaked in sunflower oil and a small amount of chlorpyrifos – can be used to observe wireworm mortality. Digging and sieving topsoil can also be conducted to check for wireworm populations.

The most effective control is an insecticide applied as a band in-furrow at planting. Seed treatments are also available, however, the wireworm must eat the seed or seedling in order to be controlled. It is therefore better suited for use in low populations. Planting in warm conditions will help seedlings grow rapidly and reduce exposure to wireworm damage.

Two-spotted spider mite (*Tetranychus urticae*)

Adults and nymphs are yellow-green with a dark spot in the middle of each side of their body. Adults are 0.5 mm long. Infestation usually starts late in the vegetative stage, increases after tasselling and dramatically increases again when the grain is at the soft dough stage. Hot, dry conditions support rapid population increase. Mites colonise the underside of leaves and though they are small, can be recognised by the characteristic webbing over the colonised area.

Damage

Damaged leaves appear chlorotic and bronzed and die prematurely. Mites normally start feeding on the lower leaves and proceed up the stem as mature, active leaves are preferred over young, unfolding leaves or older, senescent leaves. Severe infestations cause yield losses through reduced cob size, reduced grain size and lodging.

Management

Currently there are no insecticides registered to control mites in maize, however, thrips and several species of predatory mites can help to regulate populations. Synthetic pyrethroids are known to 'flare' mites, the result of eliminating mite predators hence allowing the mites to flourish.

Silage harvest

Timing

Harvest timing is a compromise between maximum dry matter yield, moisture content and potential feed quality. These factors need to be balanced to ensure the feed will ferment and ensile effectively without spoiling. Ideally, harvest should occur 10–14 days before physiological maturity when the maturing grain reaches 2.5–3 MLS. When the MLS is 2–3, half way down the grain, dry matter production is near its maximum and moisture content is 63–67%, which is ideal for fermentation (**Table 23**). This often coincides with the cob husk turning from green to white and the lower leaves dying off. Dry matter quantity declines if crops are held over past the optimum harvest time. Dry matter yield is lost and the chopped material becomes difficult to compact, resulting in poor fermentation and lower quality silage.

If rain delays harvesting at the optimum time it might be preferable to hold the crop for grain.

Frosted crops

After frost damage, the crop will generally have a higher moisture content than is apparent from looking at the damaged leaves. Leaves usually constitute 15% of the total dry matter; the remainder of the plant still retains moisture. Frosted maize must be allowed to dry to at least 30% dry matter (DM). When frost occurs early in grain fill, the moisture content will be too high for immediate harvest or ensiling. The crop could either be cut and fed as green chop or left standing to dry down. Where high field losses are expected during dry down, a silage additive such as hay or grain could be incorporated with the harvested material before ensiling to boost fermentation. When frosts occur close to the intended time of harvest, the crop should be ensiled as soon as possible as leaf loss is likely to be greater and can reduce yield.

Drought-stressed crops

The effect drought has on yield and forage quality will depend on the timing and severity of the moisture stress. Drought-stressed maize can be harvested at a DM content of 30–40%. When a crop grown with high N inputs becomes drought-stressed, there is the risk of nitrate poisoning if the crop is grazed or fed as green chop. Ensiling will reduce this risk as nitrate concentrations fall by 40–60% during the first 3–4 weeks of storage. If there is the chance of rain and the plants have green leaves, delay the harvest.

Cutting height

Nominating an optimum cutting height is difficult due to hybrid variation and growing conditions. The lower the cutting height, the higher the dry matter yield. However, higher cutting heights increase silage quality by increasing the proportion of grain in the chop. Raising the cutting height from 15 cm to 45 cm would reduce yield by 15% and raise digestibility by 2%. The potential for the remaining stubble to help or hinder establishing the next crop in the field should also be considered when nominating a cutting height.

Chop length

Calibrate machines and aim for an actual chop length of 10–15 mm. Very fine chopping will crack more grain, but increase power requirements. If harvesting is delayed (DM >38%), the chop length should be set as fine as possible to aid effective compaction. If forced to harvest early (DM <28%), a longer chop length of 15–20 mm will aid compaction. Harvesting at low DM is not advised as poor fermentation and unacceptable effluent losses can result.

Adding inoculants will improve the fermentation and speed up the process. These are added during the chopping process.

Grain harvest

Timing

Most end users require grain moisture content at 12–14%, with 12% being optimal for storage on farm. As grain reaches physiological maturity, moisture content is usually 28–34%, which requires significant drying down. Natural dry down is possible until early May in most locations. Maize can dry at a rate of 0.5–1.0% each day in suitable weather conditions. Once conditions become cool, consider harvesting crops at 16–18% moisture content and artificially drying to below 14%. Crops can be left to stand over winter for natural drying to resume in the spring, but this increases the risk of mycotoxin contamination.

With access to drying facilities, harvest can start at 18% grain moisture content. Most harvesters perform best when moisture content is between 18% and 24%, losing and damaging less grain. Aeration equipment using ambient air is not sufficient to dry maize grain.

Grain for milling markets

Grain destined for milling markets requires special care during harvest and preparation for storage. Grain with a high proportion of hard endosperm, as required for dry milling, is highly susceptible to hairline fractures known as stress cracks in which moisture evaporates from the endosperm, shrinking it. When dried too quickly, shrinkage is uneven, leading to cracks. During milling, grits break up along the cracks, making them unsuitable for products such as cornflakes. To reduce stress cracks:

- use lower drum speeds during harvest
- use large diameter augers (>200 mm) operating at low speeds and with maximum holding capacity
- use conveyor belts rather than augers
- reduce the moisture content of grain harvested above 14% using slow, steady drying rates with heated air temperatures not exceeding 49 °C and grain temperature not exceeding 38 °C
- slowly cool grain that has been dried – ideally dry grain early in the day to enable slow cooling as the day temperature decreases into the evening
- prevent dew, condensation or rain from re-wetting grain
- minimise the number of times the grain is handled.

Table 23. The relationship between MLS and forage yield and quality. Example based on dryland maize crops grown at Nowra.

	Milk line score (MLS) at harvest				
	>0–1	>1–2	>2–3	>3–4	>4
Yield (t/ha)	57.5	56.7	50.3	46.0	36.4
DM content (%)	27.3	29.8	33.2	39.1	44.0
DM yield (t/ha)	15.7	16.9	16.7	18.0	16.0
Grain content (% DM)	33.4	39.7	42.8	45.8	48.0
Crude protein (% DM)	7.2	7.1	6.9	6.7	6.6
ME (MJ/kg DM)	10.3	10.2	10.1	10.0	9.8

Source: TopFodder *Successful silage* manual.

Maize is renowned for its flexibility and variety of end uses, however, it remains necessary for maize growers to plan their marketing strategies well in advance, as demand for Australian maize relies heavily on domestic markets. All maize surplus to the requirements of human consumption markets must be valued against other feed grains such wheat, barley and, in particular, sorghum. Proximity to markets has a major influence on profitability, especially for silage.

The processors of maize grain for the human consumption markets have stringent guidelines that must be understood by growers entering the industry. Processors extensively use forward contracts to ensure reliability of supply and grain quality. Contracts can outline the hybrids to be grown, which might not necessarily be the highest yielding lines for the region. However, premiums can be offered based on quality. In most irrigation areas it is considered high risk to plant a maize crop without a portion under contract.

The popcorn market is especially small and volatile. All product is bought domestically under contract.

Forward contracting is also commonplace in the dairy and feedlotting industries for purchasing maize silage. Contracts will specify quantity and quality parameters and delivery date. Growers must consider spray drift contamination risk to the crop when growing maize under contract, as residue detection will result in rejection.

Preventing mycotoxin contamination

Mycotoxins are toxic chemicals that some fungi can produce when they infect maize. As mycotoxins are associated with diseases in humans, pets and livestock, their presence in maize is regulated in domestic and international markets. Australian maize is generally high quality regarding mycotoxin contamination compared with other exporting countries.

Table 22 summarises the key information for mycotoxins.

Further information

From DPI

Other relevant DPI publications are available through DPI offices and the **DPI website** (www.dpi.nsw.gov.au/).

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DPI website

Mycotoxins in Australian maize production: how to reduce the risk. National Research Centre for Environmental Toxicology (EnTox), University of Queensland; University of Sydney; Queensland Department of Primary Industries & Fisheries; NSW Department of Primary Industries; and the Grains Research & Development Corporation (**www.maizeaustralia.com.au**). Downloaded 31/08/2019.

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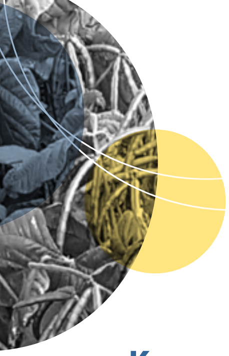

Mungbean

Key management issues

- Assess starting soil water before planting and estimate PAW (plant available water). At least 100 mm of PAW is recommended.
- Avoid paddocks with major variations in soil type or evenness; harvest losses can be as high as 50%.
- Use high-quality seed. Check the seed's germination percentage, seedling vigour, disease status and varietal purity.
- Fertilise according to soil test analyses, arbuscular mycorrhizal fungi (AMF – see **Nutrition on page 47**) status, yield potential and paddock history.
- Inoculate seed using Group I inoculant (rhizobium strain CB 1015).
- Calculate the required seeding rate to establish 20–30 plants/m^2 in dryland crops and 30–40 plants/m^2 where irrigated.
- Select row spacing to fit your farming system. Wide rows (>50 cm) offer more flexibility in planting, weed and insect management, but narrow rows (25–40 cm) offer yield advantages and greater weed competition.
- Weed control options must be carefully planned (broadleaf options are limited). Assess potential weed problems.
- Do not grow mungbean if there is a risk of herbicide residues.
- Insect monitoring should start at crop emergence and from the late vegetative (bud initiation) stage (28–35 days after planting) onwards to ensure timely and effective control decisions.
- Desiccate crops at 90% yellow to black pod stage. Maximise leaf dry down to avoid dust sticking to the seed when harvesting.

Brief crop description

Mungbean in Australia:

- consists of two main crop types:
  i. green seeds called green gram (*Vigna radiata*) – as most mungbean production is green gram, this section focuses primarily on this crop type.
  ii. black seeds called black gram (*Vigna mungo*) – a minor crop
- is a short duration summer grain legume (pulse) crop, which flowers approximately 45 days after planting and reaches maturity in 90–120 days. Mungbean plants are branching, erect and self-pollinating. They have a rooting depth between 60 cm and 100 cm. Soil type, moisture availability and subsoil constraints affect rooting depth
- is suited to double cropping situations when sufficient refilling of the soil moisture profile has occurred before planting. It is suitable for dryland or irrigation production
- has yields that are more reliable when planted into an adequate profile of stored moisture
- is typically grown in northern NSW as a dryland crop, but has also been grown under irrigation in the central west and south west of the state.
- is a relatively small summer crop, so more specialised marketing is required. Mungbean supply a human consumption market so management for high grain quality is essential.

Paddock selection

Paddocks selected for mungbean should be level, and free of sticks, stones and clods, but with stubble cover. Soil type should be relatively uniform. Low-hanging mungbean pods can be affected by these important considerations in crop maturity evenness, the ease of harvest and harvest seed quality.

Paddock history

Mungbean is best included in the rotation after a winter or summer cereal. It can be as a double crop option following a winter cereal, on short fallow following sorghum, or after a long fallow following a winter cereal.

When planning rotations, be aware that volunteer mungbean could occur in following crops and will need to be controlled.

Mungbean is sensitive to several residual herbicides so exercise caution when selecting paddocks where residual products have been used. (see ***Weed control in winter crops***)

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Weed control in winter crops (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops)

Soil management

Mungbean prefers well-drained soils with a medium to heavy texture. It does not tolerate soil compaction or waterlogging. Avoid sodic soils (*ESP >3%) and soils with salinity levels exceeding 2 dS/m in the rooting zone.

* ESP: Exchangeable sodium percentage; EC: Electrical conductivity – a measure of soil salinity levels

Mungbean is well suited to no-till situations; planting into standing cereal stubble often encourages the crop to grow taller, increasing the height from ground level to the lowest pods to make harvesting easier. No-till also increases moisture storage efficiency in the fallow, reducing the risk of crop failure.

Plant available water

It is essential that growers assess the amount of stored soil water and potential yield. Paddocks with less than 100 mm of PAW will often produce unprofitable crops. These paddocks might be best left unplanted and fallowed through to another crop.

Inoculants

All seed should be inoculated with Group I mungbean inoculant (rhizobium strain CB 1015). Stickers are essential to retain the inoculum on the seed and increase the survival rate when planting into hot soil conditions, which is sometimes unavoidable. Always follow the instructions for use.

Mungbean seed should be planted as soon as possible after inoculation into moisture, to maximise rhizobia survival.

Check nodulation 35 days after planting for sufficient numbers of active pink nodules. A nodulation failure can lead to a significant yield reduction without additional nitrogen (N) fertiliser.

Inoculation can be carried out in several ways:
- coating the seed with peat slurry
- granular products
- water injection behind the planting tynes or discs.

Planting time

Mungbean offers two options for planting time, a spring plant and a summer (main season) plant. Table 24 outlines the suggested planting times for mungbean in northern NSW, southern and central Qld.

Spring-planted mungbean is less exposed to heatwave conditions during flowering and seed fill. However, it tends to produce plants with more vegetative biomass.

Spring-planted mungbean:
- is less exposed to heatwave conditions during flowering and seed fill
- tends to produce plants with more vegetative biomass
- is predisposed to higher mirid and thrips pressure requiring critical insect control
- can have higher weed pressure as summer weeds can germinate at similar soil temperatures
- can be harvested in December or January, which could allow the soil water profile to refill before winter enabling a double crop option.

Summer-planted mungbean:
- risks hotter conditions during establishment and flowering
- can be at risk of powdery mildew during pod fill

Very late plantings:
- risk slow dry down to harvest
- delayed harvest due to autumn break rain
- greater risk of quality downgrading.

Planting time also affects the number of days to flowering, with later plantings reaching flowering quicker.

Table 24. Suggested planting times for mungbean.

Region	Early plant												Late plant													
	Sept				Oct				Nov				Dec				Jan				Feb				Mar	
	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
Warren and Narromine	<	★	★	★	>								<	★	★	★	★	★	>	>						
Gunnedah and Tamworth			<	<	★	★	★	★	★	★	>	>	<	★	★	★	★	★	>							
Goondiwindi, Moree and Narrabri			<	<	★	★	★	★	★	★	>	>	<	<	★	★	★	★	>	>						
Darling Downs				<	<	★	★	★	★	★	>	>	<	<	★	★	★	★	★	>	>					
Western Downs			<	<	★	★	★	★	★	★	>	>	>	<	<	<	★	★	★	★	>	>				
Central Queensland	<	<	★	★	★	★	★	★	★	★	★	★	>	>	<	<	★	★	★	★	★	★	★	★	>	>

< Earlier than ideal, but acceptable.
★ Optimum planting time.
> Later than ideal, but acceptable.

Row spacing

Mungbean are grown on varied row spacings. Table 25 compares the opportunities and implications for mungbean production of wide rows and narrow rows.

Narrow row spacing (25–40 cm) has delivered positive yield responses in Jade-AU⦶ compared with wide (100 cm) row spacing.

Research investigating the effect of row spacing on mungbean yield in NSW and Queensland showed positive yield responses for Jade-AU⦶ by adopting narrow (25–40 cm) over wide (100 cm) row spacing. Yield advantages for narrow over wide row spacing ranged from 150 kg/ha to >600 kg/ha under dryland and irrigated farming systems.

Table 25. Comparing wide rows vs. narrow rows.

Wide rows (40–100 cm)	Narrow rows (18–40 cm)
Easier to check for pest pressure.	Pest monitoring can be more difficult in narrow rows using traditional beat sheets. Research comparing traditional beat sheets with rigid beat sheets showed no difference in pest sampling numbers.
Input costs can be reduced by band-spraying insecticides and defoliants.	Altered microenvironment within the plant canopy that can change the pest level abundance e.g. mirids.
Able to plant into heavy stubble residue in no-till situations.	Moisture more evenly used across the paddock.
Improved likelihood of higher yields when moisture is limited.	Higher potential yields when soil moisture is not limiting.
Row-crop planters can be used to provide more accurate seed placement, resulting in better establishment and more even plant stands.	Twin rows, single or double skip row configurations are alternative options, but mungbean has limited lateral root growth and thus yield potential can be limited.
Ability to control weeds relatively cheaply by inter-row cultivation or shielded spraying.	Greater competition with weeds, particularly in late plantings when canopy closure might be more difficult to achieve.
Improved harvestability as plants tend to grow taller with higher pod set; and in low yield situations, plants feed in better over the knife section due to the concentration of growth within the row.	

Plant population and planting depth

Aim to establish 20–30 plants/m^2 in dryland crops and 30–40 plants/m^2 when irrigated.

Consider re-planting if less than 10 plants/m^2 establish, provided adequate time remains in the planting window.

Establishing a uniform plant density is critical to achieve uniform plant maturity across the paddock. Ensure the planting depth across the width of planting machinery is even.

The number of seeds per kilogram can vary widely. Generally it is 12,000–30,000 seeds per kilogram, depending on variety and season. Calculate the planting rate using germination test results, seed count per kilogram, target plant population and estimated establishment percentage. Also take into account hard seed levels and planting conditions. Worked examples are included in the following section.

The planting depth should be 3–5 cm for dryland conditions, but can be up to 7 cm in drier planting conditions when moisture seeking. Use press wheels but maintain minimal pressure over the rows.

Calculating planting rates

The following formulas can be used to calculate sowing rates.

Method

Tip – 100 seed weight

- Count out 200 seeds
- Weigh to at least one decimal point of a gram
- Divide weight in grams by two.

Example

100 seed weight # (grams)		target plant population		establishment percentage*	×	germination percentage		
.........6.7........	×	.........30.........	× 1000 ÷	..........80...........	×	..........90.........	=	your sowing rate ...28... kg/ha

\# To determine your seed weight, weigh 100 seeds in grams.
* Establishment percentage – 80% is a reasonable estimate, unless sowing into adverse conditions.

Seed quality

All seed offered for sale in NSW and Queensland must clearly state the germination percentage and purity of the seed line.

Planting seed should ideally have germination percentages above 90%. Exercise caution with some varieties as hard seed levels might be included in the germination percentage stated on the label. Crystal$^{\phi}$ typically contains less than 10% hard seed, while Celera$^{\phi}$ can contain hard seed levels as high as 50%.

The main implication from high levels of hard seed relates to uneven germination and establishment. Hard seeds might not germinate until the next in-crop rainfall after planting, or even later.

The level of hard seed (by test) should be less than 20% (above 20% hard seed is not advisable for use as planting seed). Hard seed levels can change over time, so any formal seed test should be carried out as close as practical to planting time.

Varietal purity is essential, as mixed varieties are unacceptable in both the sprouting and cooking trade. Mixed seed lines will often attract heavy discounts when marketed, purely on their visual appearance. When purchasing seed, growers should make sure the seed has been either inspected or tested for varietal purity.

The quality of seed lines retained on-farm can deteriorate markedly over 2–3 years and off-types might be quite different in seed coat appearance to the main seed line. Therefore, growers should purchase new Australian Mungbean Association (AMA) approved seed every two to three years.

Plant seed should be free from seed-borne diseases such as bacterial blight and tan spot. It is recommended growers purchase seed through the AMA approved seed scheme, which inspects the seed crop for these seed-borne diseases.

Variety characteristics

Mungbean varieties should be clearly separated at planting. Varietal mixtures are unacceptable in both cooking and sprouting grade bean markets, and will usually attract substantial discounts. Unless harvest equipment and storage facilities can be thoroughly cleaned, planting should be restricted to one variety only.

Variety selection should be based on yield, height, disease tolerance (e.g. tan spot), grain quality, market opportunities and seed availability. The following information is provided on currently recommended varieties. Characteristics of mungbean varieties are in Table 26. Disease reaction and ratings are in **Table 27**. Comparative yields on the Liverpool Plains are shown in **Table 28**.

Jade-AU$^{\phi}$. This large-seeded, bright green mungbean is broadly adapted to the northern region. It is suitable for both spring planting (Sept/Oct) and conventional summer planting (Dec/Jan). Jade-AU$^{\phi}$ has an equivalent grain quality and plant type to Crystal$^{\phi}$, with similar production agronomy to Crystal$^{\phi}$ and other current varieties. It is highly acceptable in the market place.

Celera II-AUᶲ. It is a replacement for Celeraᶲ. It is a small-seeded variety with low levels of hard seed (5%), which is grown for a niche market in many European and Asian countries where splitters and millers like small green mungbean. Note, however, that as a niche variety with a limited market size, growers are advised to consult their marketer before planting. Celera II-AUᶲ is the first mungbean variety released with improved resistance to halo blight. It is broadly adapted to northern NSW and southern Qld and is suitable for both spring and summer plantings. Under moderate to high halo blight pressure, it is higher yielding than all other commercial varieties, reducing production risk: Celera II-AUᶲ has yielded 22% higher than Jade-AUᶲ on the Liverpool Plains with halo blight present.

Crystalᶲ. A relatively tall, erect variety with widespread regional adaptation suitable for both spring and summer plantings. It offers significant advances in grain quality, and has a low level of hardseededness.

Satin IIᶲ. A replacement for Satin, it is a dull-seeded mungbean grown for a niche market. Satin IIᶲ has improved lodging resistance and equal plant maturity compared with Satin. As a niche variety with a limited market size, growers are advised to consult their marketer before planting.

Berken. This remains the favoured variety for sprouting segregation, largely due to ease of marketing (producing large sprouts) and premiums for sprouting grade. It is a good choice for lower-yielding dry areas where sprouting quality is more likely to be achieved. Berken can be prone to lodging, weather damage and seed cracking. These factors increase the difficulty of achieving a premium for sprouting-grade quality.

Onyx-AUᶲ. Onyx-AUᶲ replaces Regur. It has a similar plant type and requires similar management. It has a shorter plant height and sets flowers and pods lower in the canopy compared with large green-seeded varieties, highlighting the importance of selecting level, uniform paddocks as a key aspect of harvest management. Flowering is 3–5 days earlier than Regur and similar to Jade-AUᶲ and Crystalᶲ. Maturity is similar to Regur, and later than Jade-AUᶲ and Crystalᶲ. It is suitable for Regur production areas, but has had limited evaluation in northern NSW.

Table 26. Characteristics of currently recommended mungbean varieties for 2019.

Variety	Seed colour	Weathering resistance	Height	Lodging resistance	Seed size (100 seed weight – grams)
Berken	green	poor	short	fair	5.8
Celera II-AU	green	fair	medium	fair	3.7
Crystal	green	fair	tall	good	6.5
Jade-AU	green	fair	tall	good	6.5
Satin II	green (dull)	fair	tall	good	6.3
Onyx-AU	black	good	medium	good	5.7

Table 27. Varietal resistance to disease in mungbean.

Variety	Halo blight	Powdery mildew	Tan spot
Berken	VS	VS	VS
Celera II-AU	MR	S	MS
Crystal	MS	S	MS
Jade-AU	MS	MS	MS
Satin II	MS	S	MS
Onyx-AU	UFS	UFS	UFS

VS Very susceptible
S Susceptible
MS Moderately susceptible
MR Moderately resistant
UFS Undergoing further screening

Table 28. Grain yields for commercial mungbean varieties expressed as t/ha and as a percentage of Jade-AU on the Liverpool Plains (2012–2018).

Variety	Yield	Percentage
Jade-AU	**1.08**	**100**
Crystal	1.05	97
Satin II	1.02	94
Berken	0.83	77
Celera II-AU	1.32	122
No. of trials	**10**	

Source: National Mungbean Improvement Program

Growth and development stages

Mungbean growth and development stages include germination, emergence, vegetative growth, floral initiation, flowering, pod development and physiological maturity. The change from one stage to the next can occur in response to temperature and photoperiod. However, current commercial varieties do not respond to photoperiod, with temperature prompting the crop stage transition. Critical temperatures for mungbean are a base temperature of 7.5 °C, optimum at 28–30 °C and a maximum temperature of 40 °C. Mungbean is both chilling (cold) and frost sensitive.

Effective germination requires an average >15 °C soil temperature. Therefore, spring planted mungbean is slower than summer-planted crops to germinate and to reach all growth stages. Generally warmer temperatures speed up the plant's development.

Mungbean has epigeal emergence, meaning their cotyledons appear above the soil surface. Following cotyledon emergence the first of the trifoliate leaves begin unfolding. Alternate trifoliate leaves are attached at all nodes above the unifoliate node. It is a branching, erect or sub-erect plant and usually stands 0.50–1.0 m high when it has finished vegetative growth.

Green gram mungbean is determinate in its vegetative growth phase. Vegetative growth (leaf production) ceases once flowering begins; the result of the inherent characteristic where the end of the main stem and branches always develops into a flower bud. This feature limits the crop's ability to accumulate more biomass under favourable growing conditions, to develop a closed canopy when grown in wide (~1 m) rows and reduces crop height. However, it is indeterminate flowering, meaning that is does not have a defined flowering period, and will continue to flower as long as there is enough soil moisture and photosynthate production. Consequently, a single plant can have flowers, green pods and black pods all present at the same time.

Black gram mungbean is indeterminate, continuing to produce leaves after flowering has begun and, under favourable conditions, continuing to develop nodes that produce pods. This trait enables greater responsiveness to high yielding environments than green gram mungbean, and therefore greater yield potential.

Mungbean plants progress from emergence to flowering in around 45 days with temperature being the main control. Flowers are yellow or greenish yellow in colour and are normally grouped in clusters of 5–15. If flowers abort, new flowers will appear if moisture conditions allow. Successive flushes of flowers and pods will occur while growing conditions permit. Most of the pods will form on the top third of the plant, with each pod containing 10–15 almost round, green seeds.

Nutrition

Base fertiliser recommendations on soil test results, fallow length, yield potential and paddock history. Table 29 summarises the crop's nutritional requirements.

Mungbean is highly dependent on beneficial fungi for extracting phosphorus (P) and zinc (Zn) from the soil. The combination of the fungus and the crop root is known as AMF. AMF levels are depleted by long fallows, or by canola and lupin crops which do not host AMF. If AMF levels are likely to be low, soil test to assess P and Zn requirements.

Table 29. Mungbean nutrient removal kg/ha.

Nutrient	Yield 1 t/ha	
	Removed in grain kg/ha	Total crop requirement kg/ha
Nitrogen	35–40	60–70
Phosphorus	3–5	6–9
Potassium	12–14	45–50
Sulfur	2–2.5	3–7

Source: Certified Mungbean Agronomy Course Manual (2010)

Nitrogen (N)

Mungbean is a legume. When properly inoculated and planted into low background soil nitrogen levels, mungbean should fix sufficient N to support its own growth, and can often leave some residual N for the following crop. As a guide, a 1.5 t/ha crop requires a total of 100 kg N/ha.

Applying starter fertiliser containing low rates of N as well as P, S and Zn is often recommended.

Phosphorus (P)

Mungbean responds to high rates of P, so robust rates should be applied, especially on soils known to be responsive.

On deficient soils, 5–10 kg P/ha is commonly applied to dryland crops, with higher rates on irrigated crops.

Sulfur (S)

Problems with S deficiency are most likely with double cropping. Symptoms will first appear as yellowing of the upper leaves and petioles. Sulfur levels should be assessed through regular soil testing. Checking S levels before planting will indicate the potential for deficiency, which can then be addressed by using a starter fertiliser containing S, or with gypsum or sulfate of ammonia. Sulfur has an essential role in the N fixation process. Deficiency can cause reduced nodulation, inhibited symbiosis in N fixation and slowed nodule metabolism.

Zinc (Zn)

Indicators of Zn deficiency are found with soil test levels below 0.8 mg/kg on alkaline soils. Mungbean is responsive to Zn, and deficiency symptoms will appear as stunted plants and dead tissue between the veins. Foliar sprays can correct mild deficiencies in-crop when applied early, while regular fertiliser applications containing Zn are a longer term solution.

Subsoil constraints

Mungbean does not tolerate subsoil salinity or sodicity, which can restrict root growth and reduce the plant's ability to extract moisture and nutrients from the soil.

Where salinity is a problem, affected plants usually appear in patches and are stunted, and will quickly wilt on hot days due to the plant's inability to take up water. Leaves can appear small and grey, with older leaves being affected first. If severe, the plant dies, otherwise flower and seed production will be reduced. EC levels above 2 dS/m are sufficient to cause a yield reduction in mungbeans.

Where there is subsoil sodicity, the amount of PAW will be limited resulting in reduced yield potential. Sodicity is measured as exchangeable sodium percentage (ESP); levels above 3% ESP are considered to be sodic.

Subsoil acidity can also be a problem where the pH_{Ca} is below 4.8, which can induce nutrient imbalances.

Irrigation

Mungbean does not tolerate waterlogging, so irrigation management is critical. Waterlogging will reduce the nodules' ability to fix N, resulting in induced N deficiency. It is estimated that mungbean requires 3.5–4.5 ML/ha water under irrigation in northern NSW and southern Qld.

Spray irrigation is an option, which allows more frequent and smaller irrigation amounts to be applied. Approximately 0.5 ML/ha per week is normally required during flowering and pod fill.

Hills or raised beds will improve drainage under flood irrigation. The tail water system should to be able to quickly drain water away from the crop.

Irrigation water should be applied over 4–8 hours, hence fields with shorter runs are preferred. Using two siphons in each furrow and irrigating down alternate furrows might help.

Irrigation timing suggestions:

- Irrigation 1: about seven days before flowering starts – usually 30–40 days after planting.
- Irrigation 2: early pod development.

Water depletions of 80–100 mm are recommended on heavy, well-structured soils. Soils with less water-holding capacity require lower deficits.

Irrigating too late into grain fill can result in another flush of flowers, resulting in a split maturity in the crop, delayed harvest, and increased risk of quality downgrading.

Weed management

Mungbean is a poor competitor with weeds. Weed competition reduces water use efficiency, interferes with harvesting and contaminates the seed sample.

There are limited broadleaf herbicide options for use either pre- or post-emergence, hence emphasis must be placed on selecting paddocks clean of broadleaf weeds. However, there are a range of post-emergence options available for grass weed control.

Tables 30 and 31 include herbicides that are currently registered or permitted for use in NSW. Always read the label directions before using any agricultural chemical.

Herbicide resistance should be kept in mind, particularly as most of the options for grass weed control are Group A herbicides. Herbicide rotation and an integrated weed management (IWM) strategy are important to reduce the likelihood of herbicide resistance developing.

Mungbean does not tolerate sulfonylurea (SU) (Group B), triazine (Group C) or picloram (Group I) residues. Residues tend to persist for longer periods in alkaline soils and dry conditions.

Growers should avoid using residual herbicides in winter cereals in the 12 months before mungbean is grown. This time interval can be extended if soil pH_{Ca} is above 8.5, or in prolonged drought/dry conditions.

Weed seed contamination in harvested mungbean makes marketing more difficult and usually results in a lower price. While some weed seeds can be removed by grading, sorghum and thornapple weed seeds are particularly difficult to remove. Desiccation is recommended as an option to remove green weed material, which can cause harvesting difficulties and higher moisture in the sample, as well as removing the potential for weed seed contamination (see **Harvesting and desiccation on page 56**).

Table 30. Herbicides registered for use in mungbean.

Herbicide (active)		Example product	Group	Mungbean use pattern			
				Pre-plant	Post-plant pre-emergent	Post-emergent	Pre-harvest crop desiccation
Residual activity – check plant backs	2,4-D amine	Surpass®	I	✓			
	dicamba	Cadence®	I	✓			
	flumioxin	Valor®	G	✓			
	tribenuron-methyl	Express®	B	✓			
	trifluralin	TriflurX®	D	✓			
	pendimethalin	Rifle®	D	✓			
	imazethapyr	Spinnaker®	B		✓		
Knockdown activity	glyphosate	RoundupPowerMAX®	M	✓			✓
	paraquat	Gramoxone®	L	✓			
	paraquat + diquat	Spray.Seed®	L	✓			
	butroxydim	Factor®	A			✓	
	clethodim	Status®	A			✓	
	haloxyfop-r	Verdict®	A			✓	
	quizalofop-p-ethyl	Targa®	A			✓	
	acifluorfen	Blazer®	G			✓	
	Diquat	Reglone®	L				✓

Table 31. Mungbean Permits for weed control at October 2019.

Permit number	Date	Crop	Weeds	Active ingredient, formulation	Group	Rate	Product/s
PER14496	21 March 2014 to 31 March 2024	Mungbean, adzuki bean	Barnyard grass, liverseed grass, summer grass, common sow thistle, blackberry nightshade, fat hen and other pest weeds as listed on the product label.	960 g/L S-metolachlor	K	960 g/L S-metolachlor product: Apply at 2.25–3 L/ha.	Dual Gold herbicide (APVMA No. 50477/112583) plus other registered products containing: 960 g/L S-metolachlor as the only active ingredient.
PER82490	6 December 2016 to 30 November 2021	Mungbean only	See label for peanuts, soybeans.	350 g/L imazamox	B	100 mL plus BS 1000 (or equiv.) at 200 mL/100 L water	Crop Care Claw 350 SL herbicide plus other registered products containing: 350 g/kg imazamox as the only active ingredient.
				700 g/kg imazamox		50 g/kg plus BS 1000 (or equiv.) at 200 mL/100 L water	Raptor WG herbicide plus other registered products containing: 700 g/kg imazamox as the only active ingredient.

Diseases

Three key diseases affect mungbean: halo blight, tan spot and powdery mildew. These diseases are a focus of the National Mungbean Improvement Program (NMIP). Some varietal resistance is available (see **Table 27**). A number of other diseases could affect mungbean depending on suitable conditions or if inoculum is present.

Halo blight (*Pseudomonas savastanoi* pv. *phaseolicola*)

Halo blight is a seed-borne bacterial disease. The disease affects stems, leaves, pods and seed, and severely affected plants might be stunted. Twelves races have been identified, of which the 'T' and 'K' strains are the most prevalent, a reference to the origin of the isolates at Toowoomba and Kingaroy in Queensland.

Seedling infection is usually the result of seed-borne inoculum.

Symptoms

Brown, circular spots up to 3 mm wide and surrounded by a broad yellow halo develop on leaves. Lower leaves are often more affected. The spots coalesce, forming large yellow areas.

Dark green, water soaked areas develop on stems and circular water-soaked spots form on pods.

Conditions favouring development

Cool (18–23 °C) wet weather with symptoms appearing 7–10 days after infection. Wind, rain, people and machinery moving from infected crops spreads the disease.

Management

Use disease-free seed at planting and do not keep seed from infected crops.

Plough in diseased crops immediately after harvest and avoid people and machinery movement through diseased crops, particularly in wet weather. Control volunteers and other crop hosts such as soybean and navy bean, as well as host weeds including cowvine, bellvine and morning glory.

Tan spot (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*)

Tan spot is a seed-borne bacterial disease.

Symptoms

Leaves develop dry, irregular, papery lesions at the margins and along the interveinal areas. Later, the lesions coalesce to larger tan–brown dead areas with yellow margins. The dry tissue can disintegrate during high winds, giving the leaves a ragged appearance.

Infection can occur at any stage from seedling to maturity. Seed might not be set and plants can die. Early infection of seedlings causes stunting and poor yield. Flowers that become infected turn tan–brown and do not develop further or set seed.

Conditions favouring development

Development is often rapid following hailstorms, when temperatures are >30 °C and when the crop becomes moisture stressed. Raindrop splash and wind can help spread the disease, but unlike most other plant pathogenic bacteria it can also infect tissues when no rain is present. Tan spot is systemic within infected plants, moving from the site of infection throughout the plant.

Under favourable growing conditions the disease could go undetected.

Management

Do not retain seed from infected crops and use disease-free seed where possible.

Other hosts include cowpeas, and weeds such as cowvine and bellvine, so maintain control of both volunteers and weeds.

Powdery mildew (*Podosphaera fusca*)

Powdery mildew is a fungal disease. There can be up to 40% yield loss in susceptible varieties if infection occurs at or before flowering. Powdery mildew is more common in late-planted crops.

Symptoms

The most common symptoms include a greyish white fungal growth first appearing in circular patches that later spreads over leaf, stem and pod surfaces. Late infections could cause leaf drop.

Conditions favouring development

Favoured by cool (22–26 °C), dry growing conditions, under optimum conditions the infection cycle can be as short as five days. The disease is more damaging if it infects plants before flowering, or when crops are under moisture stress. The fungus survives on alternative living hosts (typically weeds) and is spread by wind. It will not survive in seed, soil, or on crop residues.

Management

Select varieties with higher levels of resistance and apply fungicides strategically. Two fungicides are currently permitted for use (**Table 32**). They act as protectants only, so they must be applied early in the disease development to be effective. A second application 14 days later might be warranted where conditions favour further infection. Research investigating powdery mildew control in Jade-AU⦶ at 25 cm, 50 cm and 100 cm row spacing found no difference, achieving similar control when fungicide was applied according to recommendations.

Charcoal rot (*Macrophomina phaseolina*)

Charcoal rot is an important fungal disease, responsible for causing sprouting grade beans to be downgraded. It can also cause yield loss when it infects plants in the field.

Symptoms

Symptoms are not obvious until the disease is severe. Stems usually turn a tan colour, before changing to a grey colour from ground level upwards and black spores can be seen on the infected area. Infected plants often die prematurely, usually during moisture and/or heat stress. Charcoal rot causes a soft, wet rot of the sprouts during the germination process that affects marketability.

Conditions favouring development
Charcoal rot appears to be very seasonally dependent and there is limited information on the conditions that favour its development. It generally occurs after flowering following heat and/or moisture stress.

The fungus is soil-borne and remains dormant until flowering or when plants become stressed. It survives in the soil for long periods, having a wide range of host crops and weeds. It can be particularly severe after a sorghum or cotton crop.

Movement of soil and plant debris readily spreads the fungus. Rain during early pod fill favours seed infection.

Management
Rotation seems to affect the likelihood of infection, with the disease particularly prevalent following sorghum and cotton. Avoid paddocks where charcoal rot has been a problem within the past 4–5 years. There is no known resistance.

Moving soil and plant debris can spread the fungus, so farm hygiene is important.

Planting into good soil moisture and maintaining good growing conditions can help minimise infection.

Gummy pod (*Gluconobacter* spp.)
Gummy pod is caused by a bacterial infection. The infection is a secondary process following sugar over-production in the plant's flower nectaries.

Symptoms
The symptoms appear as a sticky foam and gum on pods, stems and pod stalks, which exudes from flower nectaries and flowers. This can extend to stems collapsing and pods dropping in extreme cases.

Conditions favouring development
Excess heat and moisture stress appear to trigger this condition, which is often found in crops, but is of little consequence until ideal conditions prevail. Uneven flowering as a result of insect damage can encourage the bacteria to increase.

Management
No practical control measures are available. Regularly cleaning harvesting equipment is recommended to prevent gum buildup during harvesting. Desiccation might be an option to minimise problems at harvest.

Phytoplasma
Phytoplasma is also known as legume little leaf or witches broom. This disease is caused by extremely small, specialised bacteria known as phytoplasma, most likely 'pigeon little leaf' phytoplasma.

Symptoms
Symptoms in severely affected plants include stunted, very erect plants with distinctive masses of small, cupped leaves with no flowers or pods. Where infection levels are low or when infection occurs later in the season, flowers appear distorted with green petals and often pods are not produced or are empty. Pods can also appear curved, small and thin. Affected seed might turn brown and fail to develop.

Conditions favouring development
Phytoplasma is most likely spread by the common leafhopper (*Orosius orientalis*). It survives in summer pulses including soybean, pigeon pea and peanuts and winter chickpeas, as well as weed hosts. Dry seasons often promote leaf hopper migration into crops. Phytoplasma has been widely reported in both spring- and summer-planted mungbean, including in second flower flushes.

Management
Occurrence is not uncommon, but usually very low, <0.1% of plants affected. Monitoring leafhopper numbers is recommended, however, disease transmission probably occurs after a single feed by the leafhopper. This could explain the findings of limited survey data that suggests no correlation between levels of phytoplasma-affected plants and the number of applied insecticides. Phytoplasma is not believed to be transmitted by seed. Monitoring and reporting phytoplasma is recommended.

Puffy pod disorder

Symptoms

Mungbean pods appear enlarged (puffy), often blotchy and soft. Infected pods do not produce mature seeds, more commonly they become infected by secondary rots. Growing points are often stunted and no flowers are produced from the deformed buds.

Field observations suggest late infections of phytoplasma may have some association with puffy pod. Further research is needed to confirm this potential link.

Conditions favouring development

It is not known what causes puffy pod.

Management

It is recommended to harvest the crop before the affected pods mature where possible. Desiccate and ensure suitable drum speed and airflow to pass the unthreshed puffy pods out of the header.

Table 32. Mungbean Permits for disease management at October 2019.

Permit number	Date	Crop	Disease	Active ingredient, formulation	Group	Rate	Product/s
PER13979	3 February 2014 to 30 June 2020	Mungbean only	Powdery mildew (*Erysiphe polygoni* or *podosphaera xanthi*)	430 g/L tebuconazole	3	145 mL/ha	Relyon Teboo 430 SC fungicide (82181) plus other registered products containing: 430 g/L tebuconazole as their only active ingredient.
				750 g/kg tebuconazole		83 g/kg	Buzz Ultra 750 WG fungicide (65600) plus other registered products containing: 750 g/kg tebuconazole as their only active ingredient.
				800 g/kg tebuconazole		78 g/ha	Laguna Xtreme 800 WG fungicide (67455) plus other registered products containing: 800g/kg tebuconazole as their only active ingredient.
PER82104	1 November 2016 to 30 November 2019	Mungbean, adzuki bean, navy bean	Powdery mildew (*Erysiphe polygoni* or *podosphaera xanthi*)	120 g/L azoxystrobim + 200 g/L tebuconazole	11 + 3	300–600 mL/ha plus non-ionic surfactant at label rates	Custodia fungicide plus other registered products containing: 120 g/L azoxystrobim + 200 g/L tebuconazole as their only active ingredient.

Insect pests

Insect pests can affect the overall profitability of a mungbean crop, reducing both yield and seed quality.

Accordingly, insect damage is one of the main reasons for downgrading mungbean. Crops should be inspected weekly from the vegetative stage through to budding and twice weekly from the start of budding–flowering through to the end of pod fill. Crops that are producing buds, but not flowers, can contain damaging populations of sucking insects, causing the buds to abort before the flowers open. Avoid monitoring during the middle of the day or when conditions are hot, windy or raining as this will possibly lead to under-estimated pest populations.

The industry standard best sampling practice and the preferred sampling method for most major mungbean pests uses a beatsheet. The standard sample unit at each sample site in a crop is five non-consecutive 1 m lengths of row, taken within a 20 m radius. Beatsheet sampling is most suited for crops with a row spacing ≥30 cm.

Mungbean also usually supports quite high populations of beneficial insects, which should be considered when selecting insect control measures.

Silverleaf whitefly (SLW) does not prefer mungbean as a host. While adults are often seen on mungbean, SLW nymph development is very poor in this crop.

The AMA website (www.mungbean.org.au) or the APVMA website (www.apvma.gov.au) have a list of currently (September 2019) registered pesticides.

Table 37 lists current (September 2019) APVMA permits for pest management in mungbean.

Cowpea bruchids (*Callosobruchus maculatus* (*Fabricus*))

Bruchids have become a common pest in stored grain and can also infest mature and dry mungbean pods in the field. It is a small, brown beetle. While they have been more prevalent in Queensland, in recent years problems have also occurred in northern NSW.

Damage

The bruchids bore into the grain, leaving holes and other damage.

Threshold

There are no established thresholds for bruchids. However, even at two bruchids per tonne, in four months this could result in 100% of grains being damaged.

Management

Management in stored grain is provided through controlling storage conditions. The bruchid lifecycle is rapid, particularly at warmer temperatures, so stored grain is best kept at lower temperatures to reduce insect breeding cycles. Breeding ceases at temperatures below 20 °C.

Thoroughly checking crops and stored grains is necessary to detect bruchids.

Green vegetable bug (*Nezara viridula*)

This species is the most damaging pod-sucking bug in mungbean due to its abundance, widespread distribution, rate of damage and rate of reproduction.

Adult bugs typically invade summer legumes at flowering, but green vegetable bug (GVB) is primarily a pod feeder with a preference for pods with well-developed seeds. Mungbean remains at risk until pods are too hard to damage (i.e. very close to harvest). Damaging populations are typically highest in late summer planted crops during late pod-fill (when nymphs have reached or are near adulthood).

Damage

These sucking insects use their mouth parts to suck nutrients from the seed. Pods most at risk are those containing well-developed seeds. Damage to young pods causes deformed and shrivelled seeds and reduces yield. Seeds damaged in older pods are blemished, difficult to grade out and reduce quality.

GVB-damaged seeds have increased protein content but a shorter storage life (due to increased rancidity). These seeds are frequently discoloured, either directly from tissue breakdown, or water, which can enter where pods are pierced by bugs.

GVB also damages buds and flowers, but mungbean can compensate for this early damage.

Threshold

Green vegetable bug spray threshold: 1 GVB per m^2. Increasing the threshold to 0.3–0.6 GVB per m^2 might be warranted when very high prices are offered for premium or sprouting beans.

Management

Crops should be inspected for GVB twice weekly from budding until close to harvest.

Monitor populations using the beatsheet method and spray once numbers reach thresholds, taking into account the likely returns from the crop.

Heliothis (*Helicoverpa armigera* and *Helicoverpa punctigera*)

Helicoverpa can severely damage all crop stages and all mungbean plant parts.

Damage

High populations in seedling or drought-stressed crops can cause considerable damage if vegetative terminals and stems are eaten. This type of damage results in pods being set closer to the ground. Such pods are more difficult to harvest. In drought-stressed crops, the last soft green tissue is usually the vegetative terminals, which are more likely to be totally consumed than in normally growing crops.

Once crops reach flowering, larvae focus on buds, flowers and pods. Young larvae are more likely to feed on vegetative terminals, young leaves and flowers before attacking pods. Small pods may be totally consumed by *Helicoverpa*, but larvae target the seeds in large pods. Crops are better able to compensate for early rather than late pod damage. However, in dryland crops, where water is limiting, significant early damage can delay or stagger podding with subsequent yield and quality losses. Damage to well-developed pods also results in weather stained uneaten seeds due to water entering the pods.

Threshold

The reproductive threshold for late flowering/early podding to late pod-fill stages is conservatively based on the rate of damage at late pod-fill, and varies from 1–5 larvae/m^2, depending on the cost of control and the price of mungbean. This threshold allows for possible yield loss in drought-stressed crops damaged by *Helicoverpa* at flowering.

Table 33 is based on a measured yield loss of 35 kg/ha for every larvae/m². Cross-reference the cost of control vs the crop value to determine the economic threshold (ET), e.g. if the cost of control = $40/ha and the crop value = $600/t, the ET = 1.9. Spray *Helicoverpa* only if they exceed the threshold that is the breakeven point.

Table 33. Economic threshold chart for *Helicoverpa* in podding mungbean.

Cost of control ($/ha)	Thresholds (larvae/m²) for conventional pesticides at mungbean crop values listed below ($/t)									
	$350	$400	$450	$500	$550	$600	$650	$700	$750	$800
20	1.6	1.4	1.3	1.1	1.0	1.0	0.9	0.8	0.8	0.7
25	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0	1.0	0.9
30	2.4	2.1	1.9	1.7	1.6	1.4	1.3	1.2	1.1	1.1
35	2.9	2.5	2.2	2.0	1.8	1.7	1.5	1.4	1.3	1.3
40	3.3	2.9	2.5	2.3	2.1	1.9	1.8	1.6	1.5	1.4
45	3.7	3.2	2.9	2.6	2.3	2.1	2.0	1.8	1.7	1.6
50	4.1	3.6	3.2	2.9	2.6	2.4	2.2	2.0	1.9	1.8
55	4.5	3.9	3.5	3.1	2.9	2.6	2.4	2.2	2.1	2.0
60	4.9	4.3	3.8	3.4	3.1	2.9	2.6	2.4	2.3	2.1
65	5.3	4.6	4.1	3.7	3.4	3.1	2.9	2.7	2.5	2.3

Source: **Helicoverpa in podding munbeans**.

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Helicoverpa in podding mungbeans (https://ipmguidelinesforgrains.com.au/wp-content/uploads/Helicoverpa-in-podding-mungbean.pdf)

Management

Management uses integrated pest management (IPM) tactics to control *Helicoverpa*. Mungbean should be monitored weekly during the vegetative stage and twice weekly from early budding until late podding. Consider the number and size of grubs and eggs in the crop, and economic thresholds. Use the softest insecticides available to preserve beneficial insects.

The extensive host range that includes agriculturally important summer and winter crops, combined with the capacity of *H. armigera* to develop resistance to commonly used insecticides, has resulted in the GRDC developing a resistance management strategy (RMS), the ***Resistance management strategy for Helicoverpa armigera in Australian grains***.

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Resistance management strategy for Helicoverpa armigera in Australian grains (https://ipmguidelinesforgrains.com.au/important/uploads/GRDC_RMS_Helicoverpa-Armigera.pdf)

Mungbean (and chickpea) are central to the strategy's design to minimise selection pressure for resistance to the same chemical groups across consecutive generations of *H. armigera*. The RMS is built around product windows for products such as chlorantraniliprole (e.g. Altacor®) and indoxacarb (e.g. Steward®).

Mirids (green: *Creontiades dilates*; brown: *C. pacificus*)

Mirids are major pests of flowering and podding mungbean. They are often in the crop and can reach thresholds before budding. Mirids attack buds, flowers, small pods and seeds with the green mirid responsible for most damage.

It is very important to scout weekly through the late vegetative stage to ensure the start of budding is NOT missed. Monitor twice weekly from budding until post flowering (R4–5). Note, mungbean grown in narrow rows creates a microclimate favourable for mirid development.

The eggs are difficult to detect. The life cycle takes between 19 and 23 days from egg laying to fertile adults. Mirid numbers will develop rapidly, so regular checking is essential, particularly as nymphs are considered to be as damaging as adults. Nymphs will be visible within two weeks of adults entering the crop.

Table 34 shows the strategy for the central RMS region, covering NSW production areas.

Damage

Mirids pierce the plant with their mouth parts and release an enzyme that destroys the cells, resulting in the affected tissue blackening and dying.

Mirids can reduce pod set per raceme, reduce seed numbers in pods and reduce grain quality by marking the seed coat when feeding directly on the developing seed. Damage to buds, flowers and pods and will cause abortion which, if left unchecked, can result in a 25–50% yield loss. Mirids at late pod-fill are not nearly as damaging as other podsucking insects.

Threshold

Mirid spray threshold: 0.3–0.5/m² using beat sheet sampling.

Table 35 is based on a yield loss of 60 kg/ha per mirid/m², assuming continuous mirid activity over a 28-day period during the budding–podding stages. Cross-reference the cost of control (pesticide plus application against crop value to determine the economic threshold (ET).

Table 34. Best practice windows and use restrictions to manage insecticide resistance in *Helicoverpa armigera* in the central grain growing region.

Southern Queensland central and northern NSW regions: Balonne, Bourke, Burnett, Darling Downs, Gwydir, Lachlan, MacIntyre, Macquarie and Namoi

Selectivity	Insecticide	June (1–4)	July (1–4)	Aug (1–4)	Sept (1–4)	Oct (1–4)	Nov (1–4)	Dec (1–4)	Jan (1–4)	Feb (1–4)	Mar (1–4)	Apr (1–4)	May (1–4)
Increasing	*Bacillus thuringiensis* (Bt)	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions
	Helicoverpa viruses	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions
	Paraffinic oil Note 1	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions
	Chlorantraniliprole Note 2, 3	DO NOT USE	DO NOT USE	DO NOT USE	One application	One application	1–2: One application; 3–4: DO NOT USE	DO NOT USE	1–2: DO NOT USE; 3–4: One application	One application	One application	DO NOT USE	DO NOT USE
	Indoxacarb Note 4	DO NOT USE	DO NOT USE	One application	1–2: One application; 3–4: DO NOT USE	DO NOT USE	1–2: DO NOT USE; 3–4: One application	One application	DO NOT USE	DO NOT USE	DO NOT USE	DO NOT USE	DO NOT USE
	Spinetoram Note 2, 4, 5	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications
	Emamectin benzoate Note 2, 4, 5	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications	Two applications
	Carbamates Note 2, 4, 6	One application	One application	One application	One application	One application	One application	One application	One application	One application	One application	One application	One application
Decreasing	Pyrethroids Note 2, 4, 7	One application	One application	One application	One application	One application	One application	One application	One application	One application	One application	One application	One application

KEY: No restrictions; DO NOT USE during this period; No more than one application per crop per season; No more than two applications per crop per season

ADDITIONAL INFORMATION **Note** 1: Some *n*C27 paraffinic spray oils can be used to suppress *Helicoverpa* populations and are best used as part of an IPM program. **Note** 2: Observe withholding periods (WHP). Products in this group have WHP 14 days or longer. **Note** 3: Maximum one spray of chlorantraniliprole alone or in mixtures per crop per season. **Note** 4: Refer to label for warning of insecticide risk to bee populations. **Note** 5: Maximum two consecutive sprays alone or in mixtures per crop per season. **Note** 6: Moderate resistance is present in *H. armigera* populations – field failures likely. **Note** 7: High resistance is present in *H. armigera* populations – field failures expected.

Source: **Resistance Management Strategy for Helicoverpa armigera in Australian Grains 2018** (redrawn) (https://grdc.com.au/resources-and-publications/all-publications/publications/2018/resistance-management-strategy-for-helicoverpa-armigera-in-australian-grains).

Mungbean

Table 35. Economic thresholds for mirids in mungbean.

Control cost ($/ha)	Mirid thresholds* (adults + nymphs/m^2) at mungbean crop values below ($/t)							
	$500	$600	$700	$800	$900	$1000	$1100	$1200
10	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1
15	0.5	0.4	0.4	0.3	0.3	0.3	0.2	0.2
20	0.7	0.6	0.5	0.4	0.4	0.3	0.2	0.2
25	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.3
30	1.0	0.8	0.7	0.6	0.6	0.5	0.5	0.4
35	1.2	1.0	0.8	0.7	0.6	0.6	0.5	0.5
40	1.3	1.1	1.0	0.8	0.7	0.7	0.6	0.6

Source: GRDC Tips and Tactics: ***Mirids in mungbeans***.

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GRDC Tips and Tactics: ***Mirids in mungbeans*** (https://grdc.com.au/__data/assets/pdf_file/0037/289297/GRDC-Tips-and-Tactics-Mirids-in-Mungbeans.pdf)

Healthy vigorous crops can compensate for mirid damage inflicted in the first week after budding. By delaying the first mirid spray by up to seven days, additional sprays may be unnecessary. This reduces the risk of flaring *Helicoverpa*. Prompt control is advised in moisture-stressed crops. Monitoring should continue after control to detect new infestations.

Queensland DEEDI (now QDAF) research suggests the following strategy:

- Begin monitoring before budding starts. Check once a week during the vegetative stages and then twice a week from the start of budding through to when pod filling is complete.
- Consider using low rates of dimethoate plus salt (0.5% NaCl) to control mirids early in the season. The low rate is recommended to help reduce the effect on beneficial insects and the risk of flaring *Helicoverpa* numbers.
- Using two sprays of dimethoate, timed 5–10 days apart to target and control any emerging mirid nymphs, which were present as eggs during the first spray.

Thrips (*Thrips* spp.)

Thrips can infest crops from the seedling stage, but are more common at the bud initiation stage through to flowering. Spring crops tend to be more susceptible to damage as thrips migrate out of maturing cereal crops into mungbean.

Damage

Thrips damage the seedling growing point and embryonic leaves. However, damage is not evident until the first trifoliate leaves open. Damaged leaves can be severely distorted and discoloured. High numbers can kill young seedlings.

Damage to flowering plants can result in flower abortion and pod distortion. Deformed pods can be difficult to thresh, resulting in further yield losses.

Threshold

There are no thresholds for thrips at the seedling stage.

Flowering plants spray threshold is 4–6 thrips per flower at flowering and pod setting.

Management

Except for western flower thrips (which have shown resistance to insecticides), flower thrips are easily controlled with current systemic pesticides registered for pulses (e.g. dimethoate).

Table 36. Minimum number of samples recommended for assessing pests.

Pests	Method	Sample unit	Minimum number of replicates* recommended
Mirids	Beatsheet Sweep net	5 × 1m 20 sweeps in 20 m	6 6
Helicoverpa, loopers	Beatsheet	5 × 1m	6
Podsucking bugs#	Beatsheet	5 × 1m	6–10#
Bean podborer	Open flowers	30 flowering racemes	6
Thrips	Open flowers	25 flowers	6

* This is the number of sample sites. Multiply by 5 to get number of individual samples.
# GVB nymphs are notoriously patchy in distribution, hence more samples are desirable.
Source: AMA Northern *Mungbean best management practices training course*: Module 7 – Insect management (2017)

Harvesting and desiccation

Mungbean maturity across paddocks is often uneven, creating a difficult decision for timing desiccation to optimise yield and quality. Significant rain later in the crop's development will often mean additional flowering and pods.

While extra yield can be obtained from these later-maturing pods, it can be at the expense of achieving a higher marketing grade at delivery.

Desiccation is strongly recommended and should be applied at the 90% yellow–black pod stage. Harvest should be delayed until maximum dry down of leaf moisture. This can take 5–6 days with diquat and 8–16 days with glyphosate.

Glyphosate is not recommended for use on crops destined for use as planting or sprouting seed and has a withholding period to harvest of seven days that must be observed.

Mungbean crops that have not been effectively desiccated – or not desiccated at all – are more difficult to harvest as the plants, particularly the stems, contain a lot of sap. This often makes the plants more difficult to cut, blockages are more likely and seeds becoming stained can be more prevalent. Green sappy weeds can cause similar issues.

Seed coat staining is the most likely issue to reduce quality and profit due to the emphasis placed on visual appearance at the point of sale.

Conversely, mungbean that is too dry when harvested can result in additional harvest losses, due to the increased risk of shattering, cracking, split seed and moisture weight losses.

Mungbean is susceptible to wet weather at maturity, which causes seed swelling, discolouration, moulds and cracking, so harvest should be carried out as early as practical.

Headers with air assist fronts minimise losses. It is important to have the correct header settings, so drum speeds should be low, fan speeds high and concave settings wide.

Above all, quality checks and adjustments should be made when harvesting begins and when any significant changes to harvesting conditions occur. For example, in the middle of the day the plants and beans will be drier, so it is easier for splitting and cracking to occur.

Samples that contain a lot of green material should be graded as soon as possible to prevent mould developing, causing the sample to become downgraded.

Table 37. Mungbean permits for pest management at October 2019.

Permit number	Date	Crop	Pest	Active ingredient, formulation	Group	Rate	Product/s
PER85152	11 July 2018 to 31 July 2023	Mungbean, adzuki bean, soybean	Cowpea aphid (*Aphis craccivora*), Soya bean aphid (*Aphis glycines*)	500 g/kg pirimicarb	1A	300 g/ha	Aphidex WG Aphicide (61595) plus other registered products containing: 500 g/kg pirimicarb as the only active ingredient.
				800 g/kg pirimicarb		200 g/ha	Aphidex 800 insecticide (83468) plus other registered products containing: 800 g/kg pirimicarb as the only active ingredient.
PER86221	27 August 2018 to 31 August 2021	Mungbean, navy bean,	Redbanded shield bug, green vegetable bug	200 g/L clothianidin	4A	125–325 mL/ha product plus MAXX Organosilicone surfactant™ at 2 mL per litre of water	Sumitomo Shield insecticide (APVMA No. 60689) containing 200 g/L clothianidin as the only active ingredient.
PER8522	9 March 2006 to 31 March 2021	Mungbean, navy bean, adzuki bean, cowpea, faba bean, lentil	Wireworm, black field earwig, field crickets, false wireworm	500 g/L chlorpyrifos	1B	100 mL product plus 125 mL sunflower oil per 2.5 kg cracked sorghum or wheat seed per hectare.	Lorsban 500 EC insecticide plus other registered products containing: 500 g/L chlopyrifos as the only active ingredient.
PER12830	11 May 2011 to 31 July 2020	Pulse crops	Spur throated locust (*Austraris guttulosa*)	1000 g/L fenitrothion EC	1B	1000 g/L fenitrothion EC products – maximum 350 mL/ha	Nufarm Fenitrothion 1000 insecticide plus other registered products containing: 1000 g/L fenitrothion as the only active ingredient.
				1230 g/L fenitrothion ULV		1230 g/L fenitrothion ULV product – maximum 285 mL/ha	Sumitomo Sumthion ULV premium grade insecticide plus other registered products containing: 1230 g/L fenitrothion as the only active ingredient.
PER80936	11 October 2015 to 31 October 2020	Mungbean, adzuki bean, navybean	Two spotted mites (*Tetranychus urticae*), bean or onion thrips (*Thrips tabaci*)	36 g/L abamectin	6	36 g/L products: 150 mL product/ha	Vantal Upgrade miticide/ insecticide plus other registered products containing: 36 g/L abamectin as the only active ingredient.
				18 g/L abamectin		18 g/L products: 300 mL product /ha	Farmoz Wizard 18 miticide/ insecticide plus other registered products containing: 18 g/L abamectin as the only active ingredient.
PER81452	23 November 2015 to 30 June 2023	Mungbean	Bean pod borer (*Maruca vitrata*)	225 g/L methomyl	1A	1.5–2 L/ha. Add 25 mL/100 L of a non-ionic wetting agent	Electra 225 insecticide (48910) plus other registered products containing: 225 g/L methomyl as their only active ingredient.
PER83624	9 December 2016 to 31 March 2021	Mungbean	Red-shouldered leaf beetle (*Monolepta australis*)	150 g/L indoxacarb	22A	200 mL/ha	Steward EC insecticide (59573) as the only active ingredient.
PER82552	12 April 2018 to 30 April 2023	Mungbean, cotton, navy bean, sorghum, sunflower, soybean	Brown marmorated stink bug and yellow spotted stink bug	250 g/ha lambda-cyhalthothrin	3A	80 mL/ha	Karate Zeon insecticide (51422) plus other registered products containing: 250 g/L lambda-cyhalothrin as the only active ingredient.
PER87650	27 June 2019 to 30 June 2024	Mungbean	Bean pod borer (*Maruca testualis*)	150 g/ha indoxacarb	22A	400 mL/ha	Steward EC insecticide (59573) plus other registered products containing: 150 g/L indoxacarb as the only active ingredient.

Table 38. Permits for desiccation of mungbean at October 2019.

Permit number	Date	Crop	Situation	Active ingredient, formulation	Group	Rate	Product/s
PER81558	2 March 2016 to 31 March 2021	Mungbean only	Field crop desiccation	600 g/kg metsulfuron-methyl	3	5 g/ha when applied with glyphosate at label rates	Dupont Ally® herbicide plus other registered products containing: 600 g/kg metsulfuron-methyl as the only active ingredient.

Mungbean

Marketing

Currently, Australia exports over 90% of its mungbean production to countries such as the Philippines, Taiwan, India, USA, Canada, United Kingdom, Malaysia and Japan.

Australia is a relatively small supplier compared with the main exporters – China and Burma. The size of the industry means prices are largely dictated by the demand from the world market, and the supply from the harvest in China (Sept–Nov) and Burma (Jan–May); both of which can fluctuate between seasons. The five-year average exported out of Australia is 100,115 tonnes with a five-year export value of $104 million per year.

The main uses for mungbean are as a green vegetable, bean sprout, in cake manufacture, bean flour and livestock feed.

The grain needs to be graded, cleaned, bagged and packed into shipping containers. The mungbean industry is quite intensive with marketing occurring on an individual basis, typically traded in 25 kg bags.

Grain drying or aeration is necessary when delivery moisture is above the 12% standard. Fumigation to prevent insect contamination during storage might also be needed. Mungbean grading loss is normally 5–10% for high yielding crops. Losses can increase to as much as 20% for manufacturing beans that have had uneven growing conditions or weather damage before harvest.

Forward selling is made easy with contracts being a multi grade hectare contract. Forward selling has improved with a quantifiable test that can be conducted in the lab to take in account pod staining, wrinkling, staining and seed coat damage.

Mungbean buyers focus on visual appearance – a bright, even, green colour being critical – varietal purity and size. Prices are usually based on the final graded quality, and not agreed before grading.

Export standards are quite stringent, with processing plants requiring registration and maintaining AQIS standards, which focus on a high level of hygiene.

The Australian Mungbean Association (AMA) accredited laboratories can issue the ***Machine Dressed Mungbean Standards*** certificate. However, general comments are included below on the main attributes affecting grades.

Mungbean is sold into four main grades:

1. Sprouting – attracts the highest returns focusing on appearance, germination, oversoaks and charcoal rot. Sprouting mungbean requires microbiological testing and in many cases requires the sprouter to test the line before purchase. Main sprouting varieties are Berken and Satin II⊕, with some success with Jade-AU⊕, Regur and Onyx-AU⊕. Growers interested in targeting the sprouting market are advised to speak to a marketer for a clear understanding on the sprouting bean requirements before planting.
2. No.1 – attracts price premiums. Strict specifications focus on appearance; assessed with photographic standards for defects and colour. Seed purity and specific seed size limits apply similar to that of sprouting grade. These beans are normally sold into the repackaging markets and need to be visually appealing.
3. Processing – is classified on appearance, size range and purity with higher tolerance levels than higher grades for defects such as pod scale, seed coat, staining and wrinkled seed.
4. Manufacturing – has the lowest value, with beans used for splitting and the food manufacturing markets. Manufacturing quality is normally from poor, low yielding crops with rain damage or from an unevenly ripened crop. Manufacturing grade is classified largely on purity (98%) with no defined limits regarding defects, germination and pathogen detection.

On average, over 50% of the crop falls into a processing grade with the balance split between No. 1 and manufacturing grades depending on seasonal conditions. Only a small amount meets the sprouting grade.

The Australian mungbean industry has a robust quality assurance program. Growers should be familiar with the AMA Code of Hygenic Practice, specifically the section of the code that outlines growers' responsibilities under the heading 'Hygenic requirements on the farm and during transport to the registered establishment' in ***Code of hygienic practice for mungbeans***.

Grower commodity declaration forms can be found on the AMA website.

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Machine dressed mungbean standards (www.mungbean.org.au/assets/ama-machine-standards-20180904.pdf)

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Code of hygienic practice for munbeans: (www.mungbean.org.au/assets/201411_ama_code_hygienic_practice_mungbeans.pdf).

Grower commodity declaration forms (www.mungbean.org.au/assets/amagrower-dec-2016-17-form.pdf)

To achieve high prices from mungbean production, harvest and storage should focus on preventing:

- Soil contamination
- Insect, disease or weather damaged grain
- Cracked or split grain
- Uneven crop maturity e.g. immature beans being harvested in the sample
- Contamination from animals e.g. birds and rodents
- Weed seed contamination.

Further information

Australian Mungbean Association (www.mungbean.org.au).

Queensland Department of Agriculture and Fisheries (QDAF) (www.daf.qld.gov.au).

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Australian Mungbean Association

Queensland Department of Agriculture and Fisheries

Grains Research and Development Corporation

Mungbeans and soy insects

Physiological and agronomic strategies ....

GRDC *Mirids in mungbeans*

GRDC JADE-AU Pulse Variety Management Package.

GRDC CRYSTAL Pulse Variety Management Package.

GRDC Onyx-AU⁽ᐩ⁾ Pulse Variety Management Package.

GRDC SATIN II Pulse Variety Management Package.

GRDC Resistance management strategy for Helicoverpa armigera in Australian grains.

Summer grain insect identification

Key management issues

- Inspect crops regularly to monitor changes in insect populations throughout the season, observing the presence of both pests and beneficials.
- Inspect crops thoroughly using appropriate checking methods including:
  - a beat sheet for any grubs or pod-sucking bugs sheltering in crop foliage
  - unfurl plant growing points for feeding larvae
  - check the underside of leaves for eggs, noting parasitism
  - sieve for soil-dwelling insects and monitor during early morning and late afternoon when insects are actively feeding.
- Be aware of insect population thresholds, and spray only when populations exceed this and at the most appropriate time of day when insects are active.
- Use only registered insecticides.
- Use integrated pest management (IPM) to minimise pesticide use, increase beneficial insects and reduce environmental impact.

Introduction

This chapter is designed to help identify insects in summer crops, enabling improved crop management decisions.

These insects can be read about in greater detail in the insect section of each crop chapter, or in the sources of further information.

Figure 1. African blackbeetle larvae.

Figure 2. African blackbeetle adult.

Aphids

Figure 3. Green peach aphid.

Figure 4. Cowpea aphid.

Armyworm (*Spodoptera* spp.)

Figure 5. Common armyworm.

Figure 6. Common armyworm moth.

Brown shield bug (*Dictyotus caenosus*)

Figure 7. Brown shield bug. Source: Queensland Department of Agriculture, Fisheries (QDAF).

Cutworm (*Agrotis* spp.)

Figure 8. Cutworm larva/caterpillar.

Figure 9. Cutworm adult. Source: QDAF

Green vegetable bug (*Nezara viridula*)

Figure 10. Green vegetable bug nymphs (2nd instar).

Figure 11. Green vegetable bug adult.

Here when it matters

The team at Local Land Services are here on the ground when it matters, with knowledge, networks and experience, helping farmers improve their productivity, profitability and sustainability.

Our experienced team can connect farmers with the best services and advice to get the most out of their cropping production each year. We provide credible, independent and trusted agricultural advisory services, built on sound scientific knowledge and evidence based practices.

We have Land Services Officers who specialise in crop production, irrigation practices, mixed farming enterprises and soil management.

Advice and assistance is available on practices including:

- **Integrated weed management in crops**
- **Biosecurity practices to protect against pests and diseases**
- **Soil health improvement programs**
- **Up to date information on irrigation practices**
- **Grazing strategies for mixed farming enterprises**

To find out how our agricultural production team can help you, give us a call on 1300 795 299.

We have over 75 agricultural advisory staff across 43 locations in NSW, ready to connect you with the best services, advice and networks.

NSW GOVERNMENT | Local Land Services

Growing farm productivity and healthy environments

Weeds cost our northern grain production an estimated $141million dollars each year. They can be difficult to remove from grain production systems due to their resistive and adaptive nature to the surrounding environment. It's important as growers and advisors, you know how to adapt and implement effective weed control strategies.

Our staff are connecting farmers with a series of integrated weed management workshops to demonstrate the value of integrated strategies in reducing weed numbers throughout the seasons. By using innovation and simple tactics to combat weeds, farmers can continue to grow their productivity and profitability.

This collaborative project will develop and deliver technical content and advice to farmers to increase their understanding of integrated weed management control strategies and the best way to implement them to reduce targeted weed numbers.

Protecting against pests, diseases and environmental threats

Over the dry times, we have seen trucks carting hay and grain into our regions from all over the country. This has created the opportunity for many new weeds to be introduced to cropping areas.

Following rainfall events it is a good time to get out and have a look at what weeds are coming up in areas that fodder or grain has been fed out or stored.

Our recommendation is:
Monitor – Identify – Control

Check out our Weeds in Hay and Grain publication to assist with ID or contact one of our Ag staff in your local office.

Connecting our customers with the best services, advice and networks

Regional Agricultural Landcare Facilitator's (RALFs) are the boots on the ground, connecting you with the services to help improve the sustainability, productivity and profitability on your farm.

RALF's are an important function of the Local Land Services team as they work in partnership with communities, grower groups and industry to deliver agriculture outcomes and work with you to address common issues impacting your region.

The RALF initiative is funded by the Australian Government's National Landcare Program.
To find out how you can work with your local RALF, give us a call today!

Contact us

Give us a call on 1300 795 299 or visit www.lls.nsw.gov.au to find out how we can help you!

Connect with us on social media @llsnsw

Grass blue butterfly (*Zizina labradus*)

Figure 12. Grass blue butterfly larvae. Source: QDAF

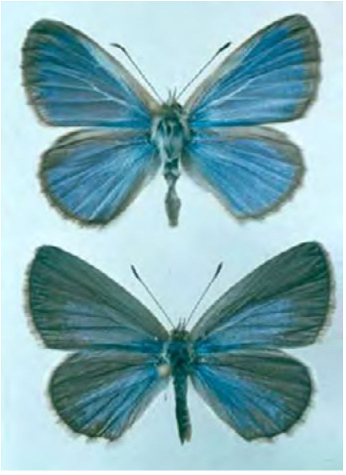

Figure 13. Grass blue butterfly adults. Source: QDAF

Heliothis (*Helicoverpa* spp.)

Figure 14. *Helicoverpa armigera* larvae. Source: QDAF

Figure 15. *Helicoverpa armigera* adult. Source: QDAF

Australian plague locust (*Chortoicetes terminifera*)

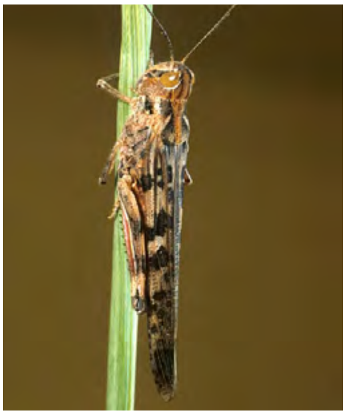

Figure 16. Australian plague locust.

Spur throated locust (*Austracris guttulosa*)

Figure 17. Spur throated locust.

Lucerne seed-web moth (*Etiella behrii*)

Figure 18. Lucerne seed web moth caterpillar.

Figure 19. Lucerne seed web moth.

Lucerne crown borer (*Zygrita diva*)

Figure 20. Lucerne crown borer adult.

Mirids

Figure 21. Green mirid (*Creontiades dilatus*).

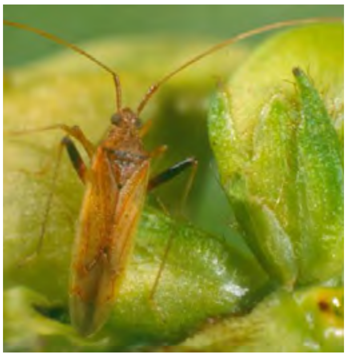

Figure 22. Brown mirid (*C. pacificus*). Source: QDAF

Mites

Figure 23. Two-spotted spider mite (*Tetranychus urticae*).

Red-banded shield bug (*Piezodorus hybneri*)

Figure 24. Female red-banded shield bug. Source: QDAF

Rutherglen bug (*Nysius vinitor*)

Figure 25. Rutherglen bug.

Figure 26. Rutherglen bug.

Sorghum midge (*Contarinia sorghicola*)

Figure 27. Sorghum midge.

Soybean moth (*Stomopteryx simplexella*)

Figure 28. Soybean moth caterpillar.

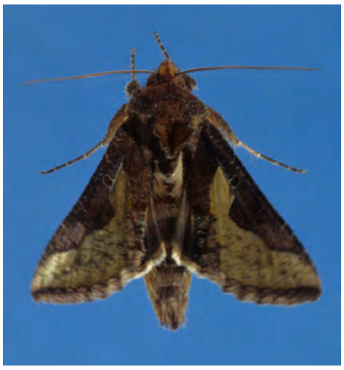

Figure 29. Soybean moth adult.

Western flower thrips (*Frankliniella occidentalis*)

Figure 30. Western flower thrips.

Whitefly

Figure 31. Silverleaf whitefly B-biotype (*Bemisia tabaci*).

Wireworms (*Agrypnus* spp.)
False wireworms (*Pterohelaeus* spp.)

Figure 32. Wireworm larvae (*Agrypnus* spp.)

Figure 33. True wireworm (*Elateridae – Arachnodima* spp., *Agrypnus* spp.).

Figure 34. False wireworms (*Pterohelaeus* spp.).

Further information

Additional information on insect identification and management in summer crops can be found at the following sources:

Publications

Crop insects: The ute guide, Northern Grain Belt, GRDC (https://grdc.com.au/resources-and-publications/apps/grdc-ute-guides).

Good bug bad bug?: An identification guide for pest and beneficial insects in summer pulses, peanuts and chickpeas, GRDC and QDAFF (https://thebeatsheet.com.au/wp-content/uploads/2012/04/GoodBadBug-FINALscreen22Feb3.pdf)

Insect and mite control in field crops 2013, NSW DPI (www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/insect-mite-crops).

Websites

The beat sheet, QDAF (https://thebeatsheet.com.au/)

IPM guidelines for grains (https://ipmguidelinesforgrains.com.au/)

CESAR **PestFacts south-eastern**, (http://cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/)

Beneficial insects and IPM

Australasian Biological Control Association, (www.goodbugs.org.au)

BioResources, (www.bioresources.com.au)

Bugs for Bugs, (www.bugsforbugs.com.au)

Ecogrow, (www.ecogrow.com.au)

Resistance management strategies for a number of pests (ipmguidelinesforgrains.com.au).

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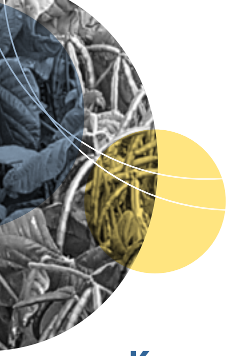


Soybean

Key management issues

- To maximise yield potential and grain quality, choose the recommended variety for the region and plant at the optimum time to take full advantage of daylight/heat units and to avoid damage from early frosts.
- In NSW, dryland (rain-fed) soybean crops should be planted into a full profile of soil moisture (100–120 cm wet soil) in the North West Slopes and Plains and 60–80 cm of wet soil in the Northern Tablelands. Irrigated soybean fields should preferably be pre-irrigated and budgeted to allow 6–8 ML/ha.
- Check seed germination and purity.
- Seed size varies between varieties and seasons. Check each bag for seed size and use the **Calculating planting rates on page 74** to calculate planting rates based on seed size and target plant population.
- Always inoculate seed using the soybean-specific strain of Group H inoculant (strain CB 1809).
- Correct any nutritional deficiencies of phosphorus, sulfur, potassium and trace elements. Zinc deficiency can occur in heavy grey clays and molybdenum in acid soils in NSW soybean production areas.
- Establish and maintain a uniform plant stand at recommended plant populations for your climatic and soil conditions.
- Plan weed control carefully: select appropriate herbicides (pre-emergent and/or post-emergent) and/or use inter-row cultivation.
- Inspect crops for pest and beneficial insects at least once a week and then twice a week from flowering to maturity.
- Reduce the risk of phytophthora root and stem rot by using resistant varieties and selecting paddocks with good drainage and a disease-free history.
- To maximise grain quality harvest soybean grain as soon as possible once mature. This reduces the risk from weather damage or harvest losses from over-dry grain.

Brief crop description

Soybean is a profitable crop for dryland and irrigated farming systems in NSW. Dryland (rain-fed) soybean production is centred on the north coast and the milder areas of the Northern Tablelands, northern slopes, and Liverpool Plains. north coast soybean crops are grown mainly in the Clarence, Richmond and Tweed valleys, but also as far south as the Manning Valley.

Irrigated soybean production is centred on two main regions: the Riverina in the south and the inland river valleys from the central west to the Queensland border including the Macquarie, Namoi and Gwydir.

Soybean crops are particularly profitable where the grain attains the quality standard for human consumption markets. Significant premiums are paid for grain suitable for these markets, making the gross margin more attractive where high yields are achieved. The expansion into human consumption markets is a result of improved Australian varieties with better grain quality including larger seed size, clear hilum, and protein levels above 40% dry matter basis. Varieties with these traits allow growers to access a wider range of markets.

While the areas currently grown are indicative of the strong competition from other summer crops, particularly cotton, many producers retain soybean in their crop rotation for farming system benefits including:

- an increased cash flow and a relatively low input/low risk option compared with other summer crops
- a contribution to the soil nitrogen (N) balance, as soybean has a very high capacity to fix N compared with other legumes
- rapid stubble breakdown and improved soil structure resulting in improved establishment for following crops or pastures

- weed and disease management options for non-legume crops such as cotton, rice, sugar cane, maize and winter cereals
- stubble and the occasional failed crop, which provides high value grazing
- expanded options for hay and silage, with a high nutritional value for beef and dairy cattle, and sheep.

Paddock selection

As a summer grain legume, soybean is well suited to growing in rotation with a range of crops including winter cereals, canola, cotton, rice, sugar cane, sorghum and maize. In irrigated and dryland farming systems in NSW, a double cropping rotation of soybean and winter cereal is considered profitable and offers growers opportunities to:

- increase water use efficiencies
- increase gross margins per megalitre of irrigation water used
- incorporate a break crop into the rotation to improve disease and weed management
- improve soil N levels in farming and pasture rotations.

Under irrigation, quicker maturing varieties are harvested before the autumn break, allowing winter cereal or fodder crops to be planted at an appropriate time into a seedbed with some stored moisture. The stored moisture and N residue can be used immediately by the following cereal crop. Soybean can be planted back into the same field after harvesting the winter cereal. The rotation can consist of two to three years of alternate crops of winter cereals and soybean, or two to three years of winter cereals followed by a similar period of soybean. However, these crops should be closely monitored for any sign of disease build up or shifts in the weed population including chemical resistance.

Soil management

Soils should be managed to maintain adequate groundcover through both fallow and cropping phases. This is beneficial for soil health (soil biology and soil structure) and to minimise soil erosion. Building up soil organic matter improves soil structure with the soil becoming softer for easier planting using disc or tyne penetration. This results in a more even planting depth and easier root penetration to depth.

Minimum- or no-till systems are used to maximise groundcover and improve soil structure, moisture content and soil biological populations. However, no-till systems can limit some pre-emergent herbicide use and control of certain perennial weeds.

In irrigated farming systems and in high rainfall zones such as the north coast, soybean crops yield well on raised bed systems. Raised beds are usually also associated with a controlled traffic and GPS guidance system that confines wheel zones to reduce compaction in the plant root zone. Major advantages result from this system including:

- improved soil structure
- improved irrigation efficiency and water infiltration
- timely access to the field after rainfall
- the ability to double-crop with successive crops.

In southern NSW, irrigated soybean crops grown on **raised beds** have been shown to produce higher and more consistent yields than soybean crops planted on a traditional border check layout. Raised beds make it possible for the soybean crop to be planted into a moist seedbed for successful and timely crop establishment.

Border check layouts often have establishment problems, due to difficulties achieving a moist soil suitable for planting that is not too wet for machinery access. Often the soil surface dries out too quickly before, during and after planting resulting in uneven and low plant population and patchy crop establishment.

In NSW, soybean crops are successfully grown on a diverse range of soil types including the better class alluvial soils, heavy black and grey clay soils, red volcanic soils, mixed coastal soil types including acidic peat soils in rotation with sugarcane, and lighter textured hill soils in pasture development programs.

Soil salinity

Yield reductions occur at soil salinity levels greater than 2.0 dS/m. Nodulation is impaired and general plant growth is affected. Paddocks with known salinity problems should be avoided for soybean cropping.

Soil acidity and liming

Soybean plants are adapted to acid soils and prefer pH_{Ca} levels from 5.2 to 6.5. As pH_{Ca} levels drop below 5, increasing amounts of toxic aluminium can enter the soil solution. This effect is common in the soils of the north coast region of NSW and is greatest in soils that are also low in organic matter as indicated by a soil test. Soils with pH_{Ca} levels of 4.5 or less are unsuitable for growing soybean.

All intensive agriculture is acidifying and a lime requirement must be factored in as an essential input for a sustainable cropping system. Soybean plants leave an N-rich residue that breaks down to nitrate and becomes available to the following crop. When nitrates are leached, the leaching zone becomes more acidic. In general terms, for maintenance incorporate 1 t/ha lime every five years to maintain pH on lighter textured soils and up to 2 t/ha on heavier textured soils.

For soybean crops, keep aluminium saturation levels less than 15% and manganese less than 20 mg/kg. If barley is also grown, depending on variety, keep aluminium saturation levels below 5% and manganese less than 50 mg/kg. For a pH_{Ca} below 5 where aluminium and manganese are at toxic levels, apply up to 2.5 t/ha of lime and monitor pH change with soil tests. Lime and all other fertiliser decisions should be based on soil test results from an accredited testing laboratory.

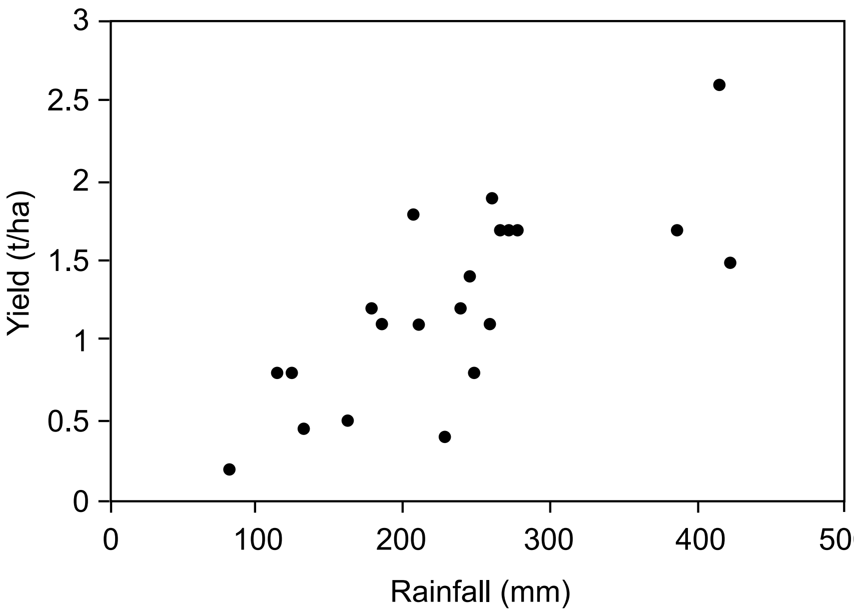
Starting soil water

Soybean crops should be planted into a full soil moisture profile where possible; 100–120 cm of wet soil is ideal. This is rarely achieved on the NSW north coast due to the large amount of double cropping. However, high in-crop rainfall usually offsets lower starting soil moisture. In the cooler, wetter areas of the Northern Tablelands, between 60 cm and 80 cm of wet soil at planting is a realistic target.

Dryland yield and rainfall

The former NSW DPI soybean breeding program led by Dr Ian Rose at Narrabri planted early indeterminate types in late November–early December for 24 seasons. In all seasons, the seeds were planted in grey vertosols with a full moisture profile on wide (100 cm) row spacing at the then recommended dryland plant population of 15–20 plants/m^2. This allowed the relationship between rainfall over the 120 days following planting and the resulting yield to be described in Figure 35.

Growers can use this relationship as a guide to the dryland yield expectation in similar wide-row farming systems. As an example, the expected rainfall at Narrabri for the 120 days from 1 December is 260 mm. This translates to a yield expectation of around 1.3 t/ha. If the in-crop rainfall expectation is less than 200 mm then yield potential will drop below 1 t/ha. At the higher yielding end of the relationship, it is clear that yields above 2 t/ha can only be expected where rainfall in the growing period exceeds 300 mm.



Each point represents the actual yield obtained (vertical axis) for the rainfall measured (horizontal axis) at NSW DPI Narrabri.

Figure 35. Relationship between dryland, wide-row soybean yield and rainfall at Narrabri.

Soybean

Irrigation

High yielding soybean crops use 6–8 ML (megalitres) of irrigation water per hectare depending upon soil type, variety, paddock/irrigation layout and seasonal conditions.

Soybean is suited to a range of irrigation systems including raised beds, hills, full flood and overhead sprinkler irrigation. An increasing number of pressurised water systems (pivots and lateral-move irrigators) are being used in NSW, providing flexibility for irrigation quantity and timing for soybean growers.

In the Riverina, soybean crops are typically grown on raised beds using furrow irrigation on slopes of 1:1500 or flatter with 400–800 m run lengths. This allows better drainage around the root zone, less waterlogging problems and diseases and minimal establishment difficulties. About 50% of raised bed layouts in southern NSW are now constructed across the slope and contained within contour bays with bankless channels for water supply and drainage. This layout has improved irrigation and labour efficiencies and is better suited to red–brown earth soils that inherently have reduced water infiltration characteristics compared with self-mulching grey clays.

The recommended practices for irrigating soybean crops are pre-irrigating fields 1–3 weeks before planting and then planting as soon as the soil is dry enough to work.

Watering up (irrigating after planting in dry soil) is possible in some situations, but is not ideal as it requires more care to ensure that soils do not crust and weeds do not germinate at the same time as the crop. Watering up is not recommended in fields that have not previously grown soybean – dry and hot summer conditions can quickly kill the rhizobia on inoculated planting seed resulting in poor nodulation and N fixation. It is also not recommended in border check systems as seed can become waterlogged and rot or burst.

Regardless of the type of irrigation system, soybean crops have a peak water demand during flowering and early pod filling. For example, a crop planted in late November or early December in southern NSW, will have a peak water demand from mid January to late March, or from 50–110 days after emergence.

Grain yield and protein content depend on appropriately timed irrigation to avoid moisture stress. Intermittent moisture stress can reduce protein content. When the plants start to become moisture stressed, they can shut down root nodules until they are watered again; once the crop is watered it can take a few days for the rhizobium in the nodules to become fully functional and reactivated. The cumulative effect over the season can have a negative effect on the total plant N content and ultimately seed protein content. High grain yield can also limit grain protein content as these factors are inversely correlated in most varieties.

The number of irrigations and amount of water used by the crop will vary depending on season, soil type, irrigation equipment and target yield. Monitoring soil moisture will help to identify when the crop is approaching water stress and help plan irrigations.

Timing the final irrigation is also critical, as it needs to ensure adequate water until physiological maturity, yet not allow the field to remain too wet for harvest.

As soybean crops are often flowering and filling pods during the hottest part of the summer, moisture stress can reduce yield by reducing the number of retained pods and/or by reducing seed size and weight. However, some moisture stress before flowering can help the crop develop a deeper root system, providing a buffer for times of unexpected moisture stress later in the season. This strategy will work best on well-structured soils that allow the crop to develop larger and deeper root systems.

Inoculation

To achieve an even plant stand, maximum crop growth, grain yield and N fixation from soybean crops, inoculate planting seed with Group H soybean inoculant (strain CB 1809) every time a soybean crop is planted. While some soybean rhizobia (cells of the bacterium *Rhizobium japonicum*) can survive in fields previously planted with inoculated soybean seed, the amount of cells and their distribution will not be uniform, particularly if there has been waterlogging or soil disturbance. Effective nodulation is critical to ensure crop vigour and grain with a high protein content. There are no native soybean rhizobia in Australia capable of effectively nodulating soybean. Selected soybean-specific rhizobia can be introduced to soybean fields by:

- coating seed with a slurry of peat or liquid inoculant immediately before planting
- injecting liquid inoculant onto seed in the furrow at planting
- placing a granular inoculant in the furrow with the seed at planting.

When purchasing inoculant, check the expiry date and look for the 'green tick' logo, which indicates quality assurance and independent testing by the Australian Inoculants Research Group.

Soybean has been shown to fix the most N per hectare (180 kg N/ha) of all the grain legume crops commonly grown in Australia. Lupin (130 kg N/ha) and faba bean (110 kg N/ha) are ranked the next highest, with chickpea (70 kg N/ha) and mungbean (34 kg N/ha) ranked among the lowest.

Soybean grain is high in protein and the soybean plant has a high N requirement, but when inoculated correctly, soybean crops fix more atmospheric N_2 than they need, leaving behind N-rich crop residues. Studies by NSW DPI on the north coast of NSW showed that on average, well-nodulated soybean crops fixed around 80 kg N/t of soybean grain produced. For each tonne of grain harvested, around 35 kg of the fixed N was left in the soil as plant-available nitrate residues for the following crop or pasture. For example, a soybean crop with a grain yield of 2.5 t/ha fixed around 200 kg of N/ha and left behind around 70 kg of residual N/ha after the grain was harvested.

Soybean inoculant contains live bacteria, which will be killed by excessively hot or dry conditions. Manage inoculum to ensure the greatest number of live bacteria are available to the seed. Store it in a cool, but not frozen, shady location until it is required. If using a peat slurry or liquid inoculant to coat planting seed, inoculate small batches of seed and sow immediately.

Do not lime-coat the seed after inoculating, and do not tank mix liquid inoculants with pesticides, fertilisers or any other products unless the inoculant label expressly states that it is safe to do so. Small amounts of starter N (up to 20 kg N/ha) can be required where large amounts of organic matter, such as sugar cane trash, have been incorporated before planting. However, too much starter N should be avoided as it will interfere with nodulation and N fixation for the crop's duration.

Growers are encouraged to check on the success of their inoculation procedures six weeks after planting. Check at several locations within the crop. Carefully dig up a group of plants along a section of row, wash the root systems and cut open several nodules. Functioning nodules should be large and firm with a whitish colour on the outside and a pink–orange colour on the inside. Nodules that are very small, not firm or that have a green, grey or white colour inside are not functional and you should seek advice from your local agronomist about N management for crops with non-functional nodules.

In addition to inoculating correctly, sound agronomic practices that promote vigorous, high biomass soybean crops will also ensure maximum N fixation. For more information refer to the GRDC ***Inoculating legumes: A practical guide***.

GO TO PAGE
Inoculating legumes: A practical guide (https://grdc.com.au/GRDC-Booklet-InoculatingLegumes).

Planting time

Planting windows and varieties vary widely across Australia's soybean production regions. **Table 39** shows the recommended variety to plant and correct window for your region. This information is based on long-term research experiments that NSW DPI has conducted to identify the optimum yield for soybean varieties based on planting times and locations in NSW.

Southern NSW: aim to sow from mid November to mid December so that crops can mature as early as possible, preferably by late March/early April. This planting window maximises plant dry matter pre- and post-flowering, setting the crop up for maximum yield. Planting in late December (after 25 December) shortens the growing season and considerably reduces total plant dry matter. This reduces yields and results in plants maturing in cooler overnight temperatures, which delays harvest. It also reduces the farmer's flexibility in timing operations and frequently exposes crops to greater insect pressure. Planting in early January in southern NSW is not recommended.

Northern inland NSW: the planting window for maximum yield potential starts in early to mid November. Yield potential declines with later plantings. The critical cut-off date varies from mid December in the Macquarie and Namoi valleys and tablelands, to late December in the irrigated border areas. By mid January, the yield potential declines by 30% and other crop options are preferred.

Manning, Hastings and Macleay valleys: the recommended planting times range from early November to the end of December.

North Coast region: current varieties can be planted from mid November to mid February. Within this range, each variety has an optimum planting period of 2–3 weeks.

Soybean plants flower and mature in response to increasing darkness hours – that is, shortening daylight hours. Soybean varieties are photosensitive and in general, the later they are planted the fewer days until flowering starts. For example, if the same variety is planted on the same day at Casino and Wauchope, it will experience longer daylight hours during summer in Wauchope and so flowering will begin a little later than in Casino.

Planting times are recommended for each variety to achieve the optimum balance between vegetative growth and yield potential. Varieties planted later than their recommended planting time will likely have shorter plants with pods set closer to the ground. This can be somewhat compensated for by increasing the plant population by up to 20% in later plantings. Conversely, varieties that are planted earlier than recommended can spend too long in the vegetative phase, grow too tall and lodge, which increases the risk of fungal diseases such as *Sclerotinia* and makes harvesting more difficult. Planting in the early part of the window is recommended, especially where early growth is likely to be slower, such as where soil fertility is low, or where crops are direct-drilled.

Table 39. Recommended planting times for soybean in NSW.

Region of NSW	Variety	November				December				January			
		1	2	3	4	1	2	3	4	1	2	3	4
Northern inland – dryland	Moonbi	<	★	★	★	>							
	Hale, Ivory		<	★	★	★	★	>					
Northern inland – irrigation (Macquarie Valley and north)	Moonbi, Richmond, Cowrie, Soya 791, Hale, Ivory		<	★	★	★	★	★	★	>			
Northern Tablelands and slopes	Hayman (for silage or hay)*	<	★	★	★	★	>						
	Moonbi, Richmond, Soya 791, Cowrie, Intrepid, Hale	<	★	★	★	★	>						
North coast – Clarence, Richmond and Tweed rivers	Hayman (for silage or hay)*	<	★	★	★	★	★	>					
	Moonbi, Soya 791	<	★	★	★	★	★	>					
	Cowrie			<	★	★	>						
	Zeus, Richmond, Manta				<	★	★	★	★	>			
	A6785					<	★	★	★	>			
	Poseidon, Surf						<	★	★	★	>		
	Hayman (for grain)*				<	★	★	★	★	★	★	★	★
Mid North Coast – Manning, Hastings and Macleay rivers	Hayman (for silage, hay or grain)	<	★	★	★	★	★	>					
	Moonbi, Richmond, Cowrie, Soya 791		<	★	★	★	>						
	Zeus				<	★	★	>					
	Manta				<	★	★	★	>				
	Poseidon					<	★	★	>				
Central west – irrigated	Moonbi, Soya 791		<	★	★	★	★	>					
Southern NSW Riverina – irrigated	Burrinjuck, Djakal, Bidgee, Snowy		<	★	★	★	★	★	>				

< Earlier than ideal for the variety to reach yield potential
★ Optimum planting time to achieve full yield potential
> Later than ideal for the variety to reach yield potential
* NOTE: On the north coast the recommended planting times for Hayman differ depending on the crop objective. For optimum silage or hay production, plant from mid November to early December. For grain production plant from the beginning of December until mid February.

Row spacing

Soybean has a large seed size relative to other crops and a delicate, thin seed coat. It is best grown in defined rows using the seeder to achieve uniform seed depth and placement along the row to obtain the target plant population. Row cropping allows more options for weed control including using banded sprays, shielded sprayers and inter-row cultivation. It also allows easier access into the crop for bug-checking and helps with using directed sprays for insect control (e.g. angled spray delivery to target the underside of leaves).

In humid coastal environments, wider row spacings aligned to the prevailing wind direction can reduce the incidence of *Sclerotinia* (white mould) infection by reducing humidity in the crop. Improving aeration in the crop canopy can also delay the development of diseases such as soybean leaf rust and bacterial blight, which are favoured by leaf wetness.

Soybean is successfully grown on a wide variety of row spacings associated with NSW's diverse cropping systems. In cotton rotations, soybean crops will yield well on a row spacing of 100 cm, but grower experience suggests that yields are up to 10–20% higher using a narrower, 50–75 cm, row spacing.

Dryland crops on the slopes and plains are traditionally planted on a 100 cm row spacing, to conserve more soil moisture for pod-fill. In high yielding situations, <75 cm row spacings out-yield wider row spacings.

In the higher rainfall areas of the Northern Tablelands and north coast, crops are normally planted on narrow (18–50 cm) row spacings to achieve maximum yield potential. Wider rows are acceptable provided complete canopy closure is achieved by early–mid flowering and weeds are well managed. Narrow rows are preferred when planting late, or where opportunities for weed management tend to be more limited as the crop canopy closes more quickly.

In cultivated seedbeds, seed is generally planted using conventional seed drills with row spacings between 18 cm and 50 cm. With minimum or no-till systems, specialised direct drills (preferably disc openers) or precision planters are necessary to ensure uniform seed placement and even access through pasture residue or crop stubble.

In southern NSW irrigation areas, the industry standard configuration is raised beds at 1.8 m furrow to furrow, with two rows planted on each bed (90 cm row spacing). However, row spacing can range from 30 cm to 90 cm depending on the farming system, stubble loads, time of planting, and inter-row planting ability. Planting an additional row of plants in the middle of the raised bed requires more water and good lateral movement of soil water to ensure that adequate moisture is available to plants in the centre row.

Soybean

Plant population and planting depth

Potential yield is determined by the ability to establish and maintain a uniform plant stand. Table 40 lists desirable plant population targets. Recent research by NSW DPI in northern inland and coastal NSW showed that variety Moonbi⊕ requires a plant population up to 30% higher than the general recommendation for other varieties in order to achieve optimum yield (**Moore and Dunn, 2019**). Lower plant populations are acceptable when planting is early, while higher densities are preferred for planting later in the recommended planting window.

With late-planted varieties, higher populations are recommended because yield steadily declines as population density is reduced to below 30 plants/m^2.

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Moore and Dunn 2019, ***Mungbean and soybean agonomy – time of sowing, row spacing and plant population: findings from combined field trial analysis 2013–2018***, (https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/08/mungbean-and-soybean-agronomy-time-of-sowing,-row-spacing-and-plant-population-findings-from-combined-trial-analysis-2013-2018).

Table 40. General recommendations for soybean plant populations for regions of NSW.

NSW region	Target plant population – established plants/m^2
Northern inland	
Irrigation/mild dryland areas	25–30
Dryland/slopes and plains	15–20
Tablelands	35–40
Coastal	
Narrow rows (< 75 cm)	30–40
Wide rows (> 75 cm)	28–32
Southern	
Mid November–mid December	30–35
Mid December–late December	35–45

Growers planting varieties for the tofu market such as Hayman⊕, Richmond⊕, Moonbi⊕, Burrinjuck⊕, Bidgee⊕, Snowy⊕ and Cowrie will need to adjust planting rates to account for these varieties' larger seed size. Seed size of current commercial varieties is given in **Table 41**. Likewise, planting rates of small seeded types such as A6785 must be adjusted to avoid overly dense plant populations, which can lead to lodging and reduced yield. See **Calculating planting rates on page 74** below.

Calculating planting rates

The following formula can be used to calculate planting rates, taking into consideration:

- number of seeds/kilogram (seed size or seed weight)
- target plant population
- germination % (e.g. 90% germination = 0.9 in the formula)
- establishment: usually 80%, unless planting into adverse conditions (80% = 0.8 in the formula)

Method

		target plant population/m²		establishment percentage*		germination percentage		seeds/kg		
.....10,000...	×	.........30.........	÷	.........0.8..........	×	..........0.9............	×	........4500.....	=	your planting rate ...92.6 kg/ha

Experience has shown that dryland soybean crops generally yield best when planted at a lower plant population than for irrigated crops, particularly in the hotter, drier regions. The variety Moonbi$^{\Phi}$ is an exception to this rule, however, and requires up to 30% higher seed rate than the general recommendations to achieve optimum yield (**Moore and Dunn, 2019**). Low plant population, e.g. lower than 15–20 plants/m^2, can cause harvesting problems because the pods are set too close to the ground, especially in the early-maturing varieties.

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Moore and Dunn 2019, ***Mungbean and soybean agonomy – time of sowing, row spacing and plant population: findings from combined field trial analysis 2013–2018***, (https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/08/mungbean-and-soybean-agronomy-time-of-sowing,-row-spacing-and-plant-population-findings-from-combined-trial-analysis-2013-2018).

Seed should be planted into moist soil no deeper than 5 cm in dryland situations. Where moisture is deeper than this, drilling to 7.5 cm has been successful, but emergence can be poor, particularly if heavy rain causes the soil to pack or crust before seedlings emerge. Using rollers after sowing is generally not advised. Planters with press wheels – that press the soil onto the sides of the seeds whilst leaving a crown of uncompacted soil for easy seedling emergence – are preferred. In irrigated situations, shallower planting (2–3 cm) is preferred when crops are planted dry and watered up. This is often the case when double-cropping.

Seed quality

Do not use low quality planting seed. Soybean seeds are relatively short-lived and, even when produced under optimum conditions, can lose germination and vigour after a few months in storage. High moisture levels and high temperatures exacerbate seed deterioration. Prolonged wet weather before harvest reduces seed quality by alternately wetting and drying seed in the pods. Carefully select paddocks intended for seed production and harvest these as early as possible.

Obtain a reliable germination test after harvest to make sure seed is worth keeping and test it again 4–8 weeks before planting to ensure it has not deteriorated. This is especially important in larger seed-sized varieties. The germination percentage of harvested seed can vary greatly depending upon the quality of storage conditions over winter. Germination tests typically cost around $80–95 for a germination and seedling vigour test.

Soybean seeds have a thin seed coat, making them more susceptible to damage than other crop species. Incorrect seed handling, using spiral augers, and long drops of seed onto hard surfaces can damage the seed coat and split seed. Belt conveyers are preferred for seed intended for the human consumption market or kept for planting. Larger seeded types grown for human consumption markets are at greater risk of mechanical damage than the smaller seeded crushing types. Harvesting soybean grain with a very low moisture content, for example 8%, can increase damage compared with harvesting at the optimum (13%) moisture content.

Variety characteristics

Select a variety according to location, disease resistance, maturity, yield potential and suitability for the target market.

If a large area of soybean is planned, consider selecting more than one variety. Use varieties of different maturity to spread planting, maintenance and harvesting operations and environmental risks. It is also important that the industry does not become reliant on one variety only, as phytophthora root and stem rot resistance could break down as new races evolve.

Information is provided with emphasis on recent releases. Recommendations are based on extensive testing by NSW DPI. Varieties with the PBR symbol ($^{\Phi}$) are covered by the ***Plant Breeder's Rights Act 1994***.

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Plant Breeder's Rights Act 1994 (https://grdc.com.au/news-and-media/news-and-media-releases/misc/2011/09/end-point-royalties-explained)

Table 41. Characteristics of soybean varieties available in NSW 2019.

Variety	Growth habit	Colour			Resistance or tolerance to							Seed size (no. seeds per kg @ 12% moisture)	Area of adaptation
							Phytophthora immunity or strong tolerance 3						
		Flower	Pod hair	Hilum	Manganese toxicity (1–10, where 10 is highly tolerant)	Weathering (1–10, where 10 is highly tolerant)	race 1	race 4	race 15	race 25	Powdery mildew		
A6785	Determinate	white	grey	brown	3	7	✓	✓	✓	✓	–	5500–6250	North Coast
Bidgee	Determinate	white	grey	clear	–	–	✓	✓	✓	✓	no	4750	Southern irrigated
Bunya	Determinate	white	grey	clear	8	6	✓	✓	✓	✓	no	4000	Northern inland irrigated
Burrinjuck	Determinate	white	grey	clear	–	–	✓	✓	✓	1	no	4150	Southern NSW and northern Victoria irrigated
Cowrie	Determinate	white	grey	clear	7	6	✓	2	2	2	–	4350	North coast and Northern Tablelands dryland, northern inland and Macquarie Valley irrigated
Curringa	Indeterminate	white	grey	clear	–	–	✓	✓	✓	✓	–	5250	Southern irrigated, outclassed
Djakal	Indeterminate	white	grey	buff	–	–	✓	✓	✓	1	–	5000	Southern irrigated
Empyle	Indeterminate	white	grey	buff	–	–	✓	✓	✓	2	–	6600	Southern irrigated, outclassed
Hale	Indeterminate	white	brown	black	–	–	✓	✓	✓	2	–	5000	Northern dryland and irrigated
Hayman	Semi-determinate	white	grey	clear	7	7	✓	✓	✓	✓	yes	4150	Northern Tablelands and north coast
Intrepid	Indeterminate	purple	brown	black	–	–	✓	2	✓	2	–	5000	Northern Tablelands
Ivory	Determinate	white	grey	clear	–	–	✓	✓	2	✓	–	4750	Macquarie Valley and northern irrigation, Northern Tablelands dryland
Manta	Determinate	purple	brown	black	6	8	✓	2	2	2	–	4750	North coast
Moonbi	Semi-determinate	white	grey	clear	7	7	✓	✓	✓	✓	yes	4550	North coast, Northern Tablelands and northern inland
Poseidon	Determinate	purple	brown	black	6	8	✓	2	2	2	–	5000	North coast
Richmond	Determinate	white	grey	clear	8	8	✓	✓	✓	✓	yes	4550	North coast and Northern Tablelands dryland and northern inland irrigated
Snowy	Indeterminate	white	grey	clear	–	–	✓	✓	✓	✓	–	4500	Southern NSW and northern Victoria irrigated
Soya 791	Determinate	white	grey	brown	3	5	✓	✓	2	✓	no	5250	North coast and Northern inland
Surf	Determinate	purple	grey	clear	7	7	✓	✓	✓	2	–	4550	North coast
Zeus	Determinate	purple	brown	black	6	9	✓	2	2	2	–	5000	North coast

✓ Indicates immunity or strong tolerance.
– Indicates the variety reaction is unknown.
1–10 scale for resistance or tolerance where 1 indicates very low tolerance and 10 is very high tolerance.
1 Some tolerance.
2 Susceptible.
3 Indicates disease assessments and field observations by Dr Malcolm Ryley, Plant Pathologist formerly of QDAF, Queensland and marker assisted screening for *Phytopthora* resistance genes by Dr Andrew James, CSIRO, St Lucia
This table was updated by Dr Natalie Moore and Mr Mat Dunn (NSW DPI) based on replicated, multi-season research experiments and field observations available to 2019.

Southern NSW varieties

In the Murrumbidgee and Murray Valleys, varieties suited to the human consumption market are Djakal, Snowy⟁, and Burrinjuck⟁ (released in 2018). Under optimum conditions, growers should be targeting over 4 t/ha yields. Although variety Curringa is still considered acceptable for the human consumption market, it is significantly lower yielding and longer maturing.

In the mid Lachlan Valley, the preferred varieties are Djakal, Snowy⟁, Burrinjuck⟁ and Bidgee⟁. All are indeterminate types. Higher yielding, early maturing human consumption varieties have largely replaced older oilseed crushing types. Older varieties now superseded include Curringa, Empyle, and Bowyer.

Central NSW varieties

In the Macquarie Valley, irrigated soybean production has traditionally been based on variety Soya 791. In variety evaluations conducted by NSW DPI from 2014–2018, new variety Moonbi⟁ out-yielded Soya 791 with faster maturity and less lodging.

Coastal NSW varieties

Characteristics important for reliable production in coastal environments and soils include:

- consistently high yield and grain protein content, above 40% (dry matter basis) for access to human consumption markets
- weathering tolerance at harvest
- good mature plant height (80–100 cm) for the relevant planting time without lodging
- tolerance to high soil manganese levels, common in soils with low pH and prone to waterlogging
- tolerance to downy mildew and powdery mildew leaf disease
- tolerance to phytophthora root rot (not a common problem in the north coast region to date).

Varieties currently recommended for the north coast include Richmond⟁, Moonbi⟁, Hayman⟁, Soya 791, Cowrie and Surf for human consumption markets and Zeus, Manta, Poseidon and A6785 for crushing markets. Varieties that are not recommended for the north coast do not have all the traits desirable for coastal environments. If grown outside their region of adaptation, varieties recommended for other regions (e.g. Bunya⟁ and Warrigal, which are recommended for the inland production regions of Queensland and NSW) have a greater risk of not performing to their full potential.

Northern inland NSW varieties

The preferred varieties for the human consumption market are Moonbi, Richmond⟁, Soya 791, Cowrie, and Bunya⟁. For crushing, the main varieties are Hale, Valiant and Intrepid. For hay and silage production, Hayman⟁ is the preferred variety.

Variety descriptions

PBR varieties have an End Point Royalty (EPR), including breeder royalties, which is payable at the grain's first point of sale from these varieties. Growers are allowed to retain seed from producing these varieties for their own use as seed only. For details on how the EPR system works and what situations attract a royalty payment, growers are encouraged to read the **GRDC information about the PBR Act**.

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GRDC information about the Act (https://grdc.com.au/news-and-media/news-and-media-releases/misc/2011/09/end-point-royalties-explained)

Asgrow A6785. This variety has a brown hilum and small seed size and is suited mainly to the crushing market and to soyflour production. It is sometimes used in soymilk manufacturing, although seed size is smaller than is preferred for this market and grain protein levels often fall below 40% dry matter. It produces high yields if planted at the correct time. It has tolerance to races 1 and 15 of *Phytophthora*, and has moderate weathering tolerance. On the NSW north coast, A6785 can lodge if planted too early or at too high a plant population.

Bidgee⟁. This variety is a clear hilum, high protein variety for southern NSW, currently licensed to Soy Australia. The Australian Soybean Breeding Program (ASBP) released it as a higher yielding, higher protein and shorter season alternative to Djakal. The variety's quicker maturity suits planting after a winter crop (double cropping) and can reduce the number of in-crop irrigations. It has a good level of resistance to lodging with good crop height. It matures around four days earlier than Djakal, and nine days before Snowy⟁. It has multiple resistance genes against phytophthora root rot disease, In hot, dry conditions at harvest, Bidgee$^{\phi}$ has shown some pod shattering.

Bunya$^{\phi}$. A large-seeded human consumption type bred by CSIRO and released in 2006 for production in irrigated inland systems of southern Qld and northern NSW – currently licensed to Soy Australia. Germination checks and careful seed handling during planting are essential. Achieving a high grain protein content (i.e. over 40% protein dry matter basis) in coastal environments with Bunya$^{\phi}$ can be difficult; it is better suited to inland irrigated production environments.

Burrinjuck$^{\phi}$. This new clear hilum variety for southern NSW was released in 2018 – currently licensed to Seednet. It has high yield potential, large seed size, high protein, and a good agronomic package including clean leaf drop and resistance to races 1, 4, 15 and 25 of *Phytophthora*. Burrinjuck$^{\phi}$ has performed well across a range of field trials and seasons, consistently achieving grain yields well above Snowy$^{\phi}$ and similar to Djakal with higher protein than Djakal and similar maturity.

Cowrie. Released as a public variety (no EPR) in 2002 by NSW DPI for northern NSW, including rain-grown coastal and inland irrigation and tableland areas, it has a colourless (clear) hilum, good protein content and large pale seed making it very acceptable to the soy milk, tofu and soyflour markets. Weathering tolerance is moderate (70% of Zeus). Cowrie is superseded by Richmond$^{\phi}$ and Hayman$^{\phi}$.

Curringa. This variety superseded Bowyer for the premium human consumption market due to better yield, lodging and disease resistance and has subsequently been superseded by Burrinjuck$^{\phi}$. It has a similar growth habit, maturity and seed size to Bowyer, but has higher yield potential in the Murrumbidgee Irrigation Area and Lachlan Valley. It has been accepted into tofu and milk markets with a similar processing quality to Bowyer.

Djakal. This brown hilum variety performs consistently over a wide range of planting times within the recommended window and is suited to all central/southern irrigation areas in NSW and irrigation areas in northern Victoria. It is a strong performer, providing growers with consistent high yields, early maturity, lodging resistance and a generally good agronomic package. Djakal carries resistance to *Phytophthora* races 1 and 4, but has only limited field tolerance to the newer race 25, found in parts of the Riverina. Djakal's protein content and seed size is consistently lower than Snowy$^{\phi}$, Bidgee$^{\phi}$ and Burrinjuck$^{\phi}$.

Empyle. Suitable for some human consumption markets, though possibly not the tofu market due to its smaller seed size. Yields are variable, but on average are 10% less than Djakal. It has a similar growth habit to Djakal, but matures four days later. In DPI trials, seed size has been small, which can reduce the premium price paid for human consumption grade.

Hale. NSW DPI bred the variety at Narrabri, and released it in 2000. It has good yield potential and disease resistance. It has shown excellent yields under both irrigated and dryland conditions. In northern NSW, Hale has out-yielded Valiant under irrigated conditions by 8.5% averaged over nine trials and six seasons. Its yield under dryland conditions is 2% higher than Valiant and 13.5% higher than Intrepid over six seasons of testing. Maturity, seed size, oil and protein content are very similar to Valiant. It is a preferred variety for dryland situations. It is also promoted along with Moonbi$^{\phi}$ as an early maturing alternative to the traditional full season varieties.

Hayman$^{\phi}$. This versatile variety was released by the ASB in 2013; currently licensed to Seednet. It produces large, pale seed with a clear hilum and readily produces grain protein content above 44% dry matter basis giving growers more market options, including the higher value human consumption markets as well as crushing markets. Hayman$^{\phi}$ possesses the 11sA4 protein null (like Bunya$^{\phi}$) that tofu processors value for its superior gelling quality. Its large biomass and longer growing season on the NSW north coast, recommended it for grain production in mid–late sowing windows and is a superior option to Warrigal or A6785 for very late planting, e.g. until mid February. Hayman$^{\phi}$ is the best option for hay and silage production for sheep and dairy producers on the north coast and Northern Tablelands of NSW, and in southern Queensland. It produces up to 25% greater biomass per hectare than Asgrow A6785, yet maintains the same feed values and has less lodging. When planted on the same date, Hayman$^{\phi}$ takes around 12 days longer to mature than A6785, giving hay and silage producers a longer window of opportunity to cut the crop. Due to its long growing season, it is not recommended for grain production where early frost risk is high, e.g. the northern slopes.

Intrepid. Bred by NSW DPI at Narrabri, it is a dryland variety recommended for northern inland NSW. It has vigorous vegetative growth, making it a good competitor with weeds and it seems suited to minimum tillage. Its lowest pods are also slightly higher than either Valiant's or Hale's. Intrepid is highly regarded by growers in the Northern Tablelands but, due to its black hilum, is not suitable to higher value human consumption markets. Northern Tablelands growers who want to access the higher value grain markets are encouraged to try Moonbiɸ or Richmondɸ. For a high biomass variety for hay or silage, growers are encouraged to try Haymanɸ.

Ivory. Bred by NSW DPI at Narrabri, it has been widely grown in irrigated systems in northern NSW from the Macquarie Valley north to the Queensland border. It has a yellow hilum, making it suitable for some segments of the human consumption trade as well as for crushing. It is a high yielding variety with resistance to bacterial pustule and bacterial blight. It is recommended for all northern irrigated and late dryland plantings.

Manta. Released in 1991 by NSW DPI for coastal environments, it combines high yield, tolerance to manganese, *Sclerotinia* and race 1 of *Phytophthora*. It also has a high level of weathering tolerance. Manta produces grain with above-average protein content (>40% DMB), but is only suitable for the crushing market due to its dark coloured hilum. It has good resistance to lodging and is recommended for coastal growers seeking to supply the crushing market. It is a popular and consistent performer in coastal soils.

Moonbiɸ. The ASBP released Moonbiɸ in 2010; currently licensed to Soy Australia. A short season variety (ready to harvest 12 days earlier than Soya 791 at the same planting date) that is particularly suited to double-cropping systems on the north coast, Northern Tablelands and slopes where planting winter crops or pastures on time is critical. It is also suited to production on the Liverpool Plains and central western NSW. It has excellent grain quality with a clear hilum, high protein, attractive round seed and is suited to higher value human consumption markets as well as crushing. Moonbiɸ has a compact plant type and has less tendency to lodge than Soya 791. Clean leaf drop and fast, even ripening makes harvest easier. Recent studies by NSW DPI show that Moonbiɸ yields better at a higher plant population than that recommended for Richmondɸ and Soya 791.

Poseidon. Bred by NSW DPI for northern coastal NSW and released as a higher yielding replacement for Manta in 1999. Weathering tolerance and protein content are similar to Manta. *Sclerotinia* tolerance is less than in Manta or Zeus. Its black hilum makes it suitable only for the crushing market.

Richmondɸ. Richmond was released by the ASBP in 2013 and is currently licensed to Seednet. It is suited to production on the north coast, Northern Tablelands, northern slopes and the Liverpool Plains. The clear hilum, high protein, large seed size and high yield provides an alternative to A6785. It is suited to an early–mid season planting window on the coast and has the highest weathering tolerance of any currently available clear hilum variety. Richmondɸ has a compact plant type to minimise lodging, clean leaf drop and even ripening for ease of harvest.

Snowyɸ. An early–mid maturing human consumption variety, currently licensed to Soy Australia. It yields lower than Djakal, but out-yields the older variety Curringa by 14% and Empyle by 5%. It matures slightly later than Djakal and earlier than Curringa. Snowyɸ has a larger seed size and higher protein content than Djakal. Snowyɸ has been subsequently outclassed by Burrinjuckɸ.

Soya 791. This popular and widely adapted variety has a light tan hilum suitable for soy flour production. It is also used for soymilk. It can produce high yields if managed well and the grain has good protein content. Soya 791 has poor tolerance to *Sclerotinia*, which is exacerbated by its tendency to lodge. It has a bushy growth habit, but does not always convert its high plant biomass to grain yield.

Surf. Released as a public variety by NSW DPI in 2004, it is suitable for the culinary market. Suited to the late planting window on the north coast (end December to mid January), Surf has been outclassed by Richmondɸand Haymanɸ in most districts.

Zeus. Bred by NSW DPI and released in 1999 for northern coastal NSW environments as a higher yielding and more weathering-tolerant replacement for Dune. Zeus has the highest level of weathering tolerance of all the currently commercially available varieties in Australia. It also has useful tolerance to *Sclerotinia*, making it a popular choice for areas with high rainfall and humidity. It is suitable only for the crushing market.

Growth stages

Soybean plants start flowering in response to lengthening hours of darkness (i.e. after the summer solstice), which has an effect on the time to maturity, mature plant height and yield. Selecting the appropriate variety and a suitable planting time are important factors for a high-yielding crop. If a variety is planted earlier than recommended it will grow too tall before flowering and probably lodge, reducing yield and creating a more favourable environment for disease to develop. If planted later than recommended, yield will be reduced and the crop might be too short in height and difficult to harvest. Varieties have been bred and selected for their adaptation to specific regions and environments in NSW.

Soybean plant growth must achieve full canopy cover by the start of flowering (determinate varieties) or by mid flowering (indeterminate varieties). Evaluate management practices if full ground cover is not achieved by the optimum time for maximum yield potential.

When using a variety recommended for your region, flowering should start at approximately 40–55 days after planting.

There are eight critical stages of crop development (**Figure 36**). Management suggestions include:

1. **Plant** the appropriate variety at the correct planting time, 5 cm deep into suitable soil moisture.
2. **Emergence** usually occurs 5–10 days after planting.
   Establish a uniform stand of 30–40 plants/m^2 depending on local variety recommendations.
   Check for insects, weeds and diseases.
3. The **early vegetative stage** is 1–5 weeks after emergence.
   Check weekly for weeds and insects; look for tip and leaf damage, and root and stem disease.
   If weeds are present, undertake post-emergence weed control before the crop canopy closes.
4. The **late vegetative stage** is in weeks 5–6.
   Check nodulation. Aim for more than 10 root nodules per plant with red/pink colour inside.
   If nodulation is very poor, consider the economics of applying fertiliser N to make up the shortfall in fixed N.
5. **Flowering** usually begins in weeks 6–7. At this stage the crop should be weed-free and 60–100 cm high with complete canopy cover in determinate varieties.
   Once flowering starts, check every three days for insects and for leaf and stem disease.
   Visually assess the crop for any nutritional problems. Determinate varieties will begin flowering at all nodes almost simultaneously. Indeterminate varieties reach about 30–50% of their final height before they start flowering.
   Soybean plants produce more flowers than needed for a high yielding crop, 50–75% of all flowers commonly abort and never form pods.

6. **Podding** starts at weeks 8–10. The first pods appear 10–14 days after flowering starts. Each pod usually contains two or three seeds, but can range from one to four.
   It is critical to monitor and control insect pests now. Check every three days for pests.
   Check for leaf and stem disease.
7. **Physiological maturity** occurs 14–18 weeks after emergence. The stage can be determined when 50% of the pods are brown/tan and the seed is no longer attached to the pod wall. Leaf drop starts at approximately 16 weeks. The seeds usually contain 40–50% moisture at this stage.
   Desiccation can be applied once physiological maturity has occurred.
8. **Harvest** usually occurs at weeks 18–20. At this time, 95% of the pods are brown/tan, and the grain moisture is within 15–18% in coastal environments and 13–15% in inland environments.
   Grain receival standards and storage require 12–13% moisture levels

NOTE: This is a guide only. Growth stages can vary depending on variety, planting date and extreme environmental conditions.

HERBICIDE APPLICATION – SOYBEAN DETERMINATE

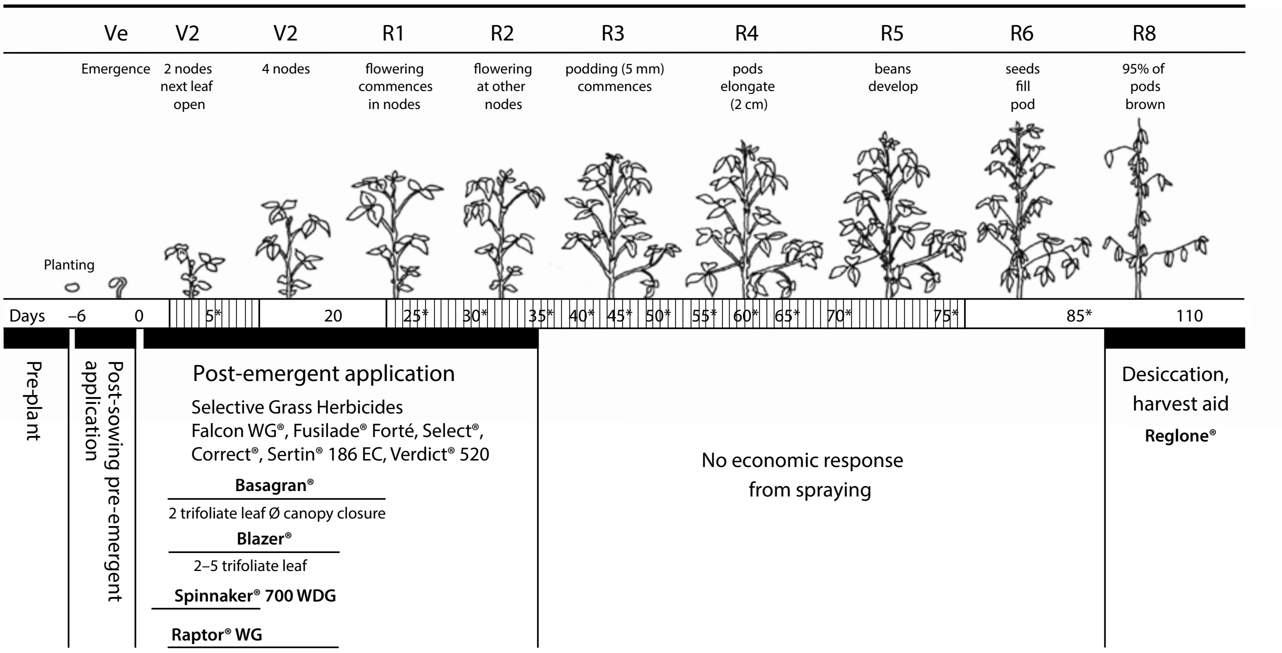

Figure 36. Soybean crop growth targets (adapted from NSW DPI SoyCheck 1997).

Nutrition

Soybean has a high demand for plant nutrients, in particular nitrogen (N), phosphorus (P), potassium (K) and sulfur (S). When deciding on fertiliser for a soybean crop it is important to know the nutrient status of the soil and the critical level of soil nutrients, particularly P and K, that are needed for maximum economic yield. A soil test is the best way to determine soil nutrient status.

Table 42 shows the approximate quantities of major nutrients used by a soybean grain crop.

Table 42. Approximate nutrient use of a 2.5 t/ha soybean crop.

Plant part	Yield 2.5 t/ha			
	Plant nutrient (kg/ha)			
	N	P	K	S
Total plant uptake	230	17	123	14.5
In seed only	167	14.5	48	11.5

NOTE: This table should not be used as a direct indicator of crop fertiliser requirements, but it is a useful guide to soil maintenance requirements – an important consideration for low fertility soils.

Nitrogen (N)

Once established the N-fixing bacteria (rhizobia) in the root nodules will supply soybean plants with all their N requirements. A small amount (up to about 15 kg N/ha) of starter N can be beneficial in certain situations. For example, for late-planted crops it helps to ensure good early seedling growth and adequate height to the lowest pod. Small amounts of starter N can also be beneficial where soybean is planted into dense sugarcane stubble. Care must be taken not to apply too much starter N as this will have a detrimental effect on the growth of nodules that supply N to the plant later in its growth cycle. Refer to **Inoculation on page 70**.

Sulfur (S)

Soybean is a high protein legume and insufficient S limits yield. Generally, single superphosphate applications supply adequate S. On high P-testing soil, inadequate S can frequently limit yields, especially with direct-drilled crops. Apply fertiliser containing S at rates up to 15 kg S/ha if KCl-40 soil tests are below 10 mg/kg.

Phosphorus (P)

Soils predominantly derived from sedimentary and granitic rocks are extremely low in P and high rates of P fertiliser are required for economic yields. Phosphorus fertiliser is required for good production on most coastal and tablelands soils.

The heavy clay flood plain soils of the Richmond Valley have high levels of reactive iron. In these soils, the iron can fix a large proportion of the P applied in fertiliser. Phosphorus drilled with or banded close to the seed is the most effective way to supply this nutrient to the soybean plant, particularly in soils with high P-buffering indices.

On podsolic soils where large amounts of single superphosphate are required, apply some P fertiliser before planting and up to a maximum of 200 kg/ha with the seed.

For practical and economic reasons, most growers with medium to high P soils broadcast and incorporate the entire fertiliser requirement before planting. Research (**2015–2016** and **2018**) conducted by Professor Mike Bell (University of Queensland) is investigating the benefits of deep placement of P and managing P and K in cropping soils of the northern grains region.

When direct drilling with minimal soil disturbance, apply up to 100 kg/ha single superphosphate with the seed and surface broadcast the balance. Use Table 43 as a guide to soybean crop P fertiliser requirements.

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2015–2016 (https://communities.grdc.com.au/crop-nutrition/tag/deep-p-application/)

2018 (https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/03/the-p-story-so-far-an-update-on-deep-p-research-findings)

Table 43. Guide to phosphorus fertiliser requirements for soybean crops in north coast NSW soils.

Extractable phosphorus (mg/kg)			Phosphorus recommendation (kg/ha)	
Colwell test		Bray no. 1 test		
PBI* <280 e.g. sandstone/shale/granite	PBI > 280 e.g. basalt/clay/alluvials	All soils	Phosphorus	Single super
0–10	0–30	0–5	35–44	400–500
11–15	30–40	5–10	26–35	300–400
16–25	40–50	10–15	13–26	150–300
26–40	50–60	15–25	5–13	60–150
Over 40	Over 60	Over 25	5	60

* Phosphorus Buffering Index (Burkitt et al. 2002)

Zinc (Zn)

Zinc deficiency is widespread on the grey clays of northern inland irrigation areas. Although it is well-known, Zn deficiency is still occasionally found. Some varieties could be more sensitive than others.

Zinc can be applied either to the soil or to the foliage. Apply 30 kg/ha of Zn oxide to the soil every 5–7 years or apply Zn sulfate heptahydrate at 4 kg/ha as a foliar spray 6–8 weeks after planting.

Molybdenum (Mo)

In acid soils (pH_{Ca} <5.0), Mo deficiency is likely and can be corrected by applying 70 g/ha of Mo every two years. Molybdenum is commonly applied as Mo trioxide (60% Mo) to the seed when inoculating, or as a pre-mixed fertiliser (e.g. Super Mo with 0.025% or 0.05% Mo). Sodium molybdate is toxic to rhizobia. Ammonium molybdate and Mo trioxide are not toxic to rhizobia. Sodium molybdate can be applied with trifluralin before planting.

Root nodule bacteria require Mo as part of an enzyme to convert atmospheric N to a form that is used by the plant. Most soils on the north coast of NSW and Northern Tablelands are acidic and deficient in plant-available Mo. Normal sized and coloured (green colour inside, instead of pink – orange) soybean root nodules indicate that Mo is not available in the plant root zone (see the GRDC ***Inoculating legumes guide***.

GO TO PAGE
Inoculating legumes guide
(https://grdc.com.au/resources-and-publications/all-publications/bookshop/2015/07/inoculating-legumes)

Potassium (K)

Soybean yields can be limited by K deficiencies on some coastal and tableland soils, particularly on sandy soils and those with a long history of intensive cropping where K has been exported in hay, silage, grain or sugarcane. Table 44 gives a guide to K fertiliser requirements for north coast soybean crops.

Potassium is deficient on heavy montmorillonite-based clay soils, when exchangeable K is less than 1% of the total cation exchange capacity, irrespective of the absolute exchangeable K value.

When planting, never place any K fertiliser in contact with the seed, as plant establishment will be impaired by the fertiliser's salt effect.

Table 44. Potassium fertiliser recommendations for soybean crops on north coast NSW soils.

Exchangeable K levels. K recommendation as muriate of potash		
C mol+/kg	**K (kg/ha)**	**Muriate of potash (kg/ha)**
0–0.1	50–75	100–150
0.1–0.2	25–50	50–100
0.2–0.4	10–25	20–50
Over 0.4	Nil	Nil

Manganese (Mn)

Where there are possible Mn problems, management strategies are to:

- improve drainage
- incorporate lime to raise soil pH
- grow manganese-tolerant soybean varieties.

Moderately acid soils can release potentially toxic soluble Mn after waterlogging. Also, heating affects exposed soils releasing soluble Mn. Improved drainage and liming to raise the pH reduces the intensity and duration of the soluble Mn pulse.

Other trace elements

Except for Mo on the north coast and tablelands, and Zn on the grey clays of inland irrigation areas, fertiliser trace elements are generally not required for soybean crops. Copper and Zn deficiency can occur in pastures and sugarcane on sandy Wallum soils in coastal areas.

Weed management

Effective weed management relies on crop rotations, herbicide rotations and specific management strategies targeted at reducing the seed banks of problem weeds, all at the appropriate time. Summer-growing weed species generally proliferate in the irrigation and coastal regions. Herbicides are therefore an important tool in cost-effectively managing weeds.

Weeds compete with soybean for moisture, nutrients and light, and can create difficulties at harvest. Weed contamination can drastically reduce grain yield and increase harvest costs. Additional costs might be incurred if weed seeds have to be graded out of the harvested grain. Barnyard grass (*Echinochloa* spp.), Bathurst burr (*Xanthium spinosum*), blackberry nightshade (*Solanum nigrum*) and bladder ketmia (*Hibiscus trionum*) are present in most irrigation regions. In some regions, some troublesome weeds grow prolifically such as apple of Peru (*Nicandra physalodes*), jute (*Corchorus* spp.), bellvine (*Ipomoea plebeia*), or sesbania pea (*Sesbania cannabina*) and can even prevent harvest.

Adverse effects of weeds on soybean yield are determined by:

- weed: species, density and duration of competition
- crop: vigour, density and planting configuration.

Weed control starts with a program to prevent a bank of weed seeds in the soil. Since no single herbicide will control all weeds, growers should be conscious of the importance of crop rotations and pasture leys. For example, rotation with maize means a range of herbicides are available to control the difficult-to-kill broadleaf weeds in soybean crops.

A weed-free fallow is essential for weed control and conserving moisture. With traditional cultivation, a weed-free seedbed is best achieved with an early-working and follow-up cultivation to kill weeds and remove new seedlings.

In no-till and reduced-till crops, herbicides are used as alternatives to cultivation. Many soybean growers who use direct drill systems apply two glyphosate sprays before planting and follow-up later with a post-emergent grass and/or broadleaf herbicide.

Dense canopy development is the key to reducing the effects of weeds germinating later in the season. Row cropping allows inter-row cultivations before canopy closure, but wet weather can interfere with correct timing. Organic growers need to use inter-row cultivation to control weeds, but will often have to employ a team of chippers to remove weeds in the plant row.

Developing a dense canopy is encouraged by:
- a good seedbed with adequate moisture and good seed-soil contact
- using high germination/high vigour seed, along with adequate fertiliser
- planting the recommended soybean variety on time.

Planting too deep (greater than 5 cm), compacted/crusted soil, waterlogged soil and/or soybean diseases are examples of factors that can reduce establishment and increase weed competition.

In north coastal and tablelands crops, early canopy closure is best achieved by planting in narrow rows, see Table45 for the effects of row spacing and weeds on soybean yield.

Table 45. The effect of row spacing in the presence or absence of weeds on soybean yield.

Row spacing	Soybean yield (kg/ha)		Reduced yield
cm	– weeds	+ weeds	%
25	3084	3065	<1
50	3018	2419	20
75	3078	2288	26
100	2964	1861	37

Source: Warwick Felton, NSW DPI, 1976.

Where weeds are likely to be a problem, there are distinct advantages in growing soybean at the higher range of the recommended plant densities and reducing the row spacing. However, increasing plant population beyond the recommended range is not sensible as the only strategy for weed management and can result in reduced grain yield and plants with thin, weak stems, predisposing the crop to lodging and fungal diseases. For plant population recommendations see **Table 40**.

Weed competition is more severe in wide-row crops, where control has been delayed. In narrow-row crops, any delay in herbicide application can result in poor coverage of the target weed. Wide rows allow inter-row cultivation and low cost band spraying.

Establishing the targeted plant population will achieve maximum crop competition with weeds and avoid gaps in the established crop where weeds can flourish.

Soybean is most sensitive to weed competition 4–7 weeks after emergence. Extreme grass competition can affect soybean yields much earlier, especially if conditions are dry.

Tall growing weeds (e.g. Apple of Peru – *Nicandra physalodes* and gooseberries – *Physalis minima*) that push through the crop canopy can shade the crop, causing leaf fall and straggly, weak-stemmed plants with low pod counts. Under cool, humid conditions these crops are more subject to disease such as *Sclerotinia*.

Pre-emergent herbicides

Metolachlor products such as Dual®Gold are best if surface applied immediately after planting. Metolachlor has limited activity on broadleaf weeds. If a serious grass weed problem is anticipated, metolachlor products can be applied with glyphosate before planting, or it can be surface applied alone immediately post-planting and before weeds have germinated. For metolachlor to work effectively, rain is necessary within 10 days of application to thoroughly wet the top 3–4 cm of soil.

Under conventional cultivation, with a fine seedbed, grass weeds are more economically controlled with soil-incorporated pre-emergent herbicides. Trifluralin and pendimethalin products are soil incorporated and need a good seedbed free from large clods (grass seeds inside clods can germinate, establish and survive after rain 'melts' clods).

Spinnaker® 700 WDG herbicide can control some broadleaf weeds, nut grass and barnyard grass with a pre-emergence application to the surface immediately after planting. To activate Spinnaker®, rain is required before weed emergence to wet the soil to 5 cm deep.

Post-emergent herbicides

Grasses and broadleaf weeds can also be controlled after emergence – preferably in the fourth week after emergence. A delayed spray can result in greater yield loss through reduced weed coverage. Best results are obtained on weeds before the four-leaf stage.

Broadleaf weeds can be controlled post-emergence with Spinnaker®, Basagran® or Blazer®. Mixtures of Basagran® and Blazer® are permitted.

Raptor® herbicide is a post-emergent herbicide to control certain annual grass and broadleaf weeds when applied at early post-emergence.

Post-emergent grass herbicides are most effective on actively growing grasses at the 3–5-leaf stage, before tillering starts.

Table 46 lists herbicides that are currently registered or permitted for use in NSW.

Always read the label directions before using any agricultural chemicals.

Table 46. Herbicides registered for use in soybean in NSW as at September 2019.

	Herbicide (active ingredient)	Example product	Group	Soybean use pattern				pre-harvest crop desiccation
				pre-plant seed-bed weed control	at-plant pre-emergence	post-plant pre-emergence	post-emergent	
Residual activity – check plantbacks	2,4-D amine ❶	Amicide®	I	✓				
	dicamba ❷	Cadence®	I	✓				
	tribenuron-methyl ❸	Express®	B	✓				
	trifluralin	TriflurX®	D		✓ PSI ❹ / IBS ❺			
	pendimethalin	Rifle®	D	✓	✓ PSI			
	metribuzin	Sencor®	C	✓		✓		
	S-metolachlor	Dual®Gold	K	✓	✓	✓		
	flumioxazin	Valor®	G	✓				
	flumetsulam	Broadstrike®	B	✓	✓ PSI / IBS	✓		
	imazethapyr	Vezir®	B			✓	✓	
	imazamox	Raptor®	B				✓	
Knockdown activity	glyphosate	Roundup Ultra®MAX	M	✓			✓ (wiper) (shield)	✓
	paraquat	Gramoxone®	L	✓				
	paraquat + diquat	Spray.Seed®	L	✓				
	acifluorfen	Ardeo®	G				✓	
	bentazone	Basagran®	C				✓	
	butroxydim	Factor®	A				✓	
	clethodim	Status®	A				✓	
	haloxyfop-r	Verdict®	A				✓	
	fluazifop-p	Fusilade®	A				✓	
	quizalofop-P	Targa®	A				✓	
	diquat	Reglone®	L					✓

❶ Plantback interval before sowing is 14–21 days + at least 15 mm rainfall.
❷ Plantback interval is 10–21 days + at least 15 mm rainfall.
❸ Plantback interval is 7–21 days depending on soil temperatures at sowing.
❹ PSI = Pre-sowing incorporated.
❺ IBS = Incorporated by sowing.

Herbicides for controlling weeds in row crops

Many row crops planted on raised beds have the option of inter-row cultivation and inter-row spraying. This can reduce herbicide costs significantly by using inter-row cultivators, hooded (shielded) sprayers, and knock-down herbicides. Knock-down herbicides are applied between the rows of soybean to achieve cost-effective weed control. There is a good range of selective herbicides also available for broadacre applications. Early weed control is recommended when weeds are small.

Important pointers for effective herbicide use

Getting the most out of herbicides depends on several factors:

- As a general rule, ground rig application is more effective than aerial application.
- Read the herbicide label carefully for details on optimum application methods and optimum spraying conditions.

- Be aware that weeds can become resistant to herbicides if they are not used as recommended. Practise good crop rotations, rotate herbicide groups and combine chemical and non-chemical weed control methods to reduce the chance of weeds developing resistance.

Diseases

Some common and important soybean diseases in NSW are described below.

Black leaf blight (*Arkoola nigra*)

Black leaf blight is caused by a fungus. To date, this fungus has only caused major outbreaks of disease in crops in the Hastings district of NSW, although it has been recorded throughout the north coast.

Symptoms

The most striking symptom is leaf blighting. Large irregular grey–brown spots with a yellow margin develop on the leaves. The centre of these spots might fall out, giving a shot-hole and tattered appearance. The disease spreads upward within the crop, blighting the top leaves and pods during the pod-filling stage.

Conditions favouring development

Infection occurs in the early part of the growing season from ascospores released from fruiting bodies on diseased trash. Warm weather promotes disease development and spread; poor ventilation in crops is also a factor.

Management

- Use seed from disease-free crops
- rotate with non-host crops
- burn or bury trash
- grow well-ventilated soybean crops
- minimise spread of infected material on boots, clothing and machinery
- use iprodione products, which are registered for controlling black leaf blight.

Charcoal rot (*Macrophomina phaseolina*)

Charcoal rot is caused by a soil-borne fungus that affects many crop and weed plants. The most common crops affected are lucerne, mungbean, cowpea, sorghum, maize, sunflower and cotton, but soybean can also be affected.

Symptoms

Symptoms usually begin to appear between pod fill and maturity. Affected plants will be seen to prematurely wilt before dying. While no visible symptoms are evident on the stem's external surface, peeling back under the bark shows an orange–caramel discoloration. Once dead, the lower stem and taproot surface will eventually turn an ashen grey colour with charcoal grey flecks also developing in stem tissue.

Conditions favouring development

Infection occurs when seedlings are actively growing, but symptoms might not become apparent until plants encounter stresses later in the season. Charcoal rot is generally more common in hot (>35 °C), dry summers, particularly if the plants are moisture stressed for prolonged periods. Hence the disease is usually more prevalent in dryland areas.

Management

Regularly irrigating the crop to avoid moisture stress where possible and rotating with non-host crops such as cereals will minimise charcoal rot. Avoid paddocks known to be previously infected as the fungus can survive in infected stubble. For more information see the Soy Australia factsheet: ***Charcoal rot of soybean***.

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Charcoal rot of soybean
(www.australianoilseeds.com/__data/assets/pdf_file/0020/10298/Charcoal_rot_of_soybean_Feb_2015.pdf)

Damping-off (*Pythium* spp.)

Symptoms

Pythium is a water mould that infects seedling roots under wet soil conditions causing damping-off. This pathogen is common in soybean-growing regions.

Conditions favouring development

Cool seedbed temperatures (<18 °C); wet soils and planting too deep or too early increases the risks of *Pythium* infection.

Management

Control by planting into well-drained soils and providing conditions that favour rapid emergence.

Phytophthora root and stem rot (*Phytophthora sojae*)

Phytophthora root and stem rot is caused by a water mould that can attack plants at all growth stages. Growers should be aware of their paddock susceptibility and implement management strategies to minimise losses.

In the irrigated soybean production regions of southern NSW and northern Victoria, this disease can be a major problem.

Seventeen races of *Phytophthora sojae* have been recorded in commercial soybean crops in Australia to date.

Race 1. Before 1990, most *Phytophthora* isolates from NSW belonged to race 1, with race 15 also present at low levels. Race 1 is the most commonly found strain on the north coast of NSW.

Race 15. Observations in Queensland during 1989–90 detected a shift from race 1 to race 15 at some sites on the Darling Downs, resulting in severe yield losses in field-tolerant varieties such as Davis, Forrest and Dragon. Shifts from race 1 to race 15 in NSW had been observed in the Berrigan/Finley area between 1993 and 1995. In the 1998–99 season the shift to race 15 was detected in commercial crops near Gunnedah, and on the research plot area at Narrabri. Race 15 has also been identified in the north coast region, but is not as common.

Races 33, 46 and 53 have been detected in southern NSW in recent years. The detections have been isolated and the effect from these races, if any, is being monitored. However, the increasing number of races detected in southern NSW irrigation areas acts as a reminder that *Phytophthora* deserves constant attention.

A native *Phytophthora* species (*P. macrochlamydospora*) has been recorded on the NSW north coast. It infects native legumes but generally has low virulence to soybean.

Symptoms

Phytophthora is first seen in poorly-drained sections of the field, typically near the tail drain at the bottom end of the field. Plants wilt and have characteristic dark brown to black, slightly sunken lesions on the stem extending from ground level upwards. If the stem and taproot are split, the tissue will show a brown discoloration. Dead plants are usually found in continuous sections of rows.

Conditions favouring development

Poorly drained soils, warm temperatures and wet weather – either through excessive irrigation or rainfall – favours disease development.

Management

- Grow tolerant varieties in well-drained fields
- improve irrigation practices
- rotate crops
- prevent disease being introduced to disease-free areas via spores in drainage water or in infested soil attached to machinery.

Once introduced, *Phytophthora* can survive in fields not growing soybean for many years.

Older varieties can be completely susceptible to certain races, while newer varieties can display different levels of field tolerance or complete resistance (see **Table 41**). The ASBP is developing varieties with multiple resistance genes to counteract new race development.

Growers should constantly monitor their crops and follow the management strategies outlined below to sustain the usefulness of the available varieties.

- Ensure that waterlogging is minimised by selecting only well-drained paddocks and by carefully scheduling irrigations.
- Develop crop rotations that minimise continuous soybean cropping.
- Monitor crops closely so that low levels of disease are detected.
- Restrict susceptible and field-tolerant varieties to well-drained sites with no previous history of either soybean growing or *Phytophthora* infection.
- If *Phytophthora* has been identified, growers should consult their agronomist for help in identifying the race(s) and developing a control strategy. This will allow disease incidences to be monitored and will also quickly detect any changes in race patterns
- For more information see the Soy Australia factsheet: ***Phytophthora root and stem rot of soybeans***.

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Phytophthora root and stem rot of soybeans (http://www.australianoilseeds.com/__data/assets/pdf_file/0019/10369/Phytophthora_Root_and_Stem_Rot_of_Soybean_Feb_2015.pdf)

Pod and stem blight (*Diaporthe-Phomopsis* spp. complex)

Pod and stem blight is a disease caused by a complex of fungi, which can be seed-borne or carried on crop residue.

Symptoms

Premature yellowing to the top of the plant and early pod maturation appear late in the season. After leaf fall, masses of small black dots (spore-producing bodies known as pycnidia) appear on stems, petioles and pods. On stems and petioles the pycnidia are arranged in rows; on pods they tend to be scattered. The fungus is present in maturing seeds and can lead to a rapid deterioration in seed quality when wet weather delays harvest – the seed coat can crack and split, reducing germination and vigour.

Conditions favouring development

The disease is most prevalent when wet weather prevails during pod fill and maturation stages.

Management

Diseased seed and infected crop residues are the main sources of infection. Plant disease-free seed, manage infected trash and implement a rotation strategy with non-host crops to reduce inoculum build up. For more information see the Soy Australia factsheet: ***Diaporthe disease complex of soybean***.

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Diaporthe disease complex of soybean (http://www.australianoilseeds.com/__data/assets/pdf_file/0017/10367/Diaporthe_disease_complex_of_soybean_Feb_2015.pdf)

Powdery mildew (*Erysiphe diffusa*)

Powdery mildew developed in many crops throughout northern NSW and southern Queensland in the very mild and wet summer of 2012–13. It was particularly severe in susceptible varieties on the Darling Downs, Liverpool Plains and in the Riverina. Significant yield losses can occur under ideal conditions due to reduced leaf function during pod-fill. Infected leaves that remain attached to the plant and unevenly ripened infected crops cause harvesting difficulties.

Symptoms

Areas of white, powdery fungal growth develop on the leaves. Wind can spread the spores many kilometres. Affected plants do not ripen as normal and as leaves become covered by fungal growth they cannot function normally, reducing grain yield.

Powdery mildew should not be confused with downy mildew (caused by the fungus *Peronospora manshurica*), which produces pale yellow blotches on the upper leaf surface with small areas of downy, pale grey fungal growth on the underside of the leaf.

Although downy mildew is common and widespread in soybean crops in Australia, particularly in coastal production areas and during mild, wet conditions, yield loss is considered insignificant.

Conditions favouring development

The disease is most serious in mild, wet summers such as those of 2011–12 and 2012–13. Anecdotal evidence suggests that widespread development of this disease in eastern Australia was last seen in the mid 1970s when similar rainfall and temperature patterns occurred. Cold (18–24 °C) and wet conditions promote growth of this fungus and photosynthesis and transpiration in the soybean plant are reduced. Disease development ceases at 30 °C.

Management

Using resistant varieties, including Moonbi⏀, Richmond⏀ and Hayman⏀, is recommended in areas where this disease is known to occur. The pathogen most likely survives from season to season on volunteer soybean plants or alternative hosts, but little is known about the fungus's host range. It can also infect green bean, mungbean, cowpea, some wild species of *Glycine* as well as some non-leguminous plants. For more information see the Soy Australia factsheet: ***Mildew diseases of soybean***.

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Mildew diseases of soybean (www.australianoilseeds.com/__data/assets/pdf_file/0018/10368/Mildews_of_soybean_Feb_2015.pdf)

Purple seed stain (*Cercospora kikuchii*)

Purple seed stain is caused by a fungus.

Symptoms

The disease causes a characteristic pink–dark purple discoloration of the seed and sometimes the seed coat cracks. Seeds, pods, stems and leaves can also be infected (cercospora blight and leaf spot). Leaf infections are characterised by small dark red–purple spots, which can develop into angular or irregular reddish purple lesions, first on the upper then lower leaf surface. Leaf symptoms are usually first observed at the seed-setting stage. Affected leaves are usually at the top of the plant with healthy, green leaves below.

Conditions favouring development

Extended periods of humidity and temperatures of 28–30 °C favour disease development.

Management

The fungus can be seed-borne and can over-winter on infected plant material, infecting soybean plants at flowering. Control is primarily by using high quality planting seed and rotating with non-leguminous crops if disease levels become too severe.

Rhizoctonia seedling blight (*Rhizoctonia* spp.)

Rhizoctonia seedling blight is caused by a soil-borne fungus. There is also a stem canker caused by a fungus (*Rhizoctonia* spp.).

Symptoms

Sunken, brick-red areas appear on the lower stem and roots. The lesions can extend up the stem. Stem canker is most evident during pod filling. Some plants might die, while others remain stunted, but can recover, after producing roots above the diseased area.

Conditions favouring development

The disease is most serious in soil containing large amounts of undecomposed plant residue and where germination and establishment is slow.

Management

Ensure good soil drainage and plant into warm soil conditions, which enables quick establishment.

Sclerotinia stem rot or white mould (*Sclerotinia sclerotiorum*)

Sclerotinia stem rot is caused by a fungus that attacks a wide range of broadleaf weeds and crops.

Symptoms

The disease is first noticed when individual plants die, most commonly between flowering and early pod-fill stage. Affected plants are characteristically bright yellow and stand out clearly in the crop. Closer examination reveals white cottony growth on the stems, where black fruiting bodies called sclerotia eventually develop. Infected stems have a characteristic water-soaked appearance that extends up and down the stem as the disease develops.

Conditions favouring development

Infection occurs at flowering. Extended periods of plant surface wetness, moist soil, humid conditions in the crop canopy, and moderate temperatures (12–24 °C) favour disease. Later flowering and dense crops are more subject to infection, particularly where there is lodging and plant stems are touching.

Management

Sclerotinia is unlikely to cause severe damage in the first year it is noticed, however, it can build up in affected fields and cause significant losses in subsequent years. Control is by:

- crop rotation
- using disease-free seed
- selecting varieties with tolerance to *Sclerotinia*
- planting by direct drilling
- establishing well ventilated crops
- avoiding lodging.

The varieties Zeus and Manta have useful tolerance to *Sclerotinia*. For more information see the Soy Australia factsheet: ***Sclerotinia rot of soybean***.

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Sclerotinia rot of soybean
(www.australianoilseeds.com/___data/assets/pdf_file/0019/10297/Sclerotinia_of_soybean_Feb_2015.pdf)

Soybean leaf rust (*Phakopsora pachyrhizi*)

Soybean leaf rust is caused by a fungus that is hosted by soybean and some of the native legumes that grow in NSW. Yield losses of up to 1 t/ha can result. In affected crops, seed size can typically be reduced by up to 20%.

Symptoms

Grey–brown pustules on the lower leaf surfaces release masses of minute spores, which can be spread by air and then germinate on leaves. Pod formation, seed size and yield are affected.

Conditions favouring development

Humid conditions and temperatures between 22–28 °C favour rust development, with build-up and spread usually occurring towards the end of the production season in autumn as temperatures cool. However, in January 2008, prolonged wet weather and cooler summer temperatures in coastal regions led to earlier and more severe disease development and significant yield losses were recorded, particularly in late planted crops.

Until the severe outbreaks in January 2008, soybean leaf rust had not been considered an economically important disease on the north coast of NSW. Previous summer weather conditions had not favoured its development until late in the season when crops were already senescing. However, conditions of continual leaf wetness and maximum temperatures below 28 °C earlier in the season mean a leaf rust outbreak is possible and severe yield loss can result.

Management

If the disease develops in the crop before mid pod fill and control measures are not taken, green leaf area is rapidly lost and seed is not able to fill. The disease tends to develop on the lower leaves first. Early detection, followed with appropriately timed fungicide application, will halt development and protect green leaves and grain yield. Folicur® 430 SC (tebuconazole) is available under permit (**PER82518**, exp. 31/02/2022) and can help to minimise rust damage and protect the green leaf required to fill pods if applied early and correctly. The ASBP has identified rust-resistant breeding lines that are being used to develop new varieties, particularly for coastal production. Current commercial varieties do not have resistance to the rust pathogen. Refer to the factsheet: ***Managing soybean leaf rust*** for more information.

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Managing soybean leaf rust (https://grdc.com.au/___data/assets/pdf_file/0016/202462/soybean-leaf-rust.pdf.pdf).

PER82518 (http://permits.apvma.gov.au/PER82518.PDF)

Soybean

Other diseases in soybean

Other diseases that have been recorded in soybean crops in Australia, but are presently thought to have minimal economic impact include:

- bacterial blight (*Pseudomonas savastanoi* pv. *glycinea*)
- bacterial pustule (*Xanthomonas axonopodis* pv. *Glycines)*
- wildfire (*Pseudomonas syringae* pv. *tabaci*)
- *Soybean mosaic virus*
- leaf spot (*Phoma* spp.)
- flower blight (*Botrytis cinerea*)
- anthracnose (*Collectotrichum*)
- downy mildew (*Peronospora manshurica*). Some varieties tolerate downy mildew
- phytoplasma.

Insect pests

Integrated pest management (IPM)

IPM is a term used to describe the approach to insect control whereby a number of strategies are integrated to minimise pesticide use and to reduce harmful effects on the environment, whilst maintaining profitability (yield and quality). It aims to maximise and use the controlling influence of beneficial insects and to use pest-specific control agents, such as viruses and fungal sprays, to control the pest species.

IPM does not preclude using chemical methods to manage pests. Rather, it encourages the decision to use chemical sprays to consider the longer term effects on all pest and beneficial insects present in the crop, and the susceptibility (or not) of the crop to economic damage at the present stage of crop development.

All soybean growers should consider adopting IPM practices in soybean cropping as it is an ideal host crop for a wide range of beneficial insects that predate on or parasitise pest insect species. It is not wise to consider controlling one crop pest in isolation, as this can easily lead to increasing the population of another pest through reducing beneficial insects that could be keeping other pests in check. The concept of IPM is extremely important when dealing with pests such as silverleaf whitefly, mites and aphids, as these pests can easily flare up when broad spectrum pesticides are used in the crop. With increasing resistance of *Helicoverpa armigera* to indoxacarb (Steward®) and chlorantraniliprole (Altacor®) in some regions, there is added impetus to conserve beneficial insect populations to reduce the frequency of using insecticides targeting this pest.

Non-chemical methods for insect pest management

The range of commercially available non-chemical methods for insect pest management is increasing in Australia. While producers of organic crops are already familiar with many of these options, they are becoming increasingly sought after in conventional soybean production. Many developments in insect pest control aim to target the pest species while minimising the non-target impacts, in particular to beneficial insect species in the crop.

Non-chemical practices include monitoring levels of both the pest and beneficial insects and managing (including releasing) the parasites, predators and biological agents of insect and mite pests. Sequential flowering of trap crops and releasing and managing *Trichogramma* wasp and other agents can mitigate *Helicoverpa* populations. Understanding the pest species ecology and life cycles and at what crop stages they do and do not cause crop damage is essential in developing IPM strategies.

Targeted selective pesticides and bio-pesticides are used when pest levels exceed action thresholds and are chosen based on understanding their non-target impacts. Some important bio-pesticides are *Bacillus thuringiensis* subsp. *kurstaki* (Bt k) products (e.g. Dipel SC®) for *Lepidopterous* larvae control (e.g. soybean looper), and *Nucleopolyhedrovirus* (NPV) of *Helicoverpa* spp. (e.g. Vivus®) for controlling *Helicoverpa* caterpillars. No products are registered or permitted for green vegetable bug (GVB) control in organic soybean production. The introduced parasitic *Tachinid* fly *Trichopoda giamocelli* might provide some GVB control.

Monitor and identify insects in the crop

Insect population development in crops varies each season. The factors for this are not well understood. However the presence of early season pest hosts (crops and weeds), early and overuse of 'hard' broad-spectrum insecticides, and the low incidence of natural enemies (predators and parasites) are likely to be contributing factors. Regularly checking the crop is crucial for:

- understanding the changing insect populations that develop throughout the season
- becoming familiar with pest management thresholds
- detecting and identifying new pests before significant damage occurs.

It is strongly recommended that growers become familiar with the key pest and many beneficial insects that inhabit soybean crops in order to make informed decisions about insect pest management. Some of the beneficial insects commonly found in soybean crops in NSW include:

- spiders
- wasps
- ladybird beetles
- hoverfly larvae
- assassin bugs
- red and blue beetles
- damsel bugs
- big-eyed bugs
- glossy shield bugs
- spined predatory bugs
- lacewings
- carab beetles
- soldier beetles
- ants.

These beneficial insects predate on the eggs, larvae and adults of pest insects. The publications ***Good Bug Bad Bug?: An identification guide for pest and beneficial insects in summer pulses, soybeans, peanuts and chickpeas*** and CottonInfo's ***Pest and beneficial insect guide*** provide a wealth of photographs and information that help growers identify and understand the insects that inhabit their crops.

Control infestations if pest insects are accurately identified and are in sufficient numbers to cause significant plant or yield loss. Growers targeting high quality milk and tofu markets should be aware of their lower insect damage thresholds.

Check crops every week before flowering and once every three days from flowering until pods begin to turn yellow at maturity. Later-maturing crops usually have increased insect pressure and require greater vigilance. Check the crop between 7 am and 9 am when the insects are most active on the crop canopy top.

Before flowering, soybean plants can tolerate up to 33% loss of leaf area without any yield penalties. However, once flowering starts, soybean is less tolerant of leaf

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Good Bug Bad Bug? (https://thebeatsheet.com.au/wp-content/uploads/2012/04/GoodBadBug-FINALscreen22Feb3.pdf)

Pest and beneficial insect guide (https://cottoninfo.com.au/publications/pests-and-beneficials-australian-cotton-landscapes)

loss, and growing points, flowers and pods can be damaged. Growing point loss can dramatically restrict plant growth and reduce yield potential. This can often happen well before visual damage can be seen. Pests such as *Helicoverpa* and grass blue butterfly larvae are most likely to cause this damage, because they attack the axillary buds, which are precursors to the floral buds, especially if the crop is stressed and the leaves are less palatable. *Helicoverpa* caterpillars often inflict collateral damage when chewing the buds as they can damage the plant stem, resulting in the plant dying above the chewed area. In contrast, soybean moth and loopers are primarily leaf feeders and rarely, if ever, target buds or flowers.

Insect infestations will vary each year. For example, during unseasonably hot weather, soybean moth and lucerne seed web moth can be a problem. Growers sometimes fail to recognise variable pest problems before significant damage occurs, because the pest was not present in the previous year or present only in low numbers. Soybean moth is present in most soybean crops in low numbers every year. However, in a severe outbreak, the population can exceed 1000 per square metre, resulting in total defoliation of the crop.

All growers need to be aware of the withholding period (WHP) specified on the insecticide product label. Harvest WHP for insecticides can vary from two days to 28 days before harvest, depending on product choice. This can preclude growers from using certain products for insect control at a critical stage in crop management. Check the **Pulse Australia** website for current registered products and permits.

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Pulse Australia (www.pulseaus.com.au/)

Always read the label directions before using any agricultural chemical.

Table 47 summarises some of the more common and economically important insect pests found in soybean crops in NSW. Thresholds are based on the beat sheet crop sampling technique and expressed in number of pests/m^2.

Black and brown cutworm (*Agrostis ipsilon* and *Agrostis munda*)

Damage

Caterpillars feed mostly at night on leaves and stems of seedlings and young plants. Plants are often eaten off at ground level. If left unmanaged, large patches can be eaten out.

Threshold

No actual threshold established. Treat at the first sign of damage.

Management

Inspect crops in the late evening or at night for feeding caterpillars. During the day they remain hidden in the soil. Treat late in the afternoon.

Grass blue butterfly (*Zizina labradus*)

Damage

The caterpillars eat into the plant leaves, growing points and sometimes stems. While control is rarely needed, high numbers can damage terminals resulting in plant branching and pods being set closer to the ground. This can indirectly affect yield as low-set pods are more difficult to harvest. Infestations can develop suddenly during dry spells and damage can be severe if growth is impeded.

Threshold

Before flowering: 33% leaf area loss or 10–25% terminal loss (tipping). From flowering onwards: 15% leaf area loss.

Management

Inspect the crop twice weekly for damage. There are no insecticides registered specifically for this pest. In experiments conducted by QDAF entomologists, good levels of control were achieved with the non-chemical Bt-based biopesticide Dipel SC®.

Heliothis caterpillars (*Helicoverpa* spp.)

Damage

The caterpillars feed on leaves and growing points. They also feed on developing flowers, pods and seeds.

Threshold

Vegetative soybean: 7–8 larvae/m^2. This economic threshold (Rogers and Brier, 2009) replaces the previous 33% defoliation threshold and/or 25% terminal loss (tipping) threshold. The threshold is based on the maximum number of larvae that can be tolerated before there is an economic yield reduction. Lower the threshold in early sown vegetative crops or where terminal loss exceeds 25%.

Table 47. Insect pests of soybean crops in NSW.

Pest	Comments	Threshold for action
Seedling pests		
Cutworms	Spray late afternoon or evening. Band spray over row.	Small uniform seedling losses up to 15% can be tolerated for early-planted crops.
White-fringed weevil	Larvae eat roots. Adults can defoliate seedlings.	Sporadic occurrence. No threshold determined.
Foliage feeding caterpillars		
Cluster caterpillar	A sporadic foliage feeder.	Vegetative threshold: 33% defoliation. Budding to podding threshold: 3 larvae/m^2
Grass blue butterfly larvae	Larvae feed on terminals, auxiliary buds and leaves.	Before flowering: 33% leaf area loss or 10–25% terminal loss (tipping). Flowering onwards: 15% leaf area loss
Helicoverpa spp. (heliothis)	Damage foliage, flower buds, flowers and pods. NPV (e.g. Vivus®) is the preferred IPM option in vegetative crops.	Vegetative threshold: 7–8 larvae/m^2 (NB. replaces the previous 33% defoliation threshold).
Loopers	Feed only on foliage. Bt (e.g. Dipel SC®) is the preferred IPM option.	Vegetative threshold: 33% defoliation. Budding to podding threshold: 15–20% defoliation.
Soybean moth larvae	Blister, roll and web the leaves – plague numbers can build-up in dry years.	Based on defoliation: >33% pre-flowering >15% flowering – early pod fill.
Pod feeders		
Helicoverpa spp. (heliothis)	A closed canopy crop does not favour *Helicoverpa* moth egg laying. Eggs laid at the top of plants suffer higher levels of mortality.	Budding to late pod fill: 1–3 larvae/m^2, based on yield loss model. About 2/m^2 pod-feeding caterpillars during pod filling on the north coast. In the Riverina, >3/m^2 for human consumption and >6/m^2 for crushing or stockfeed.
Pod-sucking bugs and other sap-suckers		
Green vegetable bug (GVB), brown bean bugs, red-banded shield bug, brown shield bug	Significant yield loss is confined to the first two weeks of early pod fill. No yield loss occurs beyond mid pod fill. Seed quality is affected until pods are too hard to penetrate. Hence bug thresholds are based on seed quality effects, not yield loss.	For calculating GVB thresholds in individual soybean crops refer to the on-line calculator at **The Beatsheet** at (http://thebeatsheet.com.au/economic-threshold-calculators/) General thresholds are based on GVB adult equivalents per metre^2. For GVB the thresholds are as follows: • 0.2–0.7 GVB/m^2 for human consumption beans • 0.5–1.0 GVB/m2 for crushing or non edible beans Important factors to consider when calculating GVB thresholds: • as GVB thresholds are measured in % seed damage, thresholds are higher in higher yielding crops with more seeds • thresholds are affected by the predicted crop yield, and are calculated accordingly in the Beatsheet calculator. The calculator also converts the damage potential of nymphs, and of other podsucking bug species, to green vegetable bug adult equivalents. For calculating thresholds for other podsucking bugs, use the following equivalents: • 1.0 large or small brown bean bug = 1.0 GVB • 1.0 red-banded shield bug = 0.75 GVB • 1.0 brown shield bug = 0.2 GVB.
Silverleaf whitefly (SLW)	Nymphs are found on the underside of leaves. They suck sap and can deposit honeydew on foliage, upon which develops a sooty mould. Adults also suck sap and deposit honeydew.	There are currently no pesticides registered or under permit for control of silverleaf whitefly in soybean crops. Conserve beneficial insects by only using 'soft' insecticides or non-chemical methods against other pests wherever possible during the crop cycle, especially during the vegetative phase.
Spider mites	Piercing and sap-sucking pests. Check under leaf surface. Can become troublesome in dry weather or after using broad-spectrum insecticide sprays.	During the flowering–pod fill stage, treatment might be warranted if there is an average of 5 mites/cm^2 on the leaf undersurface, provided natural enemies are not active.
Stem borers		
Lucerne crown borer	Larvae bore down through the main stem pith. Near the stem base, they girdle the inside of the stem when forming a pupal chamber thus weakening it and making the stem susceptible to lodging and the plant maturing early or not filling seed.	No action threshold has been determined. Control is by: • burying infested crop residue deep • crop rotation with non-host crops such as winter cereals • eradication of legume weeds including sesbania pea, budda pea and rattlepod. Monitor adult beetle presence each season. Chemical control has been possible recently with permits issued for seed treatment or in-furrow formulations of fipronil (e.g. Legion®). Check with your local agronomist on the status of permits each season. Seed treatment is recommended in paddocks with previously high incidence of lucerne crown borer and to protect early sown soybean crops.
Soybean stemfly	Larvae of this small black fly (2 mm long) tunnel into petiole and stem tissues disrupting water translocation in the plant. Extreme wet weather as experienced in the summers of 2011–2012 and 2012–2013 favours this tropical pest.	No action threshold has been determined. Early damage is likely to have a greater impact on plant growth. Plant death symptoms can be confused with those caused by charcoal rot. Control of legume weed hosts such as phasey bean is recommended.

Note: More detailed information on identification insect pests, action thresholds and control is available in *Good Bug Bad Bug?* and **The Beatsheet** (http://thebeatsheet.com.au/).

Budding to late pod fill: 1–3 larvae/m², depending on crop value and pesticide cost, and based on a yield loss model, which assumes 40 kg/ha yield loss per larvae/m². Check twice a week during pod setting. Treat if six or more (Riverina – crushing or stock feed) or three or more (Riverina – human consumption) or two or more (North Coast) larvae/m².

Management

Target larvae from 5–10 mm in length for best results (size depends on product choice). During the vegetative stage, biopesticides such as NPV are preferred to chemical insecticides. Using soft chemicals helps conserve beneficial insects for the more susceptible reproductive stages, and avoids flaring other pests such as SLW and mites.

Looper caterpillars including soybean (*Thysanoplusia orichalcea*) and tobacco (*Chrysodeixis argentifera*) loopers

Damage

Loopers predominantly eat leaves. Consequently higher numbers can be tolerated compared with *Helicoverpa*, which feed on leaves, flowers and pods. Loopers move in a looping motion and can be distinguished from *Helicoverpa* larvae by their two pairs of ventral prolegs (back legs) compared with the four pairs on the *Helicoverpa* caterpillar.

Threshold

Defoliation threshold of 33% defoliation overall or 25% terminal loss during the vegetative phase of the crop pre-flowering; 15–20% defoliation after flowering and during pod fill.

Management

Loopers are readily controlled using the bio-pesticide containing the Bt toxin (e.g. DiPel SC). Best results are achieved by targeting larvae when they are less than 10 mm long.

Lucerne crown borer (*Zygrita diva*)

Damage

Eggs are laid into stems and petioles by female beetles during the crop's early to mid vegetative stage. After hatching, larvae tunnel up and down the stems and petioles feeding on pith tissue. As the crop approaches maturity, larvae move down into the taproot pith to make a pupal chamber, plugging it with macerated plant vascular tissue. This is called girdling and kills the plant above the girdle. As a rule, the hotter the weather, the earlier the crop is infested, and the more a crop is stressed, the earlier girdling occurs and the greater the yield loss. Losses can vary from 20–80 kg/ha for every larva/m².

Threshold

Thresholds cannot be applied in the traditional manner, as the only viable insecticide treatments are applied at planting as in-furrow sprays, or direct seed treatments. Consequently, any decision must be made on the anticipated level of damage. For mid range damage (50 kg/ha), the threshold is about 10% of plants infested. However, if you think the damage level is likely to be higher (because most plants are damaged during early pod fill), then the tolerable damage falls to only 5%. Conversely, if all you see is very late damage (girdling only to late maturing plants), then the tolerable damage threshold rises to >20%.

Management

Chemical control

In the summers of 2017–18 and 2018–19, permits were obtained for fipronil-based seed treatment and in-furrow formulations. These treatments proved to be very effective at the prescribed rates of 60 g a.i./ha, equating to 200 mL/100 kg of seed for the seed treatment, and 300 mL and 75 g of product for 20% and 80% in-furrow formulations respectively. Check with your local agronomist on the current status of these permits as this treatment can only be used if an APVMA permit is granted.

Non-chemical control

There are no control methods once plants have become infested. Harvest early at the highest moisture content possible, then bury infested stems to at least 50 mm to reduce larval survival and adult emergence in the following spring. Crop rotation is also important for minimising local populations of this pest as the adults are not able to fly long distances to infect new crops. Control legume weed hosts, such as budda pea, sesbania and phasey bean.

Lucerne seed-web moth (*Etiella behrii*)

Damage

The caterpillars attack the crop from the vegetative stages through to flowering, killing growing points. Later infestations tunnel into stems and pods causing small pods to shrivel and die. Caterpillars developing inside larger pods attack the seeds. Larval development is confined within a single pod, each larvae consuming on average only one soybean seed. Larvae exit the pods to pupate in the ground. While the exit hole of 2–3 mmm diameter is readily visible, the pod entry hole is microscopic.

Threshold

None established. Insecticides have no effect on larvae once they are inside the pods. Even if larvae were controlled, in most cases control would be uneconomic as the threshold would be about 30 larvae/m^2. The high threshold is due to the small amount of seed consumed per larva; they are only a fraction of the size of a *Helicoverpa* larva.

Management

There are no registered pesticides for *Etiella* control in soybean, and once inside pods and stems, larvae are not affected by insecticides, even by chemicals such as chlorantraniliprole (Altacor®).

Pod-sucking bugs (PSB)

The main species of pod-sucking bugs in NSW soybeans are green vegetable bug, red-banded shield bug, large and small brown bean bugs and the brown shield bug. Collectively referred to as pod-sucking bugs (PSB) they cause damage by piercing pods and damaging the seed within the pods. Early damaged seeds (before mid pod fill) fail to develop properly (are shrivelled) and later damaged seeds (damaged after mid pod fill) are stained, but of similar size to undamaged seeds. Both types of damage can result in a significantly downgraded quality, but yield is only reduced by sizable PSB populations damaging seeds before mid pod fill because soybeans can compensate for low to moderate levels of early PSB damage by redirecting assimilate into undamaged seeds, which then increase in weight.

Green vegetable bug (*Nezara viridula*)

Green vegetable bug (GVB) is a major pest of soybean.

Damage

GVB is the most damaging of the pod-sucking bugs, due to their abundance, widespread distribution, rate of damage and reproduction rate. However, all the above mentioned PSBs can inflict significant damage, individually or collectively. For this reason, the damage potential of all pod sucking bugs in a crop must be calculated and combined to give an overall value in green vegetable bug adult equivalents (GVBAEQ).

QDAF research showed that pod-sucking bug thresholds in soybeans are based on their effect on seed quality, not yield loss. This is because only 3% of seed damage is tolerable in soybean grain for edible markets, and the number of PSB required to damage 3% of seeds is far too low to have any effect on yield.

Thresholds

The maximum allowable PSB seed damage in edible soybeans is 3%, after which the crop loses its edible bonus (≥$100/t). However, the 'action' PSB threshold for edible soybeans is set at only 2% damage, to allow for any additional non PSB seed damage (e.g. weather stains). PSB thresholds can be calculated easily and accurately by using the latest **on-line threshold calculator** from the QDAF entomology group.

This calculator is designed to assist growers targeting the edible market and takes into account crop factors including the:

- variety
- row spacing
- days to harvest maturity
- predicted yield and mean seed weight
- growth stages and number of GVBAEQ

to calculate an action threshold for an individual crop and situation.

A similar calculator for growers targeting the crushing market will soon be available. The bug damage penalties for crushing soybeans are quite different from those for edible soybeans, and the model also factors in crop value and the cost of control. Note that with the new model, there is no fixed conversion factor and the crushing thresholds can be 1.7–3 times the corresponding edible thresholds (in a crop with the same yield potential and mean seed weight).

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The Beatsheet (http://thebeatsheet.com.au/economic-threshold-calculators/)

Management

Examine crops twice weekly from just before flowering until harvest. Control at or above threshold numbers. There is no benefit in not spraying young GVB nymphs as they cause very little damage.

Large brown bean bug (*Riptortus serripes*) and small brown bean bug (*Melanacanthus scutellaris*)

Damage

Brown bean bugs are considered equally as damaging to crops as GVB, with the damage potential rating equal to one (i.e. 1 BBB adult = 1 GVBAEQ). The large brown bean bug tends to be more frequent on the coast.

Threshold and management

Refer to GVB on the previous page. Examine crops twice weekly from just before flowering through until harvest. Control the combined PSB population if at or above threshold numbers.

Red-banded shield bug (*Piezodorus hybneri*)

Damage

Red-banded shield bugs are 75% as damaging as GVB in summer pulses. While they are usually not as abundant as GVB, they can be harder to control. The damage potentials are calculated as 0.75 of GVB (i.e. 1 RBSB = 0.75 GVB). Shrivelled and distorted seed can severely reduce yield and grain quality.

Threshold

The threshold is 0.44 GVB/m^2 for human consumption; 1.3 GVB/m^2 for crushing, expressed as GVB adult equivalent.

Management

Examine crops twice weekly from just before flowering until harvest. Control at or above threshold numbers. QDAF research found that deltamethrin alone gave little to no control of red-banded shield bug, however, up to 66% control was achieved by adding a 0.5% salt (NaCl) adjuvant to the deltamethrin spray, and >80% control was achieved with clothianidin (e.g. Shield®) with a 0.5% salt adjuvant. Note that Shield® is under permit (**PER86221**, exp. 31/08/2021). Note also that Shield® has a 21 day withholding period.

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PER86221 (http://permits.apvma.gov.au/PER86221.PDF)

Brown shield bug (*Dictyotus caenosus*)

Damage

Brown shield bugs are considered to be only 75% as damaging as GVB. The damage potentials are calculated as 0.75 of GVB (i.e. 1 BSB = 0.75 GVB). Shrivelled and distorted seed can reduce yield and grain quality.

Threshold

The threshold is 1.7 GVB/m^2 for human consumption; 5.7 GVB/m^2 for crushing, expressed as GVBAEQ.

Management

Examine crops twice weekly from just before flowering until harvest. Control at or above threshold numbers. Similar to red-banded shield bug, research showed that deltamethrin applied alone had little effect. Adding 0.5% salt (NaCl) to the deltamethrin achieved better brown sheild bug control.

Silverleaf whitefly (*Bemisia tabaci*, B-biotype and Q-biotype)

Silverleaf whitefly (SLW) is the B-biotype of the whitefly *Bemisia tabaci*, which was first discovered in Australia in 1994. It has a very wide host range (over 500 plant species globally), and is an established pest in soybean crops in Queensland and the north coast of NSW. In 2008 a new pest, the Q-biotype whitefly, was identified in vegetable crops in north Queensland, and confirmed in cotton crops in southern Queensland (Goondiwindi) and north-western NSW (Wee Waa) in 2009. The two biotypes are morphologically identical, and can only be separated using biochemical or molecular techniques.

Damage

The nymph stage of SLW is small (1.5 mm long), they feed by sucking sap from the underside of leaves of a wide range of ornamental, crop and weed plants. SLW can rapidly generate large populations when conditions are suitable and this can reduce crop yields, damaging green leaf tissue. SLW also secretes honeydew, a food source for sooty mould that covers leaves with black growth and reduces photosynthesis. It can breed prolifically in hot dry conditions.

Threshold
No established thresholds.

Management
Bemisia tabaci B-biotype is resistant to many common pesticides and can develop resistance to new synthetic chemicals very quickly due, in part, to its rapid breeding cycle. Population explosions (billions of individuals per hectare of crop) have been experienced with inappropriate insect management. For example, when non-selective, broad-spectrum pesticide sprays are used early in the crop to control other pests, the SLW population subsequently flares with the death of many natural predators and parasites that keep SLW numbers in check.

Adopt IPM practices during the crop and between seasons. Include weed control to remove host plants, especially during winter (e.g. maintaining clean fallows), being aware of control strategies in other broadacre host crops (e.g. cotton), and plant unsprayed refuges that allow beneficial insects to build up. Currently there are no pesticides registered for use against SLW in soybean.

There are many naturally occurring insects that predate and parasitise SLW nymphal stages including several microscopic wasp species (*Encarsia* spp. and *Eretmocerus* spp.), ladybird beetles, hoverfly larvae, lacewing larvae and big-eyed bugs. Maximising the beneficial insect populations in a crop is an important long-term strategy for preventing SLW flares as well as other sap sucking pests such as mites and aphids.

To help soybean growers to understand and manage this pest, the ***Silverleaf whitefly alert for soybean growers*** was produced in March 2003.

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Silverleaf whitefly alert for soybean growers (www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops)

Soybean moth (*Aproaerema simplexella*)

Soybean moth is a very common pest of soybean, but is usually only present in very low numbers. Control will rarely be required, however in some seasons, severe outbreaks have occurred with >1000 larvae/m^2.

Damage
Soybean moth larvae initially feed inside leaves for about four days mining the leaves to give a blistered appearance. They then emerge to feed externally, folding and webbing leaves together. The leaves will often appear cupped and folded together to form cocoons for pupation. In low numbers, the larvae only cause cosmetic damage that most crops will readily overcome. However, extremely high populations can totally defoliate crops, and once the leaves are gone, the larvae graze on pod surfaces. Severe defoliation will retard development, especially during pod fill. Hot, dry weather favours infestations, with crops under severe moisture stress most at risk. Infestations are often more severe on the edge of crops or beside native vegetation. Look for the early warning signs of outbreaks, which are multiple small leaf mines on the majority of leaves. As larvae develop, the leaf mines increase in area until they coalesce, and in extreme cases, the leaf tissue is totally consumed.

Threshold
Based on defoliation: greater than 33% leaf loss during the vegetative stage (pre-flowering) or greater than 15% leaf loss during flowering and pod filling.

Management
Inspect the crop twice weekly for damage. In high pressure seasons, young caterpillars must be treated before they roll the leaflet together, by which stage it will have inflicted considerable damage to the plant. Abamectin (e.g. Wizard 18®) is permitted for use against soybean moth (**PER86185**, exp. June 2023).

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PER86185 (http://permits.apvma.gov.au/PER86185.PDF)

Soybean stemfly (*Melanogromyza sojae*)

Damage
The adult fly is small (2 mm long) and looks like a very small, black house fly. It lays eggs on the leaves, where pinpoint oviposition stings can be seen. Eggs hatch within two days and the white-coloured larvae (about 4 mm long) tunnel in the pith of petiole and stem tissues. Before pupating, larvae make a small (2 mm) elongated exit hole in the stem from which the adult fly later emerges. Fresh exit holes have a reddish colouration and can be easily seen on an affected plant's stem and petiole. Infestation early in the crop cycle causes greater damage to the crop than late infestations. In previous outbreaks (e.g. 2012–13), charcoal rot confounded crop symptoms.

Threshold
No thresholds have been developed.

Management
No insecticides are registered or under permit for control of soybean stemfly. Once

larvae are inside stems, insecticides are unlikely to affect them and the only effective target would be larvae that have just hatched from eggs laid in the leaves. Most outbreaks are not detected until larvae are tunnelling in the stems.

Two-spotted mite (*Tetranychus urticae*)

Damage

The mites form a fine web on the underside of the leaves, sucking the sap and causing the leaves to discolour and eventually die. They hasten plant maturity, reducing yield and seed size. Using broad-spectrum, non-selective pesticides can cause mites to flare, especially during the vegetative stage of the crop.

Threshold

Five mites/cm^2 on the leaf undersurface or 30% of plants infested.

Management

Control when thresholds are reached, particularly to protect green leaf tissue during the flowering to pod fill stages. Abamectin (e.g. Wizard 18®) is registered for mite control in soybean, but be aware of the 28 day harvest withholding period.

Harvesting and desiccation

Harvest-aid herbicides

Consider desiccation before harvest if the crop has a green weed problem, intensive insect pressure or when plants have ripe pods but green stems and retained leaves. Desiccation will result in easier harvesting and better quality grain.

- Diquat (e.g. Reglone®) is applied when 80% of pods are yellow/brown and seeds are ripe, yellow and pliable. Harvest 4–7 days after spraying.
- Glyphosate (e.g. Roundup Ultra®MAX) is applied only after seed pods have lost all green coloration and 80–90% of leaves have dropped. Do not apply to crops grown for seed or for sprouting. Do not harvest within seven days of application.

Harvesting

Harvest soybean as early as possible to minimise wet weather delays. The problem of wet weather at maturity is frequent in southern irrigation areas and in coastal NSW. For best results at harvest time:

- Prepare an even paddock and eliminate obstructions such as stumps, large sticks and rocks. The header can then access as many ripe pods as possible.
- Plant a recommended variety at the optimum time for your region. This will maximise harvest yield, as the variety will set pods well above the ground and ripen at the appropriate time.
- Begin harvest at 15% moisture content – usually 10 days after physiological maturity.
- Be prepared to harvest at moisture contents greater than 15% if the crop is likely to mature in May. Some drying costs will be incurred, but it is recommended to ensure grain quality.
- Consider minimising risk by purchasing or having direct access to grain drying equipment.
- Use an oven-dried sample to measure moisture. There are many cases of moisture meters reading inaccurately, especially at moisture levels above 16%. An oven-dried sample is the only reliable measurement if there is any uncertainty.

Grain moisture

The optimum moisture level for storing soybean grain is 11–12%. Because of the high risk of autumn rain on the north coast of NSW, which weathers and degrades ripe pods, crops are usually harvested at 15–18% moisture content and then fan-force air dried within 24 hours of harvest. In inland regions, crops are usually harvested at around 13% moisture content, but up to 15% depending on weather risks.

When ripe pods are left too long in the field and moisture content falls below 12%, substantial losses can occur from increased pod shattering and seed splitting.

Obtain **Grain receival standards** for soybean from Grain Trade Australia.

Header settings

Incorrect header settings result in grain losses. To minimise unnecessary grain losses during harvest ensure that the:

- cutting height is low enough to gather low-set pods and minimise the cutter bar impact higher up the plant, which increases pod shattering and grain loss
- correct header front is chosen for the crop height and topography, e.g. a wide-front header might not be the best option if the crop is on uneven or sloping

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Grain receival standards
(www.graintrade.org.au/commodity_standards)

land. A floating cutter bar, 'flexi-front' header, or narrow front might be needed to overcome variability in crop height, low pods or sloping ground
- correct position and reel speed is obtained if using an open-front header with a pick-up reel. A pick-up reel is preferable to a 'bat' reel
- reel position is 30 cm forward of the cutter bar
- speed is set at 1.25–1.5 times the ground speed to achieve an even and continuous feed into the header.

Consult the header manual or an experienced operator for further information.

Marketing

Developing a grain marketing strategy

Australia, by global standards, is a small soybean producer with annual production of around 70 000–110 000 tonnes. Production has declined since 2013, largely due to drought, flood and expanded cotton production. The USDA figures for global soybean production for 2014–15 to 2018–19 indicate that global production is around 320 million metric tonnes annually. Combined, the United States of America (particularly the states of Iowa, Minnesota and Illinois), Brazil, and Argentina produce around 80% (256 million tonnes) of the total world production of soybean grain and are key players in producing and exporting soybean and soybean products.

Australia is a net importer of soy-based products; primarily the demand for meal.

Australian grown soybean offers a number of marketing opportunities that fall into two broad market end uses:

1. crushing for oil and meal
2. edible quality beans for human consumption (e.g. flour and other baking additives, grits, kibble, soy milk, tofu, tempeh and plant-based protein products).

No genetically modified (GM) soybean is produced in Australia and this presently benefits high value export markets for human consumption including Japan, Korea and Taiwan.

Potential emerging markets are for biodiesel and high-value protein feed for aquaculture. Soybean grain can also supply industrial uses such as manufacturing membranes, waxes, and ink.

Growers should identify the market they wish to grow for and base this decision on sound principles, appreciating the characteristics of their production environment. When considering potential markets, growers are also encouraged to consider the benefits that the soybean crop will bring to their farming system as a whole.

A sound marketing strategy should start with knowing how much it costs to grow the crop. This will help to establish a target price at which to start selling. Be aware of historical highs and lows in the market when setting targets. See the **DPI website** and **GRDC website** for examples of gross margin calculations for soybean.

Identify key market information to follow, such as domestic prices and commentary, the Chicago soybean (and oil/meal) futures price, and domestic crop estimates. Most major grain buyers provide email or SMS services covering this information. Independent sources include the ABARE ***Australian crop report***.

Growers should understand contracts, including the legal obligations and what is expected of both the buyer and the seller. GRDC has produced the GrowNote: ***Soybean marketing*** that includes general marketing guidelines for growers.

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DPI website gross margin budgets (www.dpi.nsw.gov.au/agriculture/budgets/summer-crops)

GRDC website gross margin budgets (https://grdc.com.au/resources-and-publications/all-publications/farm-business-management-manuals)

Australian crop report (www.agriculture.gov.au/abares/research-topics/agricultural-commodities/australian-crop-report)

Soybean marketing (https://grdc.com.au/__data/assets/pdf_file/0029/370667/GrowNote-Soybean-North-15-Marketing.pdf)

Currency

As Australia imports soybean oil and meal, the value of the Australian dollar plays a significant part in the value of Australian soybean and products. The stronger the value of our currency against the US currency, the cheaper imports become and consequently push the value of the Australian soybean lower. The reverse will support and raise the value of imports and consequently the value of Australian soybean.

Crushing market

Soybean is crushed to produce oil and meal. Soybean is referred to as a low oil seed as they are approximately 80% meal and 20% oil. In contrast, high oil seeds such as canola and sunflowers are 60% meal and 40% oil.

The demand for soybean is a derived demand, that is, it is derived from the demand for oil and meal. There is some whole bean use for producing full fat meal. Whole soybean for crushing is generally imported from North and South America, where production is now largely based on genetically modified varieties. The import volume varies considerably from year to year depending on local production, price relativities of grain, oil and meal, and the domestic crushing requirements. Due to quarantine restrictions, imported whole soybean grain must be crushed at port locations.

Meal

Australian-produced soy meal competes with imported meal (48% minimum protein) from North and South America. The intensive livestock industry in Australia uses a wide variety of protein meals from both local and imported sources.

Australian soy meal (non GM) competes with imported meal with adjustment for quality differences, i.e. imported soy meal generally trades at 48% minimum protein with local meal at 44% or 46% protein depending on the processing method.

As soybean is approximately 80% meal, this tends to drive the crushing demand. However, oil is the higher value commodity and an important contribution to the overall crush margin.

Oil

There is only a relatively small intrinsic demand for soy oil and it is generally used in blended applications. In Australia in recent years, much of the soy oil used in blended vegetable oils has been substituted with canola oil.

Australia does import soy oil, primarily from South America, for both food and industrial purposes

Human consumption market

The edible soybean market continues to expand In Australia and there is increasing demand in both export and domestic markets for Australian-grown non-GM soybean. Premiums are usually paid by these markets. Organically produced grain also attracts a premium. The ASBP has responded to this growing market by producing varieties with a clear or light coloured hilum, high protein content and large seed size including Moonbi⦹, Richmond⦹, Hayman⦹, Cowrie, Bunya⦹, Surf, Burrinjuck⦹, Snowy⦹ and Djakal. Traditional varieties Soya 791 and A6785 also supply the human consumption markets. Growers should contact end users and buyers when making variety choices to determine preferred varieties.

Soybean is used for manufacturing a wide range of products including soy flour, soy milk, soy grits, tofu, tempeh, spreads, soup, confectionery and other Asian foods.

Human consumption markets generally prefer soybean grain with a large seed size (20–24 g/100 seeds or 5000–4100 seeds/kg), high protein (>40% DMB) and high germination percentages. Grain should be free from stains, soil, mould and seed coat damage. There is very low tolerance for admixture and dark hilum seeds. Seed grading is normally required. The Australian Oilseeds Federation ***Standards manual*** includes delivery standards for crushing and edible soybean.

Grain Trade Australia also publishes **standards** for grain trading.

Further information

Felton WL 1976. The influence of row spacing and plant population on the effect of weed competition in soybeans. *Australian Journal of Experimental Agriculture* 16, 926–931.

Australian crop report by ABARE (www.agriculture.gov.au/abares/research-topics/agricultural-commodities/australian-crop-report).

Australian Oilseeds Federation (www.australianoilseeds.com).

APVMA permit search (https://productsearch.apvma.gov.au/permits).

The Beatsheet On-line IPM resource including threshold calculator (http://thebeatsheet.com.au/economic-threshold-calculators/).

Grain Trade Australia (www.graintrade.org.au).

Grains Research and Development Corporation (GRDC)(www.grdc.com.au/).

National Oilseed Processors Association (www.nopa.org)

NSW DPI summer crops (www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops).

NSW North Coast Oilseed Growers Association(https://ncoga.com.au/).

Pulse Australia and **Pulse Check Coastal Blog.**(www.pulseaus.com.au) and (http://pulseaus.com.au/blog/category/pulsecheckcoastal).

Queensland Department of Agriculture and Fisheries beneficial insects (www.daf.qld.gov.au/business-priorities/agriculture/plants/crops-pastures/pest-beneficials).

Soy Australia (www.australianoilseeds.com/soy_australia/contact_soy_australia).

NSW DPI, QDAF and GRDC publications and management guides

Australian oilseeds standards manual (http://www.australianoilseeds.com/Technical_Info/standards_manual).

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Standards manual (www.australianoilseeds.com/Technical_Info/standards_manual)

Grain receival standards (www.graintrade.org.au/commodity_standards)

Australian crop report

Australian Oilseeds Federation

APVMA

The Beatsheet

Grain Trade Australia

Grains Research and Development Corporation

National Oilseed Processors Association (this website is not always available)

NSW DPI

NSW North Coast Oilseed Growers Association

Pulse Australia Pulse Check Coastal Blog

QDAF

Soy Australia

Australian oilseeds standards manual

Good Bug Bad Bug?: An identification guide for pest and beneficial insects in summer pulses, soybeans, peanuts and chickpeas (https://thebeatsheet.com.au/wp-content/uploads/2012/04/GoodBadBug-FINALscreen22Feb3.pdf).

GRDC GrowNotes ***Soybean northern region*** (https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/soybeansgrownotesnorthern).

GRDC ***Inoculating legumes: A practical guide*** (https://grdc.com.au/resources-and-publications/all-publications/bookshop/2015/07/inoculating-legumes)

GRDC Ute guides (https://grdc.com.au/resources-and-publications/apps/grdc-ute-guides). Order from the **GRDC catalogue** (https://grdc.com.au/resources-and-publications/all-publications/bookshop).

NSW DPI **farm budgeting tools and summer crop gross margins** (www.dpi.nsw.gov.au/agriculture/budgets/summer-crops).

Managing legume and fertiliser N for northern grains cropping (www.researchgate.net/publication/293958450_Managing_Legume_and_Fertiliser_N_for_Northern_Grains_Cropping).

Managing deep placement of phosphorus(https://communities.grdc.com.au/crop-nutrition/tag/deep-p-application/).

Raising the bar: better soybean agronomy (www.australianoilseeds.com/__data/assets/pdf_file/0018/7407/GRDC_Raising_the_Bar_-_Better_Soybean_Agronomy.pdf).

Silverleaf whitefly alert for soybean growers (www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops).

Charcoal rot of soybean (www.australianoilseeds.com/__data/assets/pdf_file/0020/10298/Charcoal_rot_of_soybean_Feb_2015.pdf).

Diaporthe disease complex of soybean (www.australianoilseeds.com/__data/assets/pdf_file/0017/10367/Diaporthe_disease_complex_of_soybean_Feb_2015.pdf).

Managing soybean leaf rust (https://grdc.com.au/__data/assets/pdf_file/0016/202462/soybean-leaf-rust.pdf.pdf).

Mildew diseases of soybean (www.australianoilseeds.com/__data/assets/pdf_file/0018/10368/Mildews_of_soybean_Feb_2015.pdf).

Phytopthora root and stem rot of soybeans (www.australianoilseeds.com/__data/assets/pdf_file/0019/10369/Phytophthora_Root_and_Stem_Rot_of_Soybean_Feb_2015.pdf).

Sclerotinia rot of soybean (www.australianoilseeds.com/__data/assets/pdf_file/0019/10297/Sclerotinia_of_soybean_Feb_2015.pdf).

Soybean variety update (http://pulseaus.com.au/blog/post/soybean-varieties-update-hayman-richmond).

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Good Bug Bad Bug?

Soybean northern region

GRDC ***Inoculating legumes: A practical guide***

GRDC Ute guides, order from the **catalogue**

NSW DPI ***farm budgeting tools and summer crop gross margins***

Managing legume and fertiliser N for northern grains cropping

Managing deep placement of phosphorous

Raising the bar: better soybean agronomy

Silverleaf whitefly alert for soybean growers

Charcoal rot of soybean

Diaporthe disease complex of soybean.

Managing soybean leaf rust

Mildew diseases of soybean

Phytopthora root and stem rot of soybeans

Sclerotinia rot of soybean.

Soybean variety update

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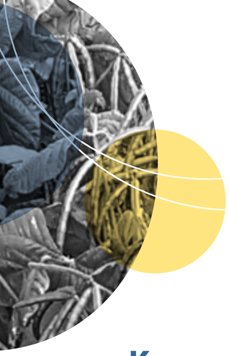

Sunflower

Key management issues

- Before making the decision to plant, determine the amount of stored water in the soil profile. If there is less than 80 cm of wet soil (less than 135 mm plant available water – PAW), consider not planting sunflowers.
- Sow into no-till paddocks for dryland crops as more soil water is stored, increasing the probability of higher yields.
- Double cropping is an option in dryland areas when there is a positive seasonal outlook and a full soil moisture profile.
- Apply nitrogen (N) fertiliser based on an N budget using your target yield, soil test results and PAW at planting. Use the previous crop yield and protein content if the soil has not been tested.
- A uniform crop stand and early canopy closure are essential to maximise competition with weeds.
- Use effective weed control options, especially for grasses. Controlling weeds during the first seven weeks after emergence is critical.
- Be aware of herbicide residues. Sunflowers are particularly sensitive to sulfonylurea (SU) herbicides.
- Select high yielding hybrids that have the desired traits for your growing conditions and suitable for your chosen end use market.
- Monitor and, if necessary, control insects, especially wireworm during crop establishment, and Rutherglen bug and heliothis from budding through to seed filling. Assess the potential for mice and bird damage.
- Familiarise yourself with the main diseases of sunflower, their lifecycle and alternative plant hosts, to help rotation planning and to limit disease effects. In particular, check for previous sclerotinia stem rot incidence.
- Do not plant too late in the cooler areas, e.g. south of Gunnedah, as the risk of disease, particularly *Sclerotinia*, is higher.
- Crops planted in late January are likely to be slow when drying down. Be prepared to harvest at higher moisture contents and use aeration where necessary.

Brief crop description

Sunflower:

- has a strong taproot capable of extracting water up to 2–3 m deep in ideal situations
- is most suited to deep clay soils, with high water-holding capacities
- can tolerate waterlogging, but long periods of inundation will lead to yield penalties
- is a good rotation crop, highly suited to planting into standing cereal stubble
- is most often planted after a long fallow following a winter cereal and is also suitable for use in a short fallow following sorghum, or as a double crop option provided the soil moisture profile is near full
- does not leave behind much stubble following harvest, so planting into paddocks with existing cereal stubble helps to prevent erosion
- is grown for three main markets; monounsaturated oil, polyunsaturated oil and the confectionary/birdseed market.

The main sunflower production region in NSW is in the state's north, primarily on the Liverpool Plains and around Moree. Smaller areas are grown under full irrigation in the state's southwest around Griffith and Hillston, mainly for seed production. Opportunity planting of sunflowers occurs mainly in the state's northwest, west of the Newell Highway, and less frequently in the central west.

Paddock selection

Paddock history

Select paddocks that were previously planted to a rotation crop. Paddocks in long fallow from wheat or barley, or a short fallow following sorghum, are preferred.

Previous crop history can affect the likelihood of disease having a major effect on the current sunflower crop. For example, many broadleaf weeds and crops host

Sclerotinia and can increase inoculum levels for the following sunflower crop (see Diseases on page 111 for more information).

Sowing sunflower following a cereal is preferred as broadleaf weed control will usually have been carried out, reducing the weed seed bank. Broadleaf weed control options in sunflower are limited.

Previously applied residual herbicides will have nominated plantback periods. Herbicides such as the sulfonylureas and atrazine can adversely affect sunflower.

Crops of monounsaturated hybrids should be isolated from other types of sunflower to reduce the risk of cross pollination, which lowers the oleic acid content. Do not plant adjoining crops of monounsaturated and polyunsaturated sunflower where flowering might coincide.

Soil management

Sunflower is 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, no-till improves moisture retention leading to consistently higher yielding sunflower crops. No-till also provides a wider planting window through retaining moisture in the seedbed longer 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 mice build-up compared with conventionally cultivated paddocks, and limits some broadleaf weed control options as pre-emergent herbicides cannot be incorporated.

Be aware that stubble can help both sunflower and other crop disease pathogens survive. Familiarise yourself with sunflower pathogens as well as those of the crops in your rotation sequence.

Soil moisture

Plant available water

Sunflower should only be planted where the soil profile is wet to a minimum depth of at least 80 cm (>135 mm PAW) in a vertosol on the north-western plains), and preferably a full profile to minimise the risk of poor yields.

Use a soil corer, push probe or a simulation model such as HowWet™ to determine starting soil water. If using soil coring, crop lower limits can be used to determine more accurately the amount of PAW. The final sunflower yield will still be correlated with starting soil water and in-crop rainfall. Starting with a full moisture profile minimises the risk of crop failure, particularly when in-crop rainfall is low.

The amount of starting soil water can be used when making decisions such as row configuration. Skip row or wide row configurations are sometimes used when starting soil water is less than desired.

Planting time

Sunflower is adapted to a wide range of planting times, which are grouped into an early and a late planting window. Aim to plant during the windows shown in Table 48.

Table 48. Suggested planting times for sunflower.

	Early plant												Late plant													
	Aug				Sep				Oct				Nov				Dec				Jan				Feb	
Region **Week**	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 planting time
> Later than ideal

The **early or spring planting window** starts in mid–late August in the most northern parts of the state and closes at the end of October in the most southern parts of northern NSW, e.g. Premer on the Liverpool Plains. The **late planting window** begins at the start of December and finishes at the end of January.

Sunflower tolerates light frosts in the early and late growth stages. It also tolerates high temperatures, except during the critical flowering and seed-filling stages.

For early plantings, the soil temperature at 10 cm depth should exceed 10–12 °C at 8.00 am (Eastern Standard Time) and heavy frosts should be finished. While 10 °C is the minimum, planting on rising soil temperatures will ensure quicker germination and establishment. Favourable growing conditions for the 7–10 days following planting will optimise crop establishment. Extremes of heat or cold can result in patchy plant stands.

Monounsaturated sunflower (>85% oleic acid) is preferred for spring plantings, but can also be planted in either the spring or summer planting window. Spring planting typically has higher temperatures during seed-fill, which has a relatively small effect on the oleic acid content unlike the effect on polyunsaturated sunflower.

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

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

Row spacing

Sunflower row spacing can be 36–100 cm or a range of skip row configurations, such as single or double skip where two rows are planted and one is missed (single skip) or two rows are planted and two are missed or skipped (double skip). A 75–100 cm row spacing allows 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, while at Moree 100 cm row spacing is more typical.

Research has shown that planting on a 100 cm solid plant or a single skip row spacing will achieve similar yields to 75 cm single skip row spacing at Moree. In contrast, planting on a 75 cm solid plant or single skip at Gunnedah, a more southern and higher rainfall zone, or a 100 cm solid plant, will achieve similar yields to each other.

Double skip or wide row (150 cm) spacing, while a sound risk management strategy, carries a yield penalty in the main sunflower growing regions. They also tend to affect the crop's architecture with plants growing taller with thinner stems that lean into the skip row area due to the increased inter-row competition.

Single skip row configurations are an option if there is limited stored soil moisture or when planting in marginal dryland environments e.g. Walgett, but are often lower yielding. In these situations, weed control is more critical and shorter hybrids will reduce the risk of lodging.

Plant population

Establishing 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 improved establishment percentages and a more even establishment within the row. The plant stand evenness affects uniformity of head size and stalk size, and soil water and nutrient use across a paddock.

Precision planters can minimise the likelihood of double or triple seeds being placed in close proximity. Ideally, plants should emerge at the same time to maintain flowering, seed set and crop maturity evenness across a paddock. Variable crop maturity makes in-crop decisions such as insect control or crop desiccation more difficult.

Aim for a plant population based on the depth of wet soil at planting, probable in-crop rainfall and growing conditions in your area. Table 49 shows the target plant populations that should be maintained regardless of the row spacing or configuration selected. Aim to establish 2.5 plants/m^2 on a 100 cm solid plant or double skip (which is five plants per linear metre of row).

Table 49. Target plant population guide (plants/m^2).

	Polyunsaturated/ monounsaturated	Confectionary/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

Sunflower

Seed for planting averages 15,000 seeds/kg, but can vary from 10,000 seeds/kg to 22,000 seeds/kg depending on seed size (Table 50). Always check the seed count on the bag. The minimum germination percentage is usually greater than 90%.

Small (7/8) and medium size seed (8/10 – Australian Sunflower Association sizing) 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 as smaller, lighter seed can result in doubles in one hole of the planter plate.

Table 50. Approximate number of seeds/kg.

ASA* seed sizes	Description	Seeds/kg
6/7	Very small seed	18,000–25,000
7/8	Small seed	15,000–22,000
8/10	Medium seed	12,000–16,000
10/14	Large seed	10,000–14,000
14/18	Very large seed	8000–11,000

* ASA – Australian Sunflower Association

Calculating seed requirements

When calculating your seed requirements, allow an extra 25% for establishment losses (see calculation below). Depending on planting conditions and the type of planter, establishment losses can range from 20% to 50%.

To determine the planting rate (kg/ha):

Method

		target plant population/m²		establishment percentage*	×	germination percentage	×	seeds/kg		
...10,000...	×	.........3.5.........	÷	......0.75............	×	..........0.93...........	×	15,000	=	your planting rate ...3.35 kg/ha

Planting depth and crop establishment

Planting depth is dictated largely by available moisture, the planter, soil temperatures at planting, and the soil type. Sowing depth could range from 2.5 cm to 7 cm, but is most commonly 3–5 cm. When soil temperatures are warmer, such as for the summer planting, place the seed slightly deeper as the seedbed will dry out more rapidly. The type of planter also affects how the seed bed dries out; disc planters cause minimal soil disturbance compared with a tyne.

Press wheels are essential for obtaining good seed-soil contact. Press wheel selection is important to ensure there is no soil cracking down the seed row. Seed row cracking causes the seedbed to dry out too quickly resulting in variable establishment. A press wheel pressure of 2–4 kg/cm width (of press wheel) is recommended. Use the heavier pressure when planting moisture is marginal or soil temperatures are warmer.

Seed used for planting is often treated with insecticide for protection against soil-dwelling insects. For a list of registered seed treatments and insect pest controls see **Insecticide seed dressings on page 129**.

Planting speed can affect establishment. Sowing too fast will cause seed bounce and result in uneven seeding depth; planting too slow allows dry soil to fall in on top of the seed.

Hybrid characteristics

Four sunflower hybrids will be marketed in NSW for planting in 2019–20. 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 51. Additional information can be found in the section **Diseases on page 111**.

Table 51. Characteristics of sunflower hybrids available in 2019–20.

Company	Hybrid	Maturity	End use	Height	Head inclination
Nuseed	Ausistripe 14	Medium	Confectionary/birdseed	Medium–tall	Semi-erect
	Ausigold 62	Medium	Monounsaturated	Medium	Semi-erect
	NHT15M265*	Early–medium	Monounsaturated	Short–medium	Semi-erect
Pacific Seeds	Sunbird 7	Medium	Confectionary/birdseed	Medium–tall	Semi-pendulous
S&W Seeds	SuperSun 66	Medium–full	Polyunsaturated	Medium–tall	Semi-pendulous

*Nuseed is intending to release at least one, but possibly two new hybrids for 2020–21 that are tolerant to imidazolinone herbicides. Registration is pending and an information package will be released when available.

Yielding ability

Select hybrids firstly on yield potential, but also on oil content if targeting the monounsaturated or polyunsaturated markets. Use hybrid trial results as a guide, but always test the hybrids on your farm and grow those that produce the best 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, which attracts a price premium.

Oil percentage

High oil percentages give growers a premium of 1.5% of price for each 1% of oil above 40%. Birdseed and confectionary hybrids such as Sunbird 7 have low relative oil percentages, as oil content is not a requirement for these end uses.

Maturity

All hybrid growth rates are largely determined by temperature, photoperiod and soil moisture. In northern NSW, a medium–slow hybrid planted at Moree in early September and at Spring Ridge in mid October takes 80–85 days to flower. The same hybrids planted in mid December to mid January take about 60 and 65 days respectively. Medium maturity hybrids are up to five days faster to flower. Quick and medium–quick hybrids are best suited to late planting times and north-western areas, west of the Newell Highway.

Head inclination and stem curvature

Hybrids with pendulous heads tend to suffer less sun scald at flowering than erect hybrids. However, pendulous hybrids with highly curved stems are more prone to lodging, making harvesting difficult, and water can collect in the back of the heads, increasing the risk of disease.

Growth stages

Planting time and temperature, and photoperiod and soil moisture affects the time taken for a sunflower plant to develop through the various growth stages. The planting location and hybrid maturity also affect the length of the growing season. Table 52 shows average times for each growth stage for a crop planted at Gunnedah.

Table 52. Development times for a sunflower hybrid at Gunnedah.

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	40	42
Stage length		
Planting to start of flowering	80	65
Planting to physiological maturity: – slow maturity hybrid – medium maturity hybrid	 120 110	 100 107
in full physiological maturity to harvest	20–30	30–40

Source: DPI, *Sunflower* Agfact 1997.

Germination and emergence

The speed of emergence can vary, but usually takes between five and 10 days, however it can be up to 30 days in certain situations. Germination speed depends on soil temperature, moisture and oxygen.

The preferred soil temperature for planting is 10–12 °C, however seeds can germinate at temperatures as low as 4 °C. Planting in cold conditions means germination and establishment will take longer. In these conditions, insect damage or disease risk is higher. Planting into warmer soils results in quicker emergence, but soil moisture around the seed will decline faster.

Sunflower has epigeal emergence, meaning their cotyledons appear above the soil surface still enclosed inside the seed coat. The seed coat then falls off to expose the cotyledons.

There is frost tolerance at certain stages: newly emerged seedlings are frost tolerant up to the 4–6-leaf stage. Sunflower plants are frost sensitive from the 6-leaf stage until the seed ripening stage.

Vegetative growth to bud initiation

Sunflower can tolerate temperatures ranging from 8 °C to 35–40 °C during growth, but grow best between 25 °C and 28 °C.

Sunlight initially controls leaf formation and development, but later development is most influenced by hybrid, day length and nutrition. Leaves initially develop in pairs and then emerge as singular alternate leaves up the stem.

Sunflower has a deep taproot, which is typically equivalent to or greater than the plant height. For example, when the plant has 8–10 leaves (~25–30 cm tall) the taproot is about 40–50 cm deep. The taproot reaches its maximum depth at flowering. The deep sunflower taproot allows the crop to extract more soil water than either sorghum or maize.

Wilting in the middle of the day in summer is common as the plant cannot close the stomates in its leaves to reduce transpiration losses. If plants do not recover at night, moisture stress is reducing yield potential.

Bud initiation to start of flowering

Once bud initiation starts, no more leaves will develop, but existing leaves continue to unfold. On average, a sunflower plant produces around 36 leaves, but this varies depending on hybrid and planting time.

During leaf development, the plant responds to day length (photoperiod), which affects development speed. This effect is reduced during the reproductive stages. The response to photoperiod also varies between hybrids. Soil N levels can also affect the size and rate of leaf expansion.

The plant will begin developing the bud, and finally ray petals will appear. At this stage the bud is usually at least 10 cm in diameter. The ray petals, which are the bright yellow petals surrounding the head; will then begin to unfold before flowering starts.

Moisture stress is important at two critical stages: head formation to the start of flowering (which affects seed yield), and grain fill when oil content will be reduced. The combination of high temperatures and moisture stress can drastically reduce yield and oil content. Rainfall or overhead irrigation during flowering can reduce seed set as the pollen is washed off the heads, preventing fertilisation. Avoid overhead irrigation during this growth stage and if rainfall occurs, check seed set approximately two weeks later to ascertain if there has been any effect on pollination.

Start of flowering to physiological maturity

Flowering starts once the ray petals are fully open.

Sunflower plants will lift their leaves and turn their heads to follow the sun during the day, referred to as heliotropism, which increases photosynthesis by around 9%. This will cease at flowering, at which time most of the heads are facing northeast.

The sunflower head consists of the yellow ray petals, which are highly attractive to bees and other insects. The disc flowers that form the face of the head are the start of developing seeds.

Disc flowers progressively open in concentric rings, beginning from the outside and working towards the centre of the head. Individual disc flowers complete flowering in three days; between one and four rings of flowers open each day, usually over five to 10 days. There are between 800 and 3,000 disc flowers per head, each of which can produce a seed.

Sunflower hybrids are largely self-pollinating, however, a large number of bees normally invade the crop during flowering, transferring some pollen between plants.

Head type becomes more important at this stage as hybrids that remain upright after flowering ends are more prone to sunburn. Many commercial varieties have semi-pendulous heads to limit this.

Temperature at this stage is critical. High temperatures during flowering and seed-fill negatively affect oil quality and quantity as well as reducing seed yield. Temperatures within the sunflower head can be up to 5 °C higher than the ambient temperature. Late-planted crops are also at risk of frost during the reproductive growth stages, which will damage the flowers and reduce seed set.

At the end of flowering, the ray petals will wilt and fall off (petal drop). The disc flowers will also fall off the sunflower face just before physiological maturity.

Physiological maturity

Sunflowers reach physiological maturity when the bracts around the edge of the sunflower head turn brown. This is usually 5–6 weeks after flowering starts.

At this time, the sunflower seeds have completed filling and their moisture content is approximately 30%. From physiological maturity to harvest the sunflower plant and seeds lose moisture (dry down). Physiological maturity is the correct growth stage to apply a desiccant.

Nutrition

Sunflower requires adequate nutrition, yet has a significantly lower requirement for several of the major nutrients compared with other crops. Table 53 shows the amount of each nutrient contained in the seed, stover (all other parts of the plant) and as a total to produce a 1–2.5 t/ha crop.

Table 53. Sunflower nutrient removal kg/ha.

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

NI = No Information
Source: *The new big black sunflower pack*, Australian Sunflower Association.

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The new big black sunflower pack (www.australianoilseeds.com/commodity_groups/australian_sunflower_association/asset_listing_for_big_black_pdf)

Nitrogen

Sunflower has a lower requirement for N compared with sorghum and winter cereals. However, N is the nutrient required in the greatest quantity by a sunflower crop. Nitrogen has a strong influence on many crop characteristics including the size and number of leaves, seed size and weight, yield and oil content. Cropping history, fallow conditions and yield potential determine the quantity of N fertiliser needed.

As a guide:

- **Liverpool Plains**: high yielding crops use 80–100 kg N/ha
- **Moree and Narrabri regions**: normally little N is applied pre-planting as carryover fertiliser from the previous cereal crop is relied on
- for responsive paddocks, up to 50 kg N/ha should be applied
- irrigated crops need 100–140 kg N/ha depending on target yields.

Nitrogen budgeting is the preferred method for determining the crop's N requirement using the following calculation.

The quantity of N removed in 1 tonne of grain is about 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 about 1.7 times the amount removed in the seed.

Target yield (t/ha)		N removed (kg/t)		N removed in seed (kg/t)
…………2………..	×	……..26……..	=	…52…

N removed in seed (kg/t)		1.7 (conversion factor)		N required for the crop
……..52……..	×	……….1.7……….	=	88.4 kg N/ha

The N the crop takes up comes from the available soil nitrate-N and from N fertiliser. Soil nitrate-N is estimated by soil testing (preferably to 120 cm depth) or reviewing the crop history, in particular the grain yield and protein content of the previous crop. In the above example, if 50 kg/ha of nitrate-N was available in the soil, then only 38 kg N/ha would be required as fertiliser.

A pre-plant application of nitrogen fertiliser or fertiliser banding 5 cm below and to the side of the seed is recommended. Germinating seed is very susceptible to N fertiliser burn if planted in close contact.

Nitrogen budgets should also be matched to the amount of starting PAW in dryland situations, or the amount of water available in irrigated situations. An imbalance of N to water could lead to oil content being lower than 40%.

Phosphorus (P)

Phosphorus fertiliser needs are best determined by soil testing, soil type, previous P test strips and the likely arbuscular mycorrhizal fungi (AMF) levels (in northern NSW). Phosphorus deficiency leads to quicker flowering and maturity, and in severe cases can reduce plant growth and causes necrotic lesions on leaves.

In northern NSW, applying at least 10 kg P/ha is recommended, typically as starter fertiliser. Responses to P are unlikely when Colwell P levels are above 40 ppm. If AMF levels are low, supplying adequate P and zinc (Zn) fertiliser is very important.

In southern NSW, at least 20 kg P/ha is normally required, increasing to 40–50 kg P/ha if sunflower follows a rice crop.

Sulfur (S)

Sunflower also requires sulfur, but to date has not been identified as a problem on the cracking clay soils of northern NSW, which usually contain ample amounts of sulfur as gypsum deeper in the profile. Several NSW DPI research trials have shown no significant responses for yield or oil content to S application.

Sulfur forms important partnerships with N affecting the total leaf area produced. Sulfur deficiency, particularly at the budding and flowering stages can lead to decreased oil yield from fewer seed numbers and seed weight. Sulfur deficiency is observed as general chlorosis of the younger leaves.

Potassium (K)

Potassium is required for stalk strength and general tissue strength. A 1 t/ha crop requires 30 kg K/ha as sunflower is a relatively K high user. 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 greater than 0.25 meq/100 g. Several NSW DPI research trials have shown no significant yield or oil content responses to K.

Zinc (Zn)

Fertiliser responses to Zn often occur in heavy alkaline soils. Zinc can be broadcast at 10–20 kg Zn/ha and incorporated into the soil well before planting for major deficiencies. Banding Zn compound fertilisers (rather than Zn-blended fertilisers) with the seed at planting is an effective method. Alternatively, when crops have 8–10 leaves, a foliar application can be a useful strategy.

Safe rates of fertiliser planted with the seed.

Table 54 shows the suggested rates of fertiliser that can be safely planted with sunflower seed.

The planter row spacing affects the safe rate: the wider the row spacing the lower the safe amount of N and P that can be placed with the seed at planting.

Table 54. Safe rates of fertiliser suggested to be planted 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.

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The new big black sunflower pack (www.australianoilseeds.com/commodity_groups/australian_sunflower_association/asset_listing_for_big_black_pdf)

Subsoil constraints

Sunflower does not tolerate acidic soils, particularly those containing toxic levels of aluminium and manganese. Soil with a pH_{Ca} of 5.0 or less is not suitable for sunflower.

Sunflower does not tolerate salinity well – it is less tolerant than wheat or sorghum but more tolerant than soybean or maize.

Soil salinity levels of 4–5 dS/m will affect sunflower growth. Paddocks with salinity as a subsoil constraint should be identified, the depth to the subsoil constraint noted, and the reduction in PAW calculated. Subsoil constraints effectively reduce the amount of PAW available to the crop.

Similarly, sodicity can affect sunflower emergence and growth. Highly sodic soils tend to develop a hard crust, which can reduce seedling emergence. Subsoil sodicity will reduce the amount of PAW available to the crop.

Compaction is another subsoil constraint that has become less of an issue with the adoption of no tillage. Paddocks with compaction issues have sometimes been considered ideal for sunflower as the taproot is thought to help break through the compacted layer. However, if the roots cannot penetrate the compacted layer then they will grow at right angles and have limited access to the water and nutrients deeper in the soil profile.

Irrigation

Sunflower can be successfully grown under irrigation: pivots, laterals or surface irrigation on raised beds are suitable. Take care with irrigation systems so as not to create a humid environment that could promote diseases such as powdery mildew.

Waterlogging will reduce sunflower yields so quick, even and efficient irrigation is important.

The maximum water extraction depth is reached at around 50% flowering. Root growth is 3.2–3.5 cm/day, with the extraction front proceeding at around 3.8 cm/day. Queensland Department of Agriculture studies showed that daily water uptake peaks at about 40 days after planting, or close to budding.

The amount of irrigation water required varies depending on whether the crop is planted in spring or summer, the growing season temperatures, in-crop rainfall and soil type. Spring-planted crops require more water as their growth rates are slower making the vegetative stage longer. 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 between 2.0–5.0 ML/ha might be required as irrigation.

Water stress between flowering and maturity has the biggest effect on grain yield. As a rule of thumb, in self-mulching clay soils a water depletion of 75–90 mm can be used to schedule irrigations, however this depends on soil type and root zone structure. Sunflower visually displays moisture stress through wilting. This will naturally occur in the middle of the day, but leaves should regain their turgor (leaf stiffness) in the evening and morning, otherwise irrigation is required.

Sunflower has a relatively low demand for water until about 10 days after the bud visible stage. The demand for water then increases rapidly until approximately 26 days after 50% flowering.

The recommended times for surface irrigations are:
1. Before planting – pre-water fields.
2. Budding – first irrigation.
3. Start of flowering – second irrigation.
4. Early seed fill– third irrigation.

If using overhead irrigation, use caution to try and avoid the flowering period to ensure seed set is not affected by pollen being washed off the florets.

Irrigating too late into seed fill will increase the risk of fields remaining wet at harvest, reducing access, and potentially causing compaction from headers.

Weed management

Good weed control is essential for high-yielding crops. The first seven weeks after emergence is the most critical period for weed competition. QDAF research has shown that early sunflower growth can be reduced by as much as 39% without effective weed control. Weeds can also harbour pests and diseases such as phomopsis stem canker.

A survey of sunflower paddocks in northern NSW from 2003–2006 found bladder ketmia, fleabane, bindweed and milk thistle to be the main broadleaf weeds. The main grass weeds were barnyard grass and volunteer sorghum.

Paddocks with high broadleaf weed populations should be avoided as in-crop control options are limited and expensive. Pre-emergence application with Stomp® or Stomp Xtra® (pendimethalin) is an option for controlling several grass and broadleaf weeds in sunflower. Dual Gold ® is another option that can be applied at the post planting, pre-emergence stage. See Table 55 for a list of registered herbicides.

Herbicides are available for post-emergence grass weed control. Several Group A herbicides are registered for use in sunflower, including Verdict®, Shogun® and Fusilade®.

Due to the increasing resistance incidence to Group A herbicides, these options should be used as part of an integrated weed management strategy.

Identifying glyphosate-resistant barnyard and liverseed grass in northern NSW is another complication for weed management. Rotating herbicide groups is difficult with many crops, including sunflower, so an integrated approach that combines a number of tactics should be used for weed control. The double-knock strategy of glyphosate followed by paraquat (e.g. Grammoxone®) is the main resistance management tactic for grass weed control pre-planting and in fallow. Using pre-emergent herbicides such as Dual Gold®can also help with weed control.

Inter-row cultivation is another option to help control broadleaf weeds. Shielded spraying is used on a limited scale because it is difficult to apply without damaging the sunflower crop.

Table 55. Herbicides registered for use in sunflower.

	Herbicide (active)	Example product	Group	Sunflower use pattern		
				Pre-plant	Post-plant pre-emergent	Post-emergent
Residual activity – check plan backs	2,4-D amine *	Baton®	I	✓	–	–
	trifluralin	TriflurX®	D	✓	–	–
	dicamba	Dicamba®	I	✓	–	–
	pendimethalin	Stomp®	D	✓	✓	–
	S-metolachlor	Dual®Gold	K	✓	✓	–
	tribenuron -methyl	Express®	B	✓	–	–
Knockdown activity	glyphosate	Roundup®	M	✓	–	–
	paraquat	Nuquat®	L	✓	–	–
	paraquat + diquat	Sprayseed®	L	✓	–	–
	butroxydim	Factor ®WG	A	–	–	✓
	propaquizafop	Shogun®	A	–	–	✓
	fluazifop-p	Fusilade®	A	–	–	✓
	haloxyfop-r	Verdict®	A	–	–	✓
	sethoxydim	Sertin®	A	–	–	✓
	Flumioxazin**	Valor®	N	✓	–	–

* New 2,4-D label restrictions came into force on 3 October 2018. See the **APVMA website** for full details.
** Plantbacks do apply. Check the label.

Diseases

The occurrence and severity of diseases in sunflower are usually related to seasonal conditions and inoculum load. In order to minimise field losses from disease, select disease-resistant hybrids where possible, control volunteer and wild sunflower, and rotate crops to include non-susceptible hosts.

The most common diseases of sunflower are alternaria leaf and stem blight, phoma black stem, phomopsis stem canker, powdery mildew, rhizopus head rot, rust and several of the *Sclerotinia* fungi: *Sclerotinia minor*, *Sclerotinia sclerotiorum* and *Sclerotium rolfsii*.

Alternaria blight (*Alternaria helianthi*)

Symptoms

The disease appears as roughly circular/angular dark brown to black necrotic spots on the lowest leaves. Stems, petioles, flower bracts and petals can show symptoms under favourable conditions. Lesions can be surrounded by yellow haloes. If the disease infects a leaf vein, a long, black lesion might develop following the vein and leading to more rapid necrosis of the leaf. Severe infection can cause leaf blighting, which leads to premature senescence displayed as shrivelled, dark brown leaves.

Note: This disease can be confused with septoria leaf spot (*Septoria helianthi*) – the most obvious difference is that *Septoria* causes a large, lighter brown lesion often without a halo, whereas *Alternaria* causes a black lesion usually with a halo. *Septoria* is generally a less damaging pathogen of the lowest leaves, although incidences have increased in the past few years in wetter conditions.

Conditions favouring development

Spores are airborne and survive on crop residues, volunteers, and wild sunflowers. *Alternaria* is favoured by wet, warm weather (26–30 °C) over 3–4 days, especially at flowering. Successive wet cycles can accelerate epidemic development, causing defoliation. Plants are more susceptible as seedlings and at flowering.

Management

Resistant hybrids are not available, so planting more than one hybrid and varying planting time is recommended. Tolerance levels in some hybrids might be reflected in the size and number of lesions and haloes produced. Avoid planting near standing sunflower stubble, which could harbour the pathogen.

Charcoal stem rot (*Macrophomina phaseolina*)

Symptoms

Diseased stalks can be discoloured at the base with the pith displaying a characteristic peppery grey appearance. Severely infected stems can appear bleached (ashy or silvery grey) as the stems dry down. In high soil temperatures and low soil moisture, plants can rapidly senesce, leading to smaller head diameters and/or lower seed weights. Severe infection can also affect oil composition by increasing the free fatty acids and discolouring the oil.

Conditions favouring development

Charcoal rot usually occurs in moisture-stressed crops when root zone soil temperatures are above 35 °C. It is a pathogen of over 300 genera of crop and weed species and often remains as a latent (dormant) infection until the crop becomes stressed. Microsclerotes (which cause the peppery appearance in the pith) are survival structures that can remain viable in the soil for many years infecting both grasses and broadleaf plants.

Management

Avoid any management practices that will stress the crop – water stress, excessive N, low K or herbicide injury.

Irrigating to avoid moisture stress during seed fill can be helpful. Crop rotations with sorghum or corn following sunflower help limit disease build-up, although sorghum will be susceptible and could lodge under favourable conditions. More susceptible crops including mungbean, soybean and navy bean will also build up inoculum.

Rhizopus head rot (*Rhizopus* spp.)

Rhizopus head rot is a common disease in sunflower, usually colonising after head damage followed by wet weather.

Symptoms

The infected area in the back of the head develops a brown colour and can become sunken with a very soft and mushy water-soaked appearance. If infection is advanced, the inside of the head will appear brown, sometimes with a dark grey–black peppery appearance caused by fruiting bodies (sporangia). These can be confused with the small black sclerotes of charcoal rot and the larger black sclerotes similar to mouse droppings that *Sclerotinia sclerotiorum* (head rot) produces. Generally, the mushy, water-soaked appearance of the head is characteristic of *Rhizopus*, often with dark greyish fungal threads giving a cotton-wool effect on the front of the head. Heads can dry prematurely, shrivel and sometimes shred.

Conditions favouring development

Rhizopus head rot is promoted by insect, bird, mouse or hail damage to the back of the head, combined with warm, humid conditions. Hybrids that tend to hold water in the back of the head as it becomes pendulous during seed fill, are also particularly vulnerable during wet weather. If water collects for a length of time, *Rhizopus* can invade the stressed tissues without pre-existing damage to the head.

Management

Limiting insect, mouse or bird damage will reduce infection risk.

Rust (*Puccinia helianthi*)

Rust incidence has been very low in recent years. This is most likely due to both unfavourable weather conditions and good resistance levels in most hybrids. Generally, incidence is higher in the more susceptible birdseed and confectionary lines as well as inbred and breeding lines in nurseries.

Currently there are more than 115 rust races characterised in Australia. Breeding programs are continuing to build rust resistance into new hybrids through multiple gene resistance.

The majority of current hybrids have good rust resistance, although all are susceptible to a small number of rust races – the susceptibilities differ with each hybrid. Since the dominance of particular races changes according to availability of specific hosts, and new virulent races can develop rapidly, vigilance is essential to ensure future outbreaks are pre-empted.

Symptoms

Small reddish-brown pustules of dark brown, dust-like spores appear that rub off onto your finger when touched. This is a good check to limit confusion with early *Alternaria* infection. Rust infection starts on the underside of the lowest leaves, moves to both upper and lower leaf surfaces and can progress up the plant to infect the flower bracts if conditions are ideal.

Conditions favouring development

Rust spores are airborne. The pathogen can also survive in crop residues as telia, which are large blackish fruiting bodies that develop amongst the reddish brown pustules in cool conditions. Wild sunflowers and volunteers also contribute to inoculum build-up. Although a significant host of rust, wild sunflowers are also an important source of resistance genes for rust and other sunflower pathogens.

Rust epidemics are favoured by successive cycles of moist, warm weather (around 18–23 °C). Infection levels can be higher later in the season, e.g. March–April as the weather cools and inoculum levels have built up during the season. Moisture from light rainfall or dew is enough to cause infection. Leaf wetness for at least 10–12 hours is ideal for the disease to develop.

Management

Serious losses are normally avoided by growing resistant hybrids. Take note when neighbouring crops are planted, consider planting more than one hybrid to limit build-up of any specific rust races, and avoid successive plantings of the same hybrid. Be aware that birdseed varieties such as Sunbird 7 are susceptible to a number of specific rust races and will be more likely to carry rust during the season, especially if planted late. Additionally, many of the older sunflower varieties might not be resistant to current dominant rust races. Ask your seed company representative about your hybrid rust resistance levels.

Sclerotinia stem and head rot (*Sclerotinia minor, Sclerotinia sclerotiorum, Sclerotium rolfsii*)

Sclerotinia species have an extensive host range of broadleaf crops and weeds including canola, chickpea, soybean, vegetable crops, legumes and sunflower. *Sclerotinia* build-up often results from inappropriate rotational choices, although floods and machinery can carry sclerotes to previously clean paddocks. Generally, planting a cereal such as wheat, barley, sorghum or maize after sunflower is the best option to limit disease build-up if *Sclerotinia* is present. *Sclerotium rolfsii* incidences have increased in recent years, particularly in northern NSW, the Darling Downs and Central Queensland.

Symptoms

Basal and mid-stem lesions usually do not appear before budding. A light-brown lesion will develop either at the base (*S. minor*, *S. sclerotiorum*, *Sclerotium rolfsii*) or mid stem (*S. sclerotiorum*), which can girdle the stem causing the plant to either lodge or senesce early. *S. sclerotiorum* can also cause head infection. Dark orange bands might stripe the basal lesion (*Sclerotium rolfsii)* and a darker edge might develop as the lesions age. The pith inside stems and/or heads infected with *Sclerotinia* becomes filled with a white cottony fungal growth, sometimes with sclerotes extending outside the stem. All *Sclerotinia* species produce black sclerotes; small, black irregularly shaped survival structures that develop in the infected tissue and can survive many years in the soil. The *S. minor* sclerotes are smaller than those of *S. sclerotiorum* and are a useful diagnostic feature. As the disease develops, stems and heads often shred, which dislodges the sclerotes into the soil as the plants lodge or the heads disintegrate. *Sclerotium rolfsii* sclerotes are a caramel–brown colour.

Conditions favouring development

Sclerotinia minor will infect during warmer conditions whereas cool, wet weather (less than 18 °C, 15–17 °C is ideal) favours *S. sclerotiorum,* which allows sclerotes to germinate in the soil. In NSW, these conditions are most prevalent in autumn. Dense canopies also favour these pathogens by allowing a cooler, wet microclimate to persist during rain and dew periods.

Hotter conditions such as those in Central Queensland and northern NSW around Moree favour *Sclerotium rolfsii*.

Management

Planting before mid January reduces stem and head rots, especially in the cooler areas, as does rotating with cereal crops. As the sclerotia can survive in plant debris and the soil for many years, rotation with non-susceptible crops is an important management tool. Be aware that unprocessed stubble protects the sclerotes and delays breakdown, and as many weeds are major hosts, broadleaf weed control is essential.

Sclerotes of all species can be difficult to sieve out of seed samples so it is important to keep seed production areas free of *Sclerotinia* to avoid spreading the disease.

Sclerotes are also easily transported on machinery, boots, plant debris and water – good farm hygiene will help limit spread.

White blister (*Albugo trogopogonis*)

White blister is not often seen in Australia and has not been recorded as causing any economic damage, unlike South Africa where it results in head and stem infections and lodging. Sunflower can tolerate high levels of leaf infection (up to 50%) without significant yield loss. (If *Albugo* spp. is seen on sunflower or any other host, please contact **Sue Thompson** as specimens are required for a current Australian study of this genus.

CONTACT SUE THOMPSON
Phone: 0407031244
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Symptoms

Leaf symptoms appear as raised pustules on the leaf top with whitish spores on the underside. The disease can also manifest as grey petioles and infected stems, appearing as grey lesions elongating down the stem, however, these symptoms are rare.

Conditions favouring development

Moderate to heavy infections of white blister might occur in spring-planted crops. Cool, wet conditions (<20 °C) help the spread and severity of the disease. Warm conditions slow disease development and spread.

Management

White blister causes only small yield losses, even when leaf damage is severe. However, if petiole and stem infection occurs, lodging and large yield loss could result. Controlling wild and volunteer sunflower is an important management strategy. Many Australian hybrids have high levels of resistance.

Powdery mildew (*Golovinomyces cichoracearum*)

Usually a minor disease, however powdery mildew can rapidly colonise crops, particularly late-planted crops, due to cooler, mild, humid conditions during the late summer and autumn.

Symptoms

Powdery mildew appears as greyish-white spots of fungal threads, firstly on the lower leaves that then spread up through the plant canopy if favourable conditions persist. The fungal threads grow across the leaf surface and the large number of spores produced gives the leaves a powdery appearance. Severe infections can cause leaf death and pinched seed.

Conditions favouring development

Powdery mildew prefers cool conditions with high humidity. Spores germinate at 20–25 °C under high humidity, in as little as 2–4 hours. Under ideal conditions the life cycle can be complete in 5–7 days. Hence powdery mildew build-up within a crop can be very rapid. Regular crop inspections are essential if conditions are favourable.

Management

Late season plantings tend to be more affected by powdery mildew, largely due to the more favourable environmental conditions. There are no established resistance ratings for hybrids. There are no registered fungicides for powdery mildew control, however, there is a minor use permit for Tilt® 250EC (250 g/L propiconazole) and several other propiconazole products under **PER82488** (exp. 33/3/2022). This permit allows 1–2 applications at 250–500 mL/ha (250 g/L propiconazole) to be applied no later than petal drop. Trials determined that protecting the top third of the plant was effective*. Check the permit for additional application requirements.

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PER82488 (http://permits.apvma.gov.au/PER82488.PDF)

Trial Results* – TILT®250EC rates and timing

Trials have shown that one application of 500 mL/ha applied between bud initiation and no later than 5% ray floret emergence will give good control of powdery mildew under moderate disease pressure until physiological maturity.

Moderate disease pressure means the bottom third of the canopy is 60–80% infected and the middle third of the canopy with colonies dotted to half way at 5% ray floret emergence. This level of disease pressure at ray floret emergence led to 30–80% leaf area of top third of the canopy being infected by physiological maturity in the untreated plots.

For further information contact **Sue Thompson**

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Phomopsis stem canker (*Diaporthe gulyae, Phomopsis gulyae* and other species, not *D. helianthi,* in Australia)

Phomopsis stem canker has emerged as a damaging disease of Australian sunflower when conditions are favourable.

Overseas, *Diaporthe helianthi* and *Phomopsis helianthi* causes yield losses of up to 50%. The species identified in Australia to date is not *D. helianthi* but the most damaging species, *D. gulyae*, which displays similar symptoms.

In Australia, a range of other *Diaporthe* species also causes stem and basal lesions on sunflower. However, incidence and severity depend on inoculum load and environmental conditions.

Symptoms

Characteristic pale brown to brown–black lesions dot the stems at the nodes. Basal lesions can occur. The lesions are similar to those of phoma black stem (*Phoma macdonaldii*), which causes shiny black lesions dotted at the nodes that generally do not affect the pith. Yield losses from phomopsis stem canker are caused by pith deterioration behind the lesions (press large lesions between thumb and fingers) and throughout the stem as the disease progresses. Lesions extend above and below the node as the plant ages and can develop a darker edge. Mid-stem lodging might occur. Dark-coloured fruiting bodies (pycnidia) might be seen as a speckle of dots at the site of the lesion as the stems dry out in susceptible hybrids or in very wet conditions. It is not possible to visually determine which species has caused the infection, however, if the infection is extensive and causing lodging or early senescence the causal species is most likely to be *D. gulyae*.

Conditions favouring development

Warm, wet conditions favour development; the optimal temperatures for infection are 23–25 °C. Infection occurs via the leaf margin then progresses down the petiole to the node, where the characteristic brown lesion becomes evident on the stems from late budding/flowering onwards.

Management

Phomopsis spp. can survive on stubble and other plant residues – hence stubble management is essential to limit disease build-up. Overseas recommendations suggest burying stubble up to 15 cm deep for *D. helianthi* (not present in Australia). Strategic burial or stubble processing should be considered to control the spread and survival of this group of pathogens. Rotation away from sunflower for a minimum of 3–5 years is recommended overseas.

Varietal differences have been observed in field trials, however, more research is required. Recent studies have revealed that *D. gulyae* and many other *Diaporthe* species are pathogenic to other crops such as soybean, mungbean and chickpea, although the risk to these crops will be determined by inoculum load and environmental conditions.

Good farm hygiene will limit pathogens spreading on plant debris. Care should be taken when allowing farm equipment such as contract headers onto your property if they come from paddocks where crops have been infected.

No chemicals are registered for *Phomopsis* spp. control on sunflower in Australia.

A number of weed species such as sowthistle, Noogoora burr and wild sunflower have also been found to be alternative hosts to *D. gulyae* and other *Diaporthe* and *Phomopsis* spp. associated with sunflower in Australia.

Diaporthe and *Phomopsis* species might be seed-borne, however, no information is available for the importance of seed-borne infection under Australian conditions. Vigilance in seed production areas is recommended.

For further information contact **Sue Thompson**.

Insect pests

The main pests of seedling sunflower are brown cutworms, wireworms, adults and larvae of false wireworms, and brown field crickets. Major pests from budding to maturity are Rutherglen bug and *Heliocoverpa* caterpillars. Check the seedbed before planting and check the crop regularly and thoroughly for insect pests. Spray only when the insect population exceeds the economic threshold and only use registered insecticides.

Cutworms including brown (*Agrostis munda*), Bogong moth (*Agrostis infusa*), black (*Agrostis ipsilon*), and variable cutworm (*Agrostis prophyricollis*)

Cutworms are caterpillars usually 25–45 mm long and can vary from grey–brown to green in colour. They will usually curl up if picked up.

Damage

Cutworms can severely damage crops during establishment. The large cutworms cut the stem off at ground level, while the smaller cutworms eat the leaves. Cutworms feed at night or on dull, overcast days. Cutworms seek shelter under the soil surface during the day.

Threshold

Treatment is recommended if there is increasing damage to the crop at the seedling stage. In older plants it is recommended to consider control options if more than 90% of plants are infested or if more than 50% of plants have 75% or more leaf tissue loss.

Management

Check crops late in the afternoon or evening and control if damage is obvious. Control at an early stage is important as sunflower does not have a compensatory mechanism such as tillering to recover from any stand losses. Seed treatment is most commonly used to prevent any establishment damage.

True wireworms (*Agrypnus* spp.) and false wireworms (*Pterohelaeus* spp.)

Wireworms live in the soil and feed on plant roots and underground stems. False and true wireworms have three pairs of legs just behind the head, are shiny and coloured cream or yellow. However, false wireworms are hard bodied, but true wireworms are soft bodied.

Damage

Wireworms are usually found at the interface between dry and wet soil. The larvae can bore into germinating seed. Activity is more common in heavier, wetter soils and damage is often more common when cool, wet conditions slows crop emergence.

False wireworm damage is similar to that caused by true wireworm, however it is more prevalent in dry seedbeds.

Threshold

The threshold for false wireworm control is one larvae per sample. The threshold for true wireworm is based on finding more than 25 wireworm in 20 germinating seed baits.

Management

Cultural control practices include using presswheels and controlling weeds in fallows to ensure adult wireworms are not encouraged to breed using this food source. Check the seedbed before planting and use treated seed. Insecticide application is an option. Check the **Insecticide seed dressings on page 129** located at the back of the guide for registered options.

Greenhouse whitefly (*Trialeurodes vaporariorum*)

Damage

Severe infestations of greenhouse whitefly (GHW) can cause significant yield loss. Severe wilting and the appearance of a sticky, sooty, honeydew exudate on the leaves are common symptoms. Crops can be killed, but this is very rare, however, sunflower crops can also support large numbers of GHW with little effect.

Threshold

There are no established threshold numbers in sunflower.

Management

Natural predators can effectively regulate GHW populations. As whitefly populations can occur as mixed species, aim to retain natural predator populations for as long as possible.

Australian native, silverleaf whitefly or B-biotype and Q-biotype (*Bemisia tabaci*)

The *Bemisia tabaci* species includes three biotypes: Australian native, silverleaf whitefly (SLW) or B biotype, and Q biotype. The Australian native is common and is not considered a problem, but cannot be distinguished from the other two species without a DNA or chemical test.

Damage

The SLW or B biotype was first discovered in Australia in 1994. Silverleaf whitefly poses a greater threat than GHW to broadacre crops. It caused significant damage to a wide range of broadleaf crops including sunflower, mungbean, soybean, peanut, and cotton in 2001–2002 in the Emerald Irrigation Area. A new biotype named Q-biotype was discovered in 2009 in Queensland and north-western NSW.

SLW has a very wide host range (over 500 plant species globally), a high reproductive capacity and can develop resistance to insecticides within 2–3 generations. Hence the further north it occurs, the shorter the period between generations and the more generations possible each season.

Management

Immature SLW is susceptible to attack by several wasp species, big-eyed bugs, lacewing larvae and ladybeetles. Maintaining beneficial insects in sunflowers can therefore play an important role in reducing SLW numbers. Maintaining clean fallows and considering nearby host crops also play a management role. There are no registered insecticides in Australia for use in sunflower crops.

Heliothis (*Helicoverpa* spp.)

Both species of *Helicoverpa* (*armigera* and *punctigera*) occur in sunflower.

Damage

Heliothis feed on leaves, buds and the face and back of heads. Developing buds can be damaged by severe infestations. Caterpillars bore holes into the backs of heads and predispose the plant to rhizopus head rot.

Sunflower can tolerate large numbers of heliothis caterpillars, especially from flowering onwards. There is no significant yield reduction documented in the absence of secondary head rots. Larvae are difficult to control when feeding on the sunflower face and under bracts, especially once the head turns over.

Threshold

At budding, more than one medium or two small larvae per plant warrants control. Natural mortality rates of 30% for larvae less than 5 mm are common and should be taken into account. Therefore, by including expected mortality, the threshold for larvae in the 1–5 mm size range is six larvae per head.

Management

Choose control options that are compatible with the heliothis insecticide resistance management strategy for your region. Control is challenging as heliothis often hide under the bracts during the budding stage or around the front of the face during flowering. Normally insecticide applications are only effective until the heads turn to face the ground.

Rutherglen bug (*Nysius vinitor*) and grey cluster bug (*Nysius clevelandensis*)

These species are considered together as they are difficult to distinguish, cause similar symptoms and can significantly reduce yield and oil content when present in high populations.

Damage

Adults and nymphs cause damage by feeding. The two main stages when the crop is susceptible to damage are at budding when buds can be distorted, stunted or killed, and flowering through to seed fill when adults lay their eggs in the sunflower heads and the young nymphs feed on the developing seeds, reducing yield and oil content.

Threshold

The thresholds are designed to prevent adults breeding in the crop, hence thresholds are higher in late crops than in early crops as higher prevailing temperatures promote more rapid Rutherglen bug development.

The thresholds proposed in Table 56 are based on field experience and knowledge that the adults will not lay eggs until the start of seed fill.

Table 56. Nysius spp. thresholds in sunflower.

Crop type and growth stage	Recommended threshold (adults/plant)
Early plant sunflower	
Budding	10–15 adults/plant
Seed fill	20–25 adults/plant
Late plant sunflower	
Budding	20–25 adults/plant
Seed fill	50 adults/plant
Confectionary sunflower	5 adults/plant

Management

Several synthetic pyrethroids are registered for use in Australia and they are the most effective pesticide for control. While synthetic pyrethroids have very little residual effect, they also severely disrupt natural predator populations. Best results are achieved by spraying before the heads turn down or at the end of flowering when adults begin to lay their eggs. However, Rutherglen bug repeatedly infest over several weeks; multiple treatments might be needed. Ideally sprays should be targeted at adults, timed to prevent them breeding.

Maintaining clean fields and fallows is important to prevent alternative hosting on weeds.

Soybean looper (*Thysanoplusia orichaicea*)

The soybean looper is a sporadic sunflower pest. They can be identified by their distinctive looping action and they only have two pairs of hind legs, unlike heliothis which has four.

Damage

The larvae feed on leaves and can rapidly defoliate a plant, although severe defoliation of a crop is unusual.

Threshold

There are no established thresholds for loopers in sunflower.

Management

A number of predators and parasitoids help reduce looper populations. Insecticide options are available.

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. When it is necessary to apply insecticides during flowering, choose insecticides with a low residual toxicity and spray in the late afternoon when bees have stopped foraging. To compare the relative bee toxicities of a range of insecticides, refer to the 'Impact of insecticides and miticides on beneficials and bees' section in the Cotton CRDC ***Cotton pest management guide***.

GO TO PAGE
Cotton pest management guide (https://www.cottoninfo.com.au/publications/cotton-pest-management-guide)

Crop desiccation

Crop desiccation is not a common practice in sunflower. However, it has been used in seasons to speed up or even out maturity. Diquat is the only product registered for use as a harvest aid in sunflower. There is also a minor use permit (**PER13118**, exp. 31/3/2021) for glyphosate as a pre-harvest desiccant and weed control option.

Sunflower crop desiccation can only begin once the crop has reached physiological maturity. This is when the bracts surrounding the head have turned brown. At this point, the seed should be mature and the moisture content below 35%.

GO TO PAGE
PER13118 (http://permits.apvma.gov.au/PER13118.PDF)

Harvest

Sunflower harvesting is best carried out as close to 9% seed moisture content as possible. There is a tendency to overestimate moisture content, meaning harvest is often delayed until moisture content is, on average, 7%. This results in a lower yield and more difficulty in obtaining a clean sample. As sunflower becomes 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.

Machinery setup can have a big effect on the quality of the sample harvested and the speed at which a crop can 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 that 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.

Harvesting sunflower when too moist can cause problems with threshing as the heads retain a moisture, particularly in the pith.

Slow drum speeds help with 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.

Receival standards

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.

Information about the **Receival standards on page 127**is included at the back of the guide. See the **Grain storage on page 121** for sunflower storage .

Marketing

Sunflower is grown to meet three main markets. The highest demand is for monounsaturated sunflower. Polyunsaturated oil demand still remains steady for the main area of margarine production. However, the confectionary/birdseed market is growing steadily. Other potential future markets for sunflower include industrial oils and biodiesel.

Monounsaturated sunflower

Monounsaturated sunflower produces oil that contains more than 85% oleic acid. High oleic sunflower oil is used in margarines and cooking. The large commercial cooking/frying oil market is expected to be the main long-term end use. This is due to the oil's health benefits and frying stability.

Headers, field bins, trucks and silos must also be free of other sunflower seed to prevent contamination.

Polyunsaturated sunflower

Polyunsaturated sunflower is primarily grown to produce linoleic oil for margarine production. To produce high quality margarine, manufacturers require a supply of oil that contains at least 62% linoleic acid. To meet these specifications, the polyunsaturated sunflower seeds need to fill during autumn when temperatures are usually milder, preferably when the average minimum temperatures are between 10 °C and 15 °C. High minimum temperatures during summer usually reduce the linoleic acid levels to well below 62%, often as low as 50%.

Confectionary sunflower

Confectionary sunflower is traditionally the grey striped sunflower, however, black hybrids with suitable dehulling characteristics can also be used in some markets.

Processors in this market segment usually contract growers to produce grey stripe and black sunflower that dehull easily. Large seed is required with a minimum of 80% of seed passing over an 8/64 slotted screen.

The crop in this market can be divided into:

1. Dehulled – the kernels minus their shell are used in a range of products including breakfast foods, biscuits, snack bars and bread.
2. Hulls – the remaining hulls are often sold for use as stockfeed, usually mixed with molasses.
3. Inshell – whole kernels that are not dehulled and are primarily sold into the birdseed market.

Further information

Better sunflowers (no security certificate, copy and paste the URL into your browser: www.bettersunflowers.com.au).

The ***The new big black sunflower pack*** (www.australianoilseeds.com/commodity_groups/australian_sunflower_association/asset_listing_for_big_black_pdf).

Sunflower – Agfact P5.2.3, 2nd edition 1997 (www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf).

GRDC fact sheets: Order through **GRDC** (www.grdc.com.au).

NSW DPI website (www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops).

Sunflower Production Guidelines for the Northern Grains Region (www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf).

Australian Oilseeds Federation grower guides (www.australianoilseeds.com/agronomy_centre/grower_guides).

Raising the bar with better sunflower agronomy (www.australianoilseeds.com/__data/assets/pdf_file/0019/7408/GRDC_Raising_the_Bar_-_Better_Sunflower_Agronomy.pdf).

Sequeira R 2003. ***Silverleaf whitefly (SLW): Threats and management issues for broad-acre crops***, Australian Sunflower Association Conference, Department of Employment, Economic Development and Innovation (http://australianoilseeds.com/__data/assets/file/0005/1220/Silverleaf_Whitefly_-_Threats_and_Management.pdf).

Osten V, Wright G and McCosker M 2003. ***Weed management studies in sunflower***, Australian Sunflower Association Conference. Department of Employment, Economic Development and Innovation (http://www.australianoilseeds.com/__data/assets/file/0012/1209/Weed_Mangement_Studies_in_Sunflower.pdf).

Meinke H, Hammer GL and Want P 1993. ***Potential soil water extraction by sunflower on a range of soils***, *Field Crops Research*, Volume 32, p. 59–81 (www.sciencedirect.com/science/article/pii/037842909390021E).

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The new big black sunflower pack

GRDC website

NSW DPI website

Sunflower Production Guidelines for the Northern Grains Region

Australian Oilseeds Federation grower guides

Raising the bar with better sunflower agronomy

Silverleaf whitefly (SLW): Threats and management issues for broad-acre crops

Weed management studies in sunflower

Potential soil water extraction by sunflower on a range of soils

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Grain storage

Growers who make use of well managed on-farm storage systems increase their harvesting options and are able to explore marketing alternatives. As summer grain crops are regularly harvested in autumn conditions, sealable storage systems that include both aeration cooling and drying facilities have the greatest flexibility at harvest and in preparation for longer term storage.

The key objective of grain storage is to maintain grain quality. The ways in which grain quality can decline in storage are through:

- insect infestation
- infection with moulds and rots
- reduction in germination potential
- changes in grain colour.

Fortunately, implementing good storage practises, as outlined here, will simultaneously reduce the likelihood of all four causes of grain quality loss. Pre-harvest, harvest and postharvest environments all influence the storage potential of grain. Good practises focus on thorough preparation to minimise opportunities for insects and diseases to establish, and controlling the conditions within the storage facility. It is important to recognise different pest insects, or signs of their damage, as this can affect which chemical treatment is used. Characteristics of the main stored pest insects are summarised in **Table 57**.

Pre-harvest

Remove grain residues – hygiene

Hygiene is a vital first step in preparing for harvest. Storage sheds, silos, headers, trucks, elevators and planter boxes should all be thoroughly cleaned out and, where appropriate, washed out. Any grain residues can harbour insects and need to be removed, even from difficult to reach spaces. Residues should be buried or burned to prevent them from being a source of infestation.

Old planting seed remaining in a shed or in silos on site poses a major infestation threat. Ensure planting seed, where possible, is treated with a grain protectant and is sieved to check for pests at least once a month. Fumigate when pests are detected. Insect pests of stored grain can fly a few kilometres to relocate and infest clean grain.

Apply protectant insecticides

After removing grain residues, the harvester and empty silos can be treated with diatomaceous earth (DE), a non-chemical alternative registered for structural treatment. A light dusting of DE on surfaces will control any remaining insect pests in storages and equipment. **Table 58** has a summary of registered products. Depending on the grain to be stored and its marketing requirements, there might be a number of options available.

Removing grain residues before treatment is critical to prevent insects surviving buried beneath the treated layer. Wherever possible avoid storing fresh grain on old grain. However, where grain is to be stored in part-filled silos, the carryover grain should be disinfested before adding the new grain. Currently (October 2019), the only treatment available to disinfest live insects from grain is fumigation. Therefore, any grain requiring this treatment will need to be in a gas-tight, sealable storage.

Estimate storage capacity

Where a summer grain is being stored on-farm for the first time, check the capacity of the facilities for storing this type of grain. Grains such as sorghum and maize have similar volumetric grain weights to wheat, but sunflowers need significantly less. If a silo is known to hold a certain tonnage of one type of grain, use the following calculation to determine the tonnage it will hold of other grain types.

Calculation:

$$\frac{\text{Silo capacity of the known grain type (tonnes)} \times \text{Volumetric weight of the new grain type (kg/hL)}}{\text{Volumetric weight of the known grain type (kg/hL)}} = \text{Silo capacity of new grain}$$

Example scenario:
A silo is known to hold 200 tonnes of wheat. How many tonnes of sunflower seeds will it hold?

$$\frac{\text{200 (tonnes of wheat)} \times \text{40 (sunflower seeds kg/hL)}}{\text{75 (wheat kg/hL)}} = \text{170 (sunflower seeds kg/hL)}$$

Repair structural faults

Grain stores must be maintained in a serviceable condition. Repair any structural fault, and for sealable, gas-tight silos, check all seals around openings and fans, replacing those that are showing signs of wear or damage.

At harvest

Monitor moisture content

Use a moisture meter to monitor the grain's moisture content as it dries down. In summer, grain dry down can occur very rapidly. Over-drying grain affects profitability as it is a direct loss of revenue, not changing the cost of the harvest operation. For example, 2% over-drying would reduce the gross margins of a sunflower crop with 2 t/ha yield potential by $22/ha, and a maize crop with 10 t/ha yield potential by $52/ha (based on a sunflower price of $550/tonne and maize price of $260/tonne.) This does not include the additional penalties incurred due to increased grain damage that is likely in over-dried grain. In autumn, when dry down is progressing slowly, the desiccation and/or grain drying costs can be weighed against the likelihood of reaching the ideal moisture content and the likely yield loss. Decisions that are made early, often achieve the best outcome. Harvest grain moisture contents are provided for each grain type in **Table 59**.

Minimise admixture contamination

At harvest, set drum speeds to minimise grain damage and fan speeds to minimise the retention of admixture in the sample. Large amounts of trash, fines and damaged grain within the harvested sample will favour insect infestation in storage, particularly by secondary feeders such as psocids, and flat grain beetles. Additionally, retained admixture and fines will compromise even air flows through the stack, limiting aeration cooling effectiveness for managing both insect and grain moulds. Low moisture grain is at greater risk of admixture contamination as it more likely to crack during harvest, and the plant structure surrounding it can become overly brittle.

Postharvest

Cool grain is far less prone to quality loss; changing grain storage temperature is a relatively quick process compared with changing grain moisture.

At any given temperature, moisture will move between the grain and the air in storage until an equilibrium is reached. Aeration is used to cool grain temperatures and create uniform grain moisture conditions throughout the grain stack. Where aeration is not used in storages, grain temperatures can remain at harvest temperatures and hot spots can develop.

Hot spots:
- are frequently the location of insect pest and mould development
- can be an ignition source.

Spontaneous combustion is also a problem if excess moisture remains in sunflowers.

The principle of aeration drying is that grain will lose moisture to air passing through the storage when this air has a lower relative humidity (is drier) than the air surrounding the grain. Although being able to dry grain allows for greater flexibility at harvest time, quality damage to some grain types, such as mungbean and maize, can occur during the drying process, particularly heated air (gas, diesel) drying.

When calculating flow rates, it is important to remember that the fans will need to work against the back pressure of the stored commodity. Grain type and density will influence the rate at which the air can flow through the storage.

Aeration cooling – low airflows

Cooling aeration is recommended for all grain storage facilities in Australia where feasible. A fan capacity of 2–4 L/s/t will provide the airflow to cool grain and help provide uniform grain moisture conditions.

These low airflow rates will also provide temporary safe storage for 2–3 weeks for grain that has 2–3% moisture content over the safe storage limits. It is, however, vital that fans are running continuously and grain is regularly checked to ensure grain does not get hot, bin burnt and mouldy. For hot air drying, use aeration before drying to provide a consistent feedstock, reducing the need to change the dryer speed and heat settings.

Grain can become damp or hot if aeration fans do not run properly or during the appropriate weather conditions. For this reason, temperature monitoring and automatic fan control systems that select suitable air are recommended. Exhaust air must be able to escape freely from the top of the storage. A vent opening on top of the silo of $0.1 m^2$ (30 cm × 30 cm) is recommended for each 500 L/s/t of air being delivered. Aeration trials have shown that an efficiently run aeration cooling system can maintain grain temperatures in storage between 18 °C and 23 °C in summer and less than 15 °C during the winter months.

Aeration drying – high airflow

High airflow aeration drying can take 1–2 weeks to achieve what hot air drying can achieve in a day or two. However, aeration drying has a much lower risk of damage to grain quality. Airflow rates of 15–25 L/s/t are generally required for effective aeration drying. The success and speed of this drying strategy relies on long fan run times each day and available air with a lower relative humidity than inside the storage. Summer harvested crops can usually be dried on a 24-hour, round-the-clock fan running regime. In coastal areas or times of higher humidity, supplementary heating can be used to reduce the air's relative humidity. Typically adding 6–8 °C to the ambient air temperature achieves the lower air humidity required.

Seek advice if undertaking aeration grain drying for the first time. Whenever higher moisture grain is handled and stored, it is critical to monitor grain daily.

Hot air drying

Hot air dryers use heated air and shallow grain depths to increase the rate that moisture is removed from the grain. Dryers can use either LPG or diesel as a fuel source to heat the air. There are several types – batch dryers are well suited to smaller quantities of grain, while continuous flow systems efficiently handle larger quantities. Drying machines can be a fixed part of the storage complex or they can be mobile. Where seed germination is important, grain temperatures should not exceed 43 °C during drying. To minimise problems with sweating and caking, grain must be cooled immediately after drying. Continuous flow systems have a cooling section built in. Storage with an aeration airflow capacity of 5–10 L/s/t is sufficient to cool batch-dried grain.

Reducing the risk of fire during drying

Sunflower seed is easy to dry, but the high oil content predisposes it to higher fire risk and spontaneous combustion than many other summer grain crops. Debris that becomes too dry and combusts is one of the main reasons for fires while drying sunflower. Fibres from the seed and other trash contained in the harvest sample are often drawn through the drying fans and on to the burner which can cause them to ignite. If these ignited particles come into contact with the sunflower seed a fire often occurs. Adjust the harvester setup to minimise admixture in the sample, or clean the sample before drying to reduce this risk.

Selecting air for aeration

For drying summer harvested crops in inland regions by aeration, there might be only a few instances of very high humidity where fans would need to be turned off. However, when aeration cooling is aiming to maintain cool grain temperatures and moisture parameters during longer term storage, automated controllers are recommended. Automated controllers continuously monitor the ambient air conditions and move 'set points' to operate fans at the times for the best air quality. Controllers typically provide an average of 100 hours of fan run time per month for this longer term storage phase of aeration management.

Monitoring stored grain

Monitoring any storage system is essential. Inspect stored grains regularly for:

- odours
- condensation
- insects, or holes/damage to grain
- moulds on the top of the stack
- hot spots (areas where temperature is elevated) in the grain.

Insect and mould presence is usually greatest near outlet hatches and the top surface. Take 10 minutes at each grain storage to sample a few litres of grain from access points. Use a grain probe or spear to sample from the top surface. Sieve the grain and inspect insect probe traps located in the grain surface. The regularity with which grain should be monitored depends on the type of grain and season. Industry recommendations for monitoring are generally once a month, or more frequently in the warmer months, see Table 59.

Grain temperature and moisture content should continue to be monitored postharvest. Changes can identify a problem with aeration fan operations.

Table 57. Characteristics of key insect pests of stored summer grains.

Insect pest	Maximum population growth rate/month	Larvae concealed in grain?	Adults walk up glass surfaces?	Means of spread	Resistance status				
					Protectant		Disinfestant		
							Phosphine		Other fumigants
					OP	S-methoprene	Weak	Strong	
Weevils *Sitophilus* spp.	25×	Yes	Yes	Adults fly or walk long distances, infest maize before harvest	Rare	NS	Common	Rare	NI
Lesser grain borer *Rhyzopertha dominica*	20×	Yes	No	Adults fly long distances	NS	Very common and increasing	Common	Widespread	NI
Rust red flour beetle *Tribolium castaneum*	70×	No	No	Adults fly long distances	Rare	Uncommon	Common	Uncommon	NI
Sawtooth grain beetle *Oryzaephilus surinamensis*	50×	No	Yes	Adults fly or walk long distances	NS	Rare	Common	Uncommon	NI
Flat grain beetle *Cryptolestes* spp.	55×	No	No	Adults long lived and fly long distances	Rare	Rare	Common	Widespread	NI
Psocids *Liposcelis* spp.	25×	No	No	On infested grain and machinery	No known cases	NS	Rare	Rare	NI
Angoumois grain moth *Sitotroga cerealella*	50×	Yes	No	Strong fliers, infest maize before harvest	No known cases	NS	NI	NI	NI
Cowpea brucid *Callosobruchus* spp.	NI	Yes	No	Adults short lived but strong fliers, infest mungbean before harvest	NR	NR	No known cases	No known cases	NI

NI No information
NS Not susceptible
NR Not registered
OP Organophosphate

Table 58. Chemical treatments for stored grain situations (ALWAYS read the label first).

Grain situation	Treatment	Examples	Notes
Live insects	Fumigation gases	phosphine ProFume® (sufuryl fluoride) Vapormate® (ethyl formate) inert gases (CO_2, nitrogen)	Sealable, gas-tight storages only: pressure test to check for leaks. Calculate dose for the volume of the storage, not grain tonnage. Some gases can only be applied by licensed fumigators.
Protect grain – in storage (3–9 months)	Contact chemical sprays	Conserve Plus® (spinosad + s-methoprene) K-Obiol® (deltamethrin + PBO) Reldan® (chlorpyrifos methyl) Fenitrothion methoprene	Check with GRAIN BUYERS before using grain protectant sprays. DO NOT apply to oilseeds or pulses: check label. ONLY ONE treatment application permitted for some sprays. Calibrate the spray unit to ensure correct dose and aim for uniform spray coverage on grain. Some sprays require adding a chemical to protect against all major insect pests: check label. Certain seed dressings state they may be used against stored insect pests, however resistance in some insect species to certain types of these products (e.g. pyrethroids) can reduce efficacy. Therefore, it is recommended to use a product specifically designed as a grain protectant.
Structural treatments – empty storage, headers, grain handling equipment	Dust, slurry and sprays	Diatomaceous earths e.g. Dryacide® Also known as amorphous silica. Some protectants are registered for structural treatments: check labels	First clean out any grain residues. Where practical, wash out grain dust and allow to dry before application.

Table 59. Parameters for storing and drying summer grains.

Crop	Maximum moisture content at harvest (%)	Ideal moisture content for grain storage (%)		Maximum air temperature for grain drying	Maximum grain temperature for grain drying	Volumetric grain weight		Storage monitoring schedule	
		Short term	Longer term			kg/hL	t/m³	Summer	Winter
Maize	24	12–13.5	12	49 °C	38 °C ❶	72	0.72	weekly ❷	weekly ❷
Mungbean	14	12–14	12	Ambient	Ambient	75	0.75	fortnightly	monthly
Sorghum	25	13–14	12	93 °C	80 °C	72	0.72	fortnightly	monthly
Soybean	18	13	10–11	55 °C ❸	40 °C ❸	75	0.75	fortnightly	monthly
Sunflower	15	<9 ❹	8 ❹	45–50 °C	43 °C	40	0.40	weekly	weekly

❶ To avoid stress cracking for milling markets.
❷ To reduce the risk of mycotoxin contamination, temperature and humidity should be checked weekly.
❸ Higher temperatures can be tolerated when grain is harvested at 14–16% moisture content and when grain is to be sold for crushing rather than into edible trade markets or used for planting seed. When using heated air for drying, maintain relative humidity at above 40%.
❹ Dependent on oil content. Seed with oil contents higher than 40% require lower moisture content for safe storage.

Insect pests

Grain insects are sensitive to temperature. Most reproduce fastest when the temperature is between 25 °C and 35 °C. Table 57 outlines the potential for key storage pest population growth and other characteristics. Cooling the temperature to below 20 °C slows their growth and development sufficiently to minimise damage. Once temperatures are below 15 °C, reproduction is halted in most species until temperatures rise again. It is important to note that these temperatures will not kill the insects and they will become more mobile when grain temperature increases. Also, continue to monitor for signs of insects as some species can adapt to cooler grain temperatures.

While it is not common, there are some specific storage pest insects that are able to start infestations in the field before the crop is harvested. Maize weevil lays eggs in maturing maize crop cobs and bruchids lay eggs in mungbean pods. The immature stages feed on the maturing grain, completing their development after harvest and continue infesting the grain in storage. Sieve and check for these pests during maize and mungbean harvest while filling storages. If detected, proceed with standard aeration cooling management during the first one to two weeks. Follow this with a 10-day phosphine fumigation to control pests as directed on the label.

Protectants

Where chemical residues on grain are accepted in the market place, protectant chemicals can be used to provide 3–9 months insect protection. However, when applied in hot weather the chemicals tend to degenerate more quickly so the protection period can be shorter. Treating grain with aeration cooling can reduce this problem.

Protectant sprays can be applied to grain at harvest time while it is entering storage. However, they are not designed or registered to control infestations that are already in the grain. Fumigations are required for infested grain. Table 59 summarises the insecticide registrations for protecting stored grain

For most grains, protectant mixtures are required to protect against all major stored grain insect pests. Recent products on the market (K-Obiol Combi® and Conserve® Plus grain protectant) might require stewardship programs run by their relevant manufacturer to ensure they are used correctly to prevent resistance developing. In addition, due to the risk of exceeding maximum residue limits, these chemicals can only be applied once for each parcel of grain.

Disinfestation

When insect infestations do occur, there are limited options for pest control, particularly for some storage and marketing situations (Table 58).

Fumigation

The primary option for fumigation is aluminium phosphide. This is effective only where grain is being stored in a sealable, gas-tight silo. Before fumigating, silos should be tested to confirm they are gas tight. This is done by pressurising the silo to an oil level difference of 25 mm at the silo relief valve. The level should hold above 12 mm for at least five minutes in a full silo.

Phosphine fumigation is highly effective when used correctly in a gas-tight, sealable silo for the required time as the label directs. There are populations of lesser grain borer, weevils and flat grain beetles with some high levels of resistance to phosphine throughout eastern Australia. Under-dosing by fumigating in leaky silos selects for stronger resistance.

Preferably fumigate by hanging trays of tablets, bag chains or blankets of aluminium phosphide in the sealable silo's headspace. If using tablets, spread them out to one layer deep on trays. Do not mix tablets with the grain as toxic residues can persist. Do not add water to the tablets. Phosphine gas is generated naturally in the headspace and distributed through the bulk by gas diffusion. For larger silos (>150 t capacity), it will be more effective to use recirculation to speed up the gas distribution throughout the storage.

Fumigations need to be long enough to allow time for the gas to evolve, diffuse through the grain and kill all the insect life stages (egg, larvae, pupae, adult). At grain temperatures below 25 °C, it takes phosphine more time to kill the cool, less active insects. Table 60 summarises the times taken for fumigation using tablets in a small silo to be successful. Larger silos where blankets might be used require longer periods. Always refer to the label for dose and fumigation duration information.

Table 60. Phosphine fumigation in a sealable silo.

Grain temperature	Exposure period	Ventilation period	Withholding period	Total exposure time
≥25 °C	7 days	1–5 days	2 days	10–14 days
15–24 °C	At least 10 days	1–5 days	2 days	13–17 days

An alternative fumigant, ProFume® (sulfuryl fluoride) is now on the market. It also requires a sealable gas-tight silo and can only be applied by a licenced fumigator who has undertaken specific training to use the product. Vapormate® (ethyl formate) is also available, but can only be applied using specialised equipment and by trained fumigators.

Moulds

Mould grows rapidly on warm, moist grain. Incomplete drying, moisture migration, condensation and self-heating all encourage mould growth. Moisture migration occurs when there are temperature differences within the grain stack and results in localised increases in grain moisture. This encourages mould growth and insect infestations. The peaks and edges of the grain bulk are at higher risk.

Reducing the risk of moulds through regular aeration with cool, fresh air and storing grain at the ideal moisture content, is particularly important in maize storage. Storage moulds in maize are associated with increased risk of grain contamination with mycotoxins. More detailed information about mycotoxins and their prevention is provided in **Maize on page 19** of this guide.

Further information

NSW Department of Primary Industries (www.dpi.nsw.gov.au)

Stored grain information hub (www.storedgrain.com.au)

Grains Research and Development Corporation (www.grdc.com.au)

Queensland Department of Agriculture and Fisheries (www.daf.qld.gov.au)

Australian Pesticides and Veterinary Medicines Authority (APVMA) (www.apvma.gov.au)

Grain Trade Australia (www.graintrade.org.au)

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NSW Department of Primary Industries

Stored grain information hub

Grains Research and Development Corporation

Queensland department of Agriculture and Fisheries

APVMA

Grain Trade Australia

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Receival standards

Receival standards are used by industry to manage grain quality. Decisions throughout the crop production process will influence the likelihood of meeting certain requirements. From variety and paddock selection in the planning phase, weed and insect control decisions in-crop, to the timing of harvest and post-harvest storage decisions, all will effect grain performance against receival standards.

Receival standards are set by Grain Trade Australia (GTA). In conjunction with various organisations, GTA develops and publishes grain standards to ensure objectivity in grain specifications. These standards are updated yearly and accepted as the industry's standard reference.

For the latest receival standards and information about the role of the GTA, refer to their website.

Other sources of information are the websites of industry organisations including:

- Australian Mungbean Association (www.mungbean.org.au)
- Australian Oilseeds Federation (www.australianoilseeds.com)
- **Better sunflowers** (no security certificate, copy and paste the URL into your browser: www.bettersunflowers.com.au).
- Australian Oilseeds Federation (sunflowers) (www.australianoilseeds.com/commodity_groups/australian_sunflower_association)
- Graincorp (www.graincorp.com.au)
- Maize Association (www.maizeaustralia.com.au)
- Pulse Australia (www.pulseaus.com.au)
- Soy Australia (www.australianoilseeds.com/soy_australia)

Always refer to your marketing agent or contract arrangement for specific delivery requirements.

Terminology used in a receival standard may have a specific meaning in that standard. Both the GTO and AOF provide a glossary of terms on their websites to clarify the intention of the standards. Refer to these useful guides when interpreting receival standards.

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Grain Trade Australia (www.graintrade.org.au)

Australian Mungbean Association

Australian Oilseeds Federation

Australian Oilseeds Federation (sunflowers)

Graincorp

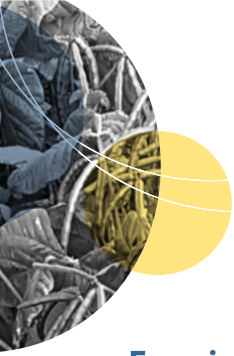
Maize Association

Pulse Australia

Soy Australia

GTO standards (http://www.graintrade.org.au/commodity_standards)

AOF standards (http://www.australianoilseeds.com/Technical_Info/standards_manual)



Seed dressings

Fungicide seed dressings

Table 61. Permits for disease management.

Permit number	Date	Crop	Pest	Active ingredient	Group	Rate	Product/s
PER13979	3 February 2014 to 30 June 2020	Mungbean	Powdery mildew (*Erysiphe polygoni* or *Podosphaera xanthi*)	430 g/L tebuconazole	3	145 mL/ha	Relyon Teboo 430 SC fungicide (82181) plus other registered products containing: 430 g/L tebuconazole as the only active constituent.
				750 g/kg tebuconazole		83 g/kg	Buzz Ultra 750 WG fungicide (65600) plus other registered products containing: 750 g/kg tebuconazole as the only active constituent.
				800 g/kg tebuconazole		78 g/ha	Laguna Xtreme 800 WG fungicide (67455) plus other registered products containing: 800 g/kg tebuconazole as the only active constituent.
PER82104	1 November 2016 to 30 November 2019	Mungbean, adzuki bean, navy bean	Powdery mildew (*Erysiphe polygoni* or *Podosphaera xanthi*)	120 g/L azoxystrobim + 200 g/L tebuconazole	11 + 3	300–600 mL/ha plus non-ionic surfactant at label rates	Custodia fungicide plus other registered products containing: 120 g/L azoxystrobim + 200 g/L tebuconazole as the only active constituent.

Table 62. Registered seed dressings for disease management.

Example product	Active ingredient	Group	Rate	Sorghum	Sunflower	Maize	Soybean
Thiroflo® Flowable	600 g/L thiram	M3	2.5–3.5 L per tonne seed	Seedling decay complex (*Pythium* and *Rhizoctonia* spp.)	–	–	–
Thiroflo® Flowable	600 g/L thiram	M3	Up to 4 L per tonne seed to meet export requirements	yes	yes	–	–
Maxim® XL	25 g/L fludioxonil + 10 g/L metalaxyl-M	4, 12	100–200 mL/100 kg seed	Damping off and root rot caused by *Pythium* and *Fusarium* sp.	–	Damping off and root rot caused by *Pythium* and *Fusarium* sp.	–
Maxim® 100 FS	100 g/L fludioxonil	12	50 mL/100 kg seed (includes sweet corn)	–	–	Damping off caused by Fusarium (*Fusarium* spp), *Penicillium* (*Penicillium* spp)	–
Vitavax 200FF ❶	200 g/L carboxin + 200 g/L thiram	G, Y	500 mL/100 kg seed	–	–	Boil smut	–
			250 mL/100 kg seed			Seedborne head smut and seed decay/ seedling blight complex	
4Farmers Metalaxyl-M 350	350 g/L metalaxyl-M	4	150 mL/100 kg seed	–	–	–	Phytophthora stem rot, damping off.
Rampart® 350 SD	350 g/kg metalaxyl-M	D	300 g/100 kg seed	–	–	–	Phytophthora stem rot, damping off.

❶ Includes sweet corn

Acknowledgements: Matt Needham – Advanta Seeds Pty Ltd

Insecticide seed dressings

Table 63. Permits of seed dressings registered for insect pest management.

Permit number	Date	Crop	Pest	Active ingredient	Group	Rate	Product
PER8522	9 March 2006 to 31 March 2021	Mungbean, adzuki bean, cowpea, navy bean	Wireworm, black field earwig, field cricket, false wireworm	500 g/L chlorpyrifos	1B	100 mL product plus 125 mL sunflower oil per 2.5 kg cracked sorghum or wheat seed per hectare	Lorsban 500 EC plus other registered products

Table 64. Registered seed dressings for insect pest management.

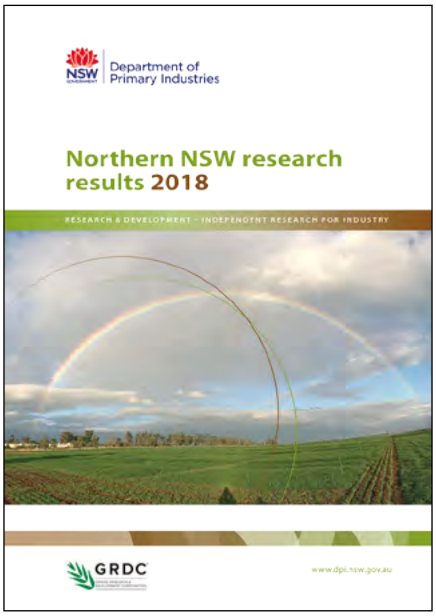
Example product ❶	Active ingredient	Group	Rate per 100 kg of seed ❷	Sorghum	Sunflowers	Maize
Cosmos® Insecticidal seed treatment – BASF	500 g/L fipronil	2B	150 mL sorghum, sunflowers	False wireworm. Protection from black field earwig.	False wireworm. Protection from black field earwig.	–

❶ Major products readily available in NSW. Other trade names may also be available.
❷ Check water rates on the label as they may vary.
❸ Only available to accredited applicators. Price is included in seed costs.

Acknowledgements: Matt Needham – Advanta Seeds Pty Ltd

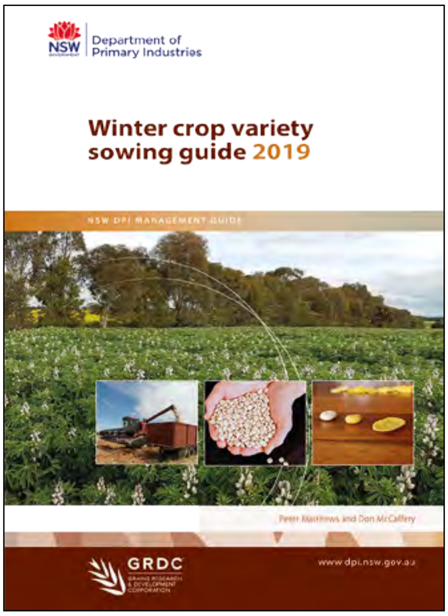
Table 65. Scientific names of common pests managed with seed dressings.

Pest	Scientific name
Eastern false wireworm	*Pterohelaeus darlingensis*
Southern false wireworm	*Gonocephalum macleayi*
Large (striate) false wireworm	*Pterohelaeus alternatus*
Sugarcane (true) wireworm	*Agrypnus variabilis*
Black field earwig	*Nala lividipes*
Corn aphids	*Rhopalosiphum maidis*

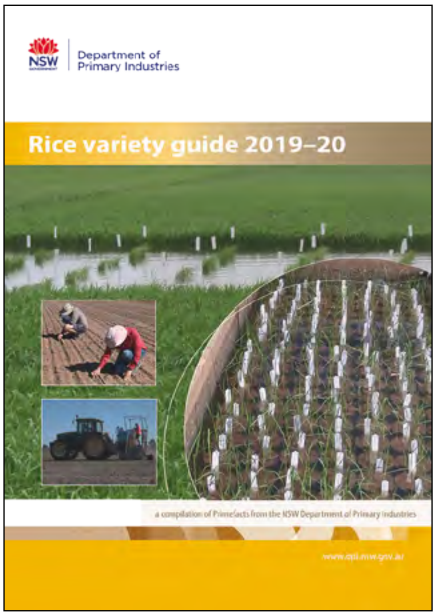


Northern NSW research results 2018

Weed control in winter crops



Winter crop variety sowing guide



Rice variety guide 2019–20

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